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How Emotional Stimuli Modulate Cognitive Control: A Meta-Analytic Review of Studies With Conflict Tasks

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How do emotional stimuli change the way we control our behavior? The interaction between emotion and behavior-shaping, cognitive control mechanisms remain little understood in psychological science. The present meta-analysis addresses this controversy by means of a quantitative review. We analyzed data from 71 studies published through December 2018 that investigated control in conflict tasks, like the Stroop, Simon, and/or flanker tasks, which are well-known tools for psychologists in various subdisciplines used to probe cognitive control mechanisms. We considered studies that experimentally manipulated emotional stimulus presentation and asked how perception of emotional stimuli modulates the size of the congruency effect (CE), as an index of control. Results of two primary meta-analyses found no clear evidence that emotional stimuli modulate cognitive control in general. Yet, moderator analysis suggested that specific aspects of the task, stimuli, and testing conditions show reduced CE for emotional stimuli. Thus, at a theoretical level, emotional stimuli can facilitate control under specific conditions, supporting views that attribute enhanced control either to overload of perceptual distractor processing or to increased amplification of target information and/or suppression of distractor information.

Public Significance Statement

This meta-analysis shows that emotional stimuli have only a very small if at all existing influence on cognitive control in general. The effects are stronger for fully attended and verbal emotional stimuli, suggesting that emotional stimuli can increase control under specific conditions.

Keywords: cognitive control, valence, arousal, emotion

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The question of how emotional meaning interacts with cognitive control mechanisms to shape behavior remains an unsolved question in psychological science. It occupied philosophical scholars from ancient times, was central to early psychological work, and remains a strongly debated question today. For many reasons, emotions are often portrayed as opposing forces to controlled behavior. For instance, it has been suggested that successful goal pursuit requires people to resist distracting impulses caused by affective states (Metcalfe & Mischel, 1999; Strack & Deutsch, 2004). In contrast to this view, more recent theorizing has highlighted a functional interaction between cognitive control and affect (S. Duncan & Barrett, 2007; Eder et al., 2007; Hommel, 2019; Pessoa, 2008). Although there is a rapidly growing interest in the interaction between control and affect, including research on clinical disorders (e.g., Duggirala et al., 2020), social (e.g., J. Baumann & DeSteno, 2010; Duggirala et al., 2020), and developmental aspects (e.g., Mueller, 2011), the precise interface between emotions and cognitive control remains controversial.

The present study addresses this controversy through a quantitative review. Therefore, the goal of this research was to systematically compare emotional influences on cognitive control across different experiments. We use the term *emotion* to refer to a brief

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sensation in response to a stimulus that is characterized by the potential for mobilization (arousal) and the pleasantness or hedonic tone (valence; F. L. Barrett & Russell, 1999). This view of emotions differs from others focused on specific emotions (Ekman & Friesen, 1971; Panksepp, 2007), appraisal of emotional stimuli (Scherer, 1999), and motivational dispositions (Harmon-Jones, 2003). It follows from these conceptual definitions that a number of other interesting and related issues, like effects of reward, mood, or affect regulation on control, do not fall in the scope of this meta-analysis.

Emotional Modulation of Cognitive Control

Characterizing human goal-directed behavior in a complex world is a major task for psychology. Many problems arise during goal-directed behavior because unlimited amounts of stimuli and actions compete for a limited pool of resources (Kahneman, 1970; Navon & Gopher, 1979; Posner, 1975). Consequently, not every stimulus can be fully processed and not every action is based on relevant information. Managing this overload of information requires selection. It has been suggested that cognitive control accomplishes this function by modifying the flow of information (Broadbent, 1958; Norman & Shallice, 1986). Cognitive control is a multifaceted construct. Although many of its mechanisms might be shared across different mental faculties (see J. Duncan, 1996, for discussion), there is now growing consensus for a fraction among different components. For instance, Miyake and colleagues differentiated the updating of information in working memory, the shifting of attention between tasks and mental sets, and the inhibition and control of interference (Miyake et al., 2001; see also Eisenberg et al., 2019; but see Posner & Rothbart, 2007). The present review focuses on inhibition and control of interference (for reviews on emotional modulation of updating and shifting, see Goschke & Bolte, 2014; Schweizer et al., 2019). The importance of a better understanding how emotions modulate this control mechanism becomes obvious when considering cases in which it is out of balance. For instance, inhibition and control of interference are critical aspects of affective disorders such as depression and anxiety; it has been suggested that impairments in this domain act as a vulnerability factor for the developmental of clinical symptoms (Gladstone & Parker, 2006; Joormann et al., 2007; Richard-Devantoy et al., 2012; Rosenbaum et al., 1991). It is the goal of the present research to fill this gap and provide a synthesis of relevant findings.

A number of different tasks have been used to probe inhibition and control of interference (Posner & Rothbart, 2007; for an overview, see N. P. Friedman & Miyake, 2004). Perhaps the most popular approach, also used in our research, have been so-called conflict tasks, like the Stroop task (Stroop, 1935; for a recent review, see Parris et al., 2021), the Simon task (Simon & Rudell, 1967; for a recent review, see Cespón et al., 2020), and the flanker task (Eriksen & Eriksen, 1974; for a recent overview, see Merz et al., 2021). These tasks have been central for the development of major cognitive control theories and hundreds of empirical studies have characterized their underlying mechanisms, making them a vital tool for clinical, social, and applied research (for reviews, see, e.g., Hommel, 2011; MacLeod, 1991; Mullane et al., 2009). In conflict tasks, participants must respond to a relevant target while ignoring a nominally irrelevant distractor. For instance, in the Stroop task, participants must name the print color of a word (e.g., blue), while ignoring the semantic meaning of the carrier word (e.g., RED). Empirical observations show that irrelevant distractor information affects target processing despite the instruction to ignore this information. This influence of task-irrelevant information is evidenced by performance measures that compare congruent (target and distractor afford the same response, e.g., RED printed in red) and incongruent (target and distractor afford different responses, e.g., RED printed in blue) combinations. The congruency effect (CE) refers to the difference between these conditions and provides a measure of inhibition and interference control. Increased magnitude of the CE has been taken as evidence that a share of irrelevant information escapes attentional selection, which is usually considered as an index of control impairment. Conversely, decreased magnitude of the CE is interpreted as enhanced control.

Inhibition and control of interferences in Stroop, Simon, and flanker tasks are characterized by the prioritization of relevant stimuli at the expense of irrelevant stimuli. But what makes a stimulus relevant? Relevance refers to both bottom-up (e.g., properties of the stimulus) and top-down influences (e.g., properties of the task set). Emotional stimuli recruit both aspects and in this way modulate cognitive control in a bottom-up and top-down manner. On the one hand, emotional stimuli are powerful bottom-up cues that pull attention and hold attention longer than other neutral stimuli (Fox et al., 2001; Schimmack, 2005; Wyble et al., 2008; for a review, see Carretié, 2014). For instance, research showed that emotional stimuli facilitate detection if they act as targets but impair detection if they serve as distractors (Ihssen & Keil, 2009; Pessoa, 2009). Because of these attention-grabbing effects, emotional stimuli are said to tax-limited resources. Consequently, depleted resources limit (a) which stimuli gain access to control processes and (b) how many resources are available for control. On the other hand, emotional stimuli have a strong signaling function that affects top-down processes. Theoretical views suggest that emotions may announce that goal achievement is threatened and engage cognitive control mechanisms (Norman & Shallice, 1986; for a recent review, see Dignath et al., 2020). Furthermore, emotions may also guide behavior more directly. For instance, cognitive control models have long recognized that attention covaries with arousal (Berlyne, 1960; Kahneman, 1973; Mather & Sutherland, 2011; Posner, 1975). Similarly, neurophysiological data suggest a close link between brain networks involved in the processing of negative emotions and networks associated with control of interference (Braem et al., 2017; Pessoa, 2010; Shackman et al., 2011; Vermeylen et al., 2020; for different opinions, see, e.g., de la Vega et al., 2016; Jahn et al., 2016; Kragel et al., 2018; Lieberman et al., 2016; Silvestrini et al., 2020).

How do emotional stimuli and the affective states that follow from these stimuli modulate cognitive control? A test of this question requires the combination of a conflict task with an emotional stimulus. More specifically, assessing how emotional stimuli modulate control requires that the emotional stimuli are *entirely* irrelevant to the conflict task. Consider that in a conflict task, irrelevant stimuli are logically related to the target and cause conflict (or facilitation) due to their mapping with responses. In contrast, entirely irrelevant emotional stimuli are not mapped to any response, in fact they do not require a response at all. This "get-left-out" status of emotional stimuli in relation to the conflict task is critical because it allows to compare both bottom-up (limited resources) and top-down (engage control) accounts. According to a bottom-up account, emotional stimuli can either compete for resources at the level of perception or executive control. According to a top-down account, emotional stimuli can directly trigger or factor into control processes. Still, an empirical answer to the question how emotional stimuli modulate control has proven to be far more complex given that data support both hypotheses. The ambiguous status quo of empirical findings is illustrated by a quote from Liu and colleagues (Liu et al., 2017):

> Compared to neutral state, positive affect has been found to have beneficial (Kanske & Kotz, 2011a; Kuhl & Kazén,1999), detrimental (Phillips et al., 2002; Rowe et al., 2007), or no effect (Martin & Kerns, 2011; Sommer et al., 2008) on conflict resolution. Similarly, negative affect has been found to improve (Kanske & Kotz, 2011b), impair (Sommer et al., 2008), or have no effect (Rowe et al., 2007) on conflict resolution. (p. 69)

Several critical moderators have been proposed (e.g., properties of emotional stimuli: Kanske & Kotz, 2007; Liu et al., 2017; O'Toole et al., 2011; properties of the conflict task: Cohen & Henik, 2012; Hart et al., 2010; Kanske, 2012; individual differences: Cohen et al., 2012; Kanske & Kotz, 2012), but it remains to be specified how these factors can provide a comprehensive account for the heterogeneous findings. Thus, understanding how emotional stimuli bias control is an open question. In the next section, we will review different perspectives on emotion–control interactions, and a summary of relevant perspectives is also presented in Table 1. Only then, we provide an overview of potential moderators for the impact of emotional stimuli on cognitive control.

Theoretical Views on the Emotional Modulation of Control

In the following, we sketch several theoretical views on the question how emotions modulate cognitive control. The aim of this section is to enable a better understanding of the assumed processes induced by emotional stimuli and an overview on the diverse predictions of effects on cognitive control before we discuss the list of potential moderators that will be included in the meta-analysis. Please note that some theoretical views refer to arousal only and thus are restricted to the impact of the potential to mobilize without considering the valence component of emotional processing.

Emotions as Load—The Attentional View

This perspective assumes that emotional stimuli increase processing load. Their processing competes with and is prioritized over task-irrelevant stimuli for limited resources and thus emotional stimuli decrease interference effects of task-irrelevant stimuli. Our use of the term *attentional view* derives from Chajut and Algom (2003) work investigating the impact of psychological stress on Stroop performance. It refers to a

> major distinction … between to-be-responded-to attributes and to-be-ignored attributes. Stress affects the two classes of attributes differentially. The diminished resources available are fully engaged by the former with the net result of better selectivity in responding. This differential deployment of attention occurs regardless of the composition of the two classes of dimensions. The to-be-responded-to dimension always commands priority, if not exclusivity, in attentional processing. (Chajut & Algom, 2003, p. 232)

In a similar vein, load theory suggests that because stimuli compete for processing, selection prioritizes task-relevant stimuli (Lavie, 2010; Lavie et al., 2004). Consequently, task-relevant stimuli absorb resources and task-irrelevant information is processed to a lesser degree depending on the remaining resources. Given the fact that emotional stimuli capture attention (Fox et al., 2001), boost stimulus representation (Brosch et al., 2010), and accentuate competition with neutral stimuli for resources (Pessoa, 2008), not only nominally task-relevant stimuli but also emotional stimuli could be prioritized over task-irrelevant information for these spare resources. As a consequence, emotional stimuli are expected to reduce interference effects from task-irrelevant information.

Please note that this perspective can be dated back even earlier. Easterbrook (1959) suggested that negative arousal limits the impact

Table 1

A Summary of Perspectives on How Emotion Influences Cognitive Processing in Conflict Tasks

Reference	Assumptions	Prediction
Emotions as load—The attentional view		
Chajut & Algom, 2003 Easterbrook, 1959 Lavie, 2010 Lavie et al., 2004	Task-relevant stimuli are always prioritized; emotional stimuli compete with task-irrelevant stimuli for limited resources and are prioritized over task-irrelevant neutral stimuli.	A smaller CE for emotional versus neutral stimuli
Emotions as competitors—The capacity view		
Kahneman, 1973 Logan, 1980 Ridderinkhof, 2002 White et al., 2011	Processing of task-irrelevant stimuli in conflict tasks is automatic; emotional stimuli compete with task-relevant stimuli for limited central resources.	A larger CE for emotional versus neutral stimuli
Emotions as catalysts—The biased competition view		
Mather et al., 2016	Biased competition between task-relevant and task-irrelevant stimuli in resource allocation; emotional stimuli bias processing in favor of task-relevant stimuli.	A smaller CE for emotional versus neutral stimuli
Emotions as cues—The stability–flexibility view		
Fredrickson, 1998 Fenske & Eastwood, 2003	Negative affect cues a focused attentional scope or processing style, while positive affect cues a global attentional scope or processing style.	A smaller CE for negative versus positive stimuli

Note. CE = congruency effect.

of irrelevant information (see also R. W. Booth, 2019; R. Booth & Sharma, 2009; Chajut & Algom, 2003; Wachtel, 1967). Based on work showing that stressful noise and pharmacological interventions change the "focus of attention" (Callaway & Dembo, 1958; see also Broadbent, 1971; Hockey, 1970), Easterbrook (1959) argued that arousal reduces the range of information processing and predicted that the effects of arousal on performance should depend on the complexity of tasks:

> On some tasks reduction in the range of cue utilization improves performance. Irrelevant cues are excluded and drive is then said to be organizing or motivating. In other tasks, proficiency demands the use of a wide range of cues, and drive is disorganizing or emotional. (Easterbrook, 1959, p. 197)

It becomes clear that Easterbrook and more recent load accounts portrayed the influence of emotional stimuli on control as a rather passive process. Distractors are not actively filtered out, but simply not perceived, because emotional stimuli "overload" limited resources. Importantly, overload refers to perceptual processing and affects first and foremost irrelevant information. In this regard, the attentional view contrasts sharply with another account that we will discuss next.

Emotions as Competitors—The Capacity View

Capacity models argue that emotional stimuli impair control based on the assumption that cognitive control processes require central resources. First, according to early views, arousal impairs the optimal allocation of resources for task-relevant processing:

> In the terms of a capacity model, the allocation of capacity becomes both more uneven and less precise when arousal is high. Consequently, performance is impaired in tasks that require either the deployment of attention over a broad range of information-processing activities, or the control of selection by fine discriminations. (Kahneman, 1973, p. 40)

Second, capacity models have been central in the discussion of automaticity (Posner, 1975; Shiffrin & Schneider, 1977). Indeed, automatic processes have been defined as independent from capacity constraints. In this regard, automatic processes are key to many dual-process models that describe activation of irrelevant information as an automatic process competing against a controlled process to identify the task-relevant information (e.g., Stroop: Logan, 1980; Simon: Ridderinkhof, 2002; Flanker: White et al., 2011). Accordingly, the capacity view holds that depletion of resources by emotional stimuli will mostly affect controlled processes, but not automatic activation of distractors. As a consequence, it has been assumed that emotional stimuli block resources needed to recruit control mechanisms (i.e., to suppress distractor activity). For example, Pessoa (2009) argued that "Because high-threat is expected to recruit such 'common-pool resources,' it will impair other executive functions that are reliant on them, including inhibition, shifting and updating" (p. 162).

These arguments converge on the notion that emotional stimuli tax central resources and impair controlled behavior, while leaving supposedly automatic distractor activation unaffected. This view has been further developed to account for the effects of anxiety (Eysenck & Calvo, 1992; Eysenck et al., 2007; Mathews & Mackintosh, 1998) or depression (Joormann & Vanderlind, 2014) on cognitive control.

Emotions as Catalysts—The Biased Competition View

In contrast to accounts that cast emotions as antagonists to controlled processes, the biased competition view suggests that emotions *modulate* competition of neutral target and distractor stimulus processing. For instance, the arousal-biased competition model by Mather et al. (2016) assumes that "arousal amplifies the stakes of ongoing selection processes, leading to 'winner-take-more' and 'loser-take-less' effects in perception" (p. 2). This prioritization is flexible and depends on the task structure (e.g., surprise for rare stimuli) and stimulus properties (e.g., saliency). For congruency tasks with carefully balanced probabilities and stimuli closely matched in saliency, predictions are straightforward. With task-relevance as the key factor for competition (Mather et al., 2016), emotional stimuli will favor task-relevant information at the expense of irrelevant information. Thus, emotional stimuli are expected to reduce the size of CEs.

A complementary perspective has been suggested by models that explain control in conflict tasks. Although initially formalized to account for control across consecutive trials, recent empirical research (Kałamała et al., 2020; Scherbaum et al., 2011) and modeling work (Weichart et al., 2020; see also Ridderinkhof et al., 2004) suggest similar control mechanisms for conflict resolution within a trial. Here, affective extensions of these models (Dreisbach & Fischer, 2015; Inzlicht et al., 2015; Van Steenbergen, 2015) suggest "that conflict elicits a negative affective reaction, and that it is this affective signal that is monitored and then triggers control adaptation" (Dignath et al., 2020, p. 193).

Although some accounts focus on negative valence as driving cognitive control, others suggested that arousal independently of valence (Verguts & Notebaert, 2008, 2009) should facilitate control. Together, these accounts portray emotions as a signal that modulates control and more specifically emotions act as a catalyst that amplifies other ongoing control processes.

Emotions as Cues—The Stability–Flexibility View

According to these models, emotions guide behavior by cueing different mindsets or processing styles. Critically, different accounts converge on the assumption that affective valence has opposing influences on perception and control (Ashby et al., 1999; Fredrickson, 1998; R. S. Friedman & Förster, 2010; Goschke, 2014; Hommel, 2015; see also N. Baumann & Kuhl, 2005; Isen, 1987). Regarding attention as a mechanism for selection, it is assumed that "a negative affective state narrows the scope of attention, whereas a positive affective state expands the scope of attention" (Fenske & Eastwood, 2003, p. 329).

Evolutionary reasoning suggests that negative emotions occur often in situations that are dangerous or difficult and require more focused processing, while benign situations, usually accompanied by positive affect, allow for more global processing (see Schwarz & Clore, 2003). Evidence comes mostly from spatial conflict tasks like the flanker task that has been often linked to the spotlight metaphor of attention (e.g., Fenske & Eastwood, 2003; Huntsinger, 2012; Moriya & Nittono, 2011). For instance, Rowe et al. (2007) found that positive compared to negative affect increased CEs in the flanker task. Interestingly, the notion of attentional tuning is not restricted to spatial attention, and Rowe and colleagues reported further that positive affect facilitated performance in a remote-associate task. In line with the assumption of a common affectively influenced mechanism, the affective modulation of CEs in the flanker task and enhanced semantic access in the remote-associate task were correlated (Rowe et al., 2007). Based on these and many other findings, it has been suggested "that states of emotional arousal not only moderate the scope of attention on the perceptual level, but on the conceptual or representational level, influencing the breadth of activation of stored mental representations" (R. S. Friedman & Förster, 2010, p. 876).

Corroborating this interpretation, Phaf (2015) suggested that modulation of CEs in the flanker task is not due to the broadening of spatial attention, but rather reflects increased flexibility to switch back-and-forth between distractor and target stimuli (see also Dreisbach & Goschke, 2004, for further evidence that positive affect increases flexibility). In sum, this set of theories assumes a differential impact of emotional stimuli in so far as negative hedonic value limits perceptual and conceptual analysis (i.e., excluding distractors), while positive hedonic value widens perception and conceptual analysis (i.e., including distractors).

This short review on theoretical accounts demonstrates that there is no unifying theory or framework but that the diverse accounts differ regarding their prediction of how emotions facilitate or hinder cognitive control and they differ regarding the assumed mechanism underlying the modulation. Consequently, the different accounts would also predict different moderators regarding the impact of emotional stimuli on CEs. In the following, we discuss the list of moderator variables that we considered in the meta-analysis.

Moderators Characterizing Emotional Modulation of Control

Emotions have been linked to changes in cognitive control. Yet, empirical results are inconclusive whether emotional stimuli facilitate or impair control. Theoretical views support both positions, but for different reasons. As explained above, critical differences between theories arise in terms of underlying processes and emotional dimensions. To investigate these questions, we coded several moderators. First, we utilized the large variety of stimulus material and stimulus presentation in the literature to assess potential influences of *properties of emotional stimuli*. Second, we exploited differences in conflict tasks and timing aspects to investigate potential influences of the *experimental procedure.* Third, we coded several moderators that reflect the *relation between properties of emotional stimuli and experimental procedure*. Fourth, we considered *individual differences* like sample characteristics, age, and gender. And fifth, we coded several moderators to account for *publication bias* in the existing literature.

Properties of Emotional Stimuli

Valence and Arousal of Emotional Stimuli. Modulation of control can be driven by either both or only one of the two dimensions of emotions: (a) arousal of the emotional stimulus or (b) valence of the emotional stimulus. Bottom-up accounts assuming competition for limited resources suggest that negative, high arousing stimuli tax resources stronger than other stimuli. Based on evolutionary arguments, for example, detection of stimuli threatening survival (Lang et al., 2000), it is assumed that these stimuli should be given highest priority. In line with this reasoning, the dual competition model assumes that threatening stimuli that are often highly arousing and negative stimuli should impair control in particular (Pessoa, 2008). Yet, there are exceptions: first, recent results provide evidence that also positive stimuli have a privileged status (Pool et al., 2016), suggesting not valence, but rather arousal might underlie the prioritization of emotional stimuli. Second, a recent study suggested that perceptual load effects are confined to negative stimuli (Gupta & Srinivasan, 2015). Because limited perception accounts closely overlap with load theory, it might be possible that positive stimuli do not "overload" perception and leave distractor perception intact.

In contrast, top-down accounts make different predictions. On the one hand, arousal is assumed to bias competition irrespective of valence. On the other hand, alternative accounts suggest that "emotions act as cues" and consider valence as a relevant dimension for control modulation. Further, some accounts assume that positive and negative stimuli have opposing effects on control. To test these different views, we coded *arousal* and *valence* of emotional stimuli. In addition, we coded whether a study referred to stimuli explicitly as *threatening*.

Format of Stimuli. Studies differed in the way how emotional stimuli were presented. Many studies used emotional words that can be carefully controlled on multiple dimensions. Nonetheless, the frequent usage of words to induce emotions has been criticized as ecologically invalid (see Schimmack, 2005). In contrast, pictures of emotional scenes can be considered as more valid ecologically but also differ in many physical aspects and are subject to different contextual interpretations, which might explain considerable variation of behavioral and neurophysiological responses to stimuli similar in explicit rating (see Okon-Singer et al., 2013). Such contextual information is often extremely reduced for photographs of emotional faces that have been widely used to elicit more specific emotions (see Wieser & Brosch, 2012, for a review). To assess how differences affect emotional-biased control, we coded *stimulus format* (word, picture, face [photo], face [drawing]) as a moderator.

Duration of Stimulus Presentation. Prolonged presentation times of emotional stimuli might enhance competition for limited resources because the intensity of cognitive representation scales with stimulus duration. Furthermore, studies showed that longer presented emotional stimuli hold attention longer, impair attentional disengagement, and therefore render processing of subsequent stimuli more problematic. For instance, a study found emotional-biased control was impaired (in terms of increased CE for emotional relative neutral faces) for longer relative to shorter emotional stimulus presentation (O'Toole et al., 2011). In contrast, it has been suggested that longer presentation duration of threatening stimuli can cause an avoidance response (Mogg et al., 1997). More generally, longer presentation times allow for better regulation of emotional responses. To assess how exposure time to emotional stimuli modulates emotional-biased control, we coded the *presentation duration* of emotional stimuli.

Properties of the Experimental Procedure

Repetition of Emotional Stimuli and Number of Trials. Behavioral responses to emotional stimuli habituate quickly (Codispoti et al., 2016). This fading of emotional responses might result from repetition of the same emotional stimuli over time or might be due to increasing ignorance to task-irrelevant emotional stimuli over time. Therefore, too many repetitions of emotional stimuli might reduce the validity of the emotion manipulation. Nevertheless, psychometrics suggest that increased trial numbers enhance the reliability of the measurement. To test the influence of both factors, we coded the *number of emotional stimulus repetitions* and the *number of trials* used as moderators.

Trial Design. The way how emotional stimuli are presented changes emotional experiences. While random presentation of stimuli referring to different arousal/valence categories (e.g., negative, neutral, neutral, …) induces short-term (phasic) emotional responses, blocked presentation of stimuli of the same valence or arousal category (e.g., negative, negative, negative, …) induces longer lasting mood states (Ben-Haim et al., 2014; Okon-Singer et al., 2007). Although the present meta-analysis is concerned with the former, we controlled for potential mood effects by coding *trial design* (random vs. blocked) as a moderator.

Task. To study the influence of emotional stimuli on CEs, three different conflict tasks are used (Stroop, flanker, Simon). Although these tasks are often treated interchangeably, closer examination of theoretical models and empirical findings suggests marked differences. In the Stroop task, participants are asked to classify the print color (relevant information) of a color word (irrelevant information). Conflict in the Stroop task is elicited due to semantic meaning of the word, which interferes with the classification of the print color. Conflict has been attributed to interference at the level of stimulus identification, response selection, and task activation (for an overview, see Banich, 2019). Control in the Stroop task is assumed to resolve conflict by amplification of the relevant information and suppression of irrelevant information (e.g., Polk et al., 2008). In the flanker task, participants have to identify a centrally presented target item surrounded by irrelevant "flanking" items. Conflict in the flanker task arises due to processing of the irrelevant flanker items, which interfere with the identification of the central target item. Conflict in the flanker task is caused by stimulus and response conflict (De Houwer, 2003a), and control is assumed to increase spatial activation of the target location (Nigbur et al., 2015; Wendt et al., 2012). In the Simon task, participants have to respond to the identity (e.g., color) of a lateralized stimulus. Conflict in the Simon task is caused by interference between the relevant response and the irrelevant stimulus location of the stimulus on the screen. Control in the Simon task suppressed irrelevant spatial location codes (Stürmer & Leuthold, 2003; Töbel et al., 2014). We coded *task* as a moderator to assess how this influences the size and direction of emotional-biased control because the tasks reflect different aspects of control.

Stimulus Target Asynchrony. In the present meta-analysis, studies assessed the impact of emotional stimuli on a subsequent target response. To study timing aspects that might influence emotion-biased control, we coded three moderators. First, we assessed *emotional stimulus duration*, that is, how long the emotional stimulus was presented because longer presentation might correlate with more intense emotional responses. Second, we coded the time from offset of the emotional stimulus until onset of the target as the *interstimulus interval*. With longer delays between emotional stimuli and target onset, the emotional response could decay and competition between emotional stimuli and conflict task stimuli is reduced (see Mather & Sutherland, 2011).

Attention for Emotional Stimuli. Theoretical accounts hypothesized that emotional stimuli presented as part of the target/distractor objects will have a different impact than emotional stimuli that are separated in time, space, and objects from the target/distractor (e.g., Pessoa, 2008). Merging emotional information with relevant and irrelevant information in conflict tasks via spatial proximity (Pessoa, 2008) or object-based attention (Egly et al., 1994) might enlarge emotional influences on control (see Okon-Singer et al., 2007). Furthermore, Kanske (2012) proposed that emotional stimuli will enhance control only, if attended.

To assess the role of *attention for emotional stimuli*, we coded how emotional stimuli were merged with task-relevant and -irrelevant information. Emotional information could be presented either (a) as part of task-relevant and -irrelevant stimuli, (b) part of the task-relevant stimulus only, or (c) part of the task-irrelevant stimulus only, (d) spatial overlapping with task-relevant and -irrelevant stimuli, or (e) spatially distinct.

Modality of Emotional and Task-Related Stimuli. Multiple resource theories suggest that competition should be reduced for stimuli presented in different modalities, because they tax different resources (Wickens, 2002). Similarly, the arousal-biased competition account predicts that emotions in different modality as the target should even enhance the processing of the target (Mather & Sutherland, 2011). To assess the role of multiple resources for emotional stimuli and stimuli of the conflict task, we coded the modality match, that is, whether emotional stimuli and conflict task-relevant/-irrelevant stimuli are presented in the same or different modalities.

Overall Reaction Time. Mean reaction time (RT) was coded across congruency level:[1]

$$\mathrm{RT}_{\mathrm{overall}} = W_{\mathrm{inc}} \times \mathrm{RT}_{\mathrm{inc}} + W_{\mathrm{con}} \times \mathrm{RT}_{\mathrm{con}}. \quad (1)$$

More specfcically, we normalized reaction times (RTs) for each congruency level according to the relative proportion of congruency. Some theoretical accounts hold that emotional stimuli can be processed automatically (Carretié, 2014, for a review). Consequently, emotional stimuli should rather impact on relatively fast responses and could, according to the attentional view, reduce interference effects from task-irrelevant information. Still, controlled processing requires time, and it has been found that control is more pronounced for overall slower RTs (e.g., as indicated by δ plots, see Pratte et al., 2010; Ridderinkhof, 2002). According to the capacity view, emotional stimuli should compete with central resources required for controlled processing and such resource competition should stronger for relatively slow responses. In contrast, the emotions as a signal view suggests emotional stimuli can boost control, which should be more effective for slower (and more controlled) processing.

Individual Differences

Sample. We coded the countries where studies were conducted in order to test how culture affects the results, since culture differences have been suggested to influence emotion (L. F. Barrett, 2006; Fiske, 2020). And recent literature suggests that Western, educated, industrialized, rich, democratic (WEIRD) cultures can have large effects (e.g., Henrich et al., 2010). Therefore, examining whether results

[1] We thank an anonymous reviewer for this suggestion.

differ for WEIRD and non-WEIRD countries helps to show how universal phenomena are.

Age. We coded the mean age of participants to assess developmental changes across the life span. Coding of age was motivated by research revealing opposing effects of age on cognitive control and emotional responses. While cognitive control declines with increasing age (e.g., Zysset et al., 2007), the ability to regulate emotions and distraction by irrelevant emotional stimuli seems to increase for older adults (Samanez-Larkin et al., 2009; see also Reed et al., 2014). Even so, it is unclear whether and how both processes interact and the only study that addressed the modulation of cognitive control by emotional stimuli observed no differences between a group of young and older adults (Zinchenko, Obermeier, Kanske, Schröger, Villringer, et al., 2017).

Gender. We coded whether self-indicated gender of participants modulated the effect of emotional stimuli on cognitive control. It has been suggested that women and men differ in their response to emotional stimuli (e.g., Codispoti et al., 2008) and in their ability to regulate emotional response (e.g., McRae et al., 2008). Research also pointed toward gender differences in terms of distractibility by irrelevant negative stimuli (Gohier et al., 2013) and control of emotional distraction (e.g., Koch et al., 2007).

Publication Bias

Sample Size. Spurious findings are more likely with smaller samples. Therefore, we coded the sample size of each experiment to test whether significant effects are more often observed in smaller samples.

Primary Versus Secondary Measure. It has been suggested that publication bias is smaller for studies that used RT and ERs as secondary measures because results might be publishable due to effects in primary measures. Therefore, we coded whether the experiment measured only RT and ERs or also functional magnetic resonance imaging or electroencephalogram (EEG)/event-related potentials.

Publication Year. The decline effect refers to the observation that the effect sizes decrease with more time passed since the initial publication of an effect. To control for this publication bias, year of publication was coded.

Interaction Effects Between Moderators

The present meta-analysis focuses on control processes that might differ between conflict tasks. Therefore, a possible moderation of the affect–control interface could be specific to the task employed. An exploratory analysis tested this hypothesis and asked whether moderators influence affective effects on CEs differently for flanker, Simon, and Stroop by estimating interaction effects between the factor "task" and respective moderator variables.

Summary and Hypotheses

Multiple lines of research suggest that cognitive control is not encapsulated from emotional processing. Instead, mounting evidence demonstrates that emotional stimuli modulate cognitive control. According to some theories, arousal of irrelevant emotional stimuli competes with task-related processes for limited resources. Because high-arousal stimuli capture attention in a bottom-up fashion, they (a) block resources for perception and (b) deplete resources for executive control. Whereas these theories agree that emotional stimuli bias allocation of a common pool of resources, they make different predictions when and how this affects performance. Attentional accounts suggest that arousing stimuli overload resources and thereby exclude irrelevant distractor from being perceived. These accounts predict that high-arousal stimuli (irrespective of valence) reduce the magnitude of CEs. In contrast, capacity accounts argue that emotional stimuli strain central resources and thus reduce the ability to control distractor activity. These accounts predict that high-arousal and negative stimuli increase the magnitude of CEs.

Yet, other theories suggest that emotional stimuli feed into controlled processes more directly, either by (c) biasing ongoing competition between targets and distractors or (d) changing control states associated to stable shielding of distractors or more flexible attention to irrelevant background information. Whereas these theories agree that emotional stimuli are functional for control, they disagree on the relevant emotional dimensions and how these impact on performance. Bias competition accounts hold that arousing stimuli boost ongoing target selection, which favors the target at the expense of distractors. These accounts predict that high-arousal stimuli reduces the magnitude of CEs. According to the stability–flexibility view, valence of emotional stimuli represents a cue that changes information processing and gives more (positive emotions) or less (negative emotions) weight to distractor relative to target information. These accounts predict opposing influences of valence with increased (decreased) magnitude of CEs for positive (negative) emotional stimuli.

Against this background, the present research reconsiders the question how emotional stimuli modulate control by means of a meta-analysis. We had three main goals. First, we wanted to test whether emotional stimuli increase or decrease the magnitude of the CE. Second, we wanted to test how arousal and valence modulate this emotional bias. Together, these goals allow us to compare relevant theoretical views on emotional control interactions against each other. A third goal was to assess whether the effect size of emotional-biased control varies as a function of characteristics of the emotional stimuli, the experimental procedure, or the interaction of both and to assess influences of individual differences and publication bias.

To quantify increasing or decreasing control due to emotional stimuli, we computed the magnitude of the CE for all included studies and assessed the magnitude and direction of the overall effect size. To disentangle arousal and valence, we submitted the data to two independent analyses. The first meta-analysis compared the CE for arousing (positive and negative) relative to neutral stimuli. The second meta-analysis compared the CE for positive relative to negative stimuli. Regarding the third goal, several moderators were coded to assess more specific predictions about when and how emotional stimuli bias control. A more exploratory question was whether moderators modulate control differently for flanker, Stroop, and Simon tasks. Therefore, we assessed interactions between the task employed and other moderators.

Method

Literature Search

We searched (a) Web of Science and Pubmed for records in English, German, or Chinese from 1935 (the year of Stroop's seminal publication) until December 2018. For Web of Science, we used this search string "TS = (affect OR emotion OR affective OR emotional OR valence OR arousal OR negative OR positive) AND TS = ('flanker task' OR 'Simon task' OR 'Stroop task' OR 'Erikson task')"; for Pubmed, we expected text words to contain *affect*, *emotion*, *affective*, *emotional*, *valence*, *arousal*, *negative*, or *positive*, and "flanker task," "Simon task," "Stroop task," or "Erikson task." We also (b) consulted the references section of (c) relevant reviews and included articles. Furthermore, (d) we contacted (April 2019) the corresponding authors of all included articles to ask for additional published (e.g., currently in press/accepted) and unpublished studies. Finally, (e) we posted requests for summarized and unpublished data via several mailing lists of scientific societies (European society for cognitive psychology, Deutsche Gesellschaft für Psychologie).

Inclusion/Exclusion Criteria

We included an article only if it included one experiment or more that satisfy all the inclusion criteria summarized below. Here, experiments were defined in accordance with groups of participants (Borenstein et al., 2009). Specifically, if two groups of participants within one study were distinguished by individual characters (e.g., trait anxiety, age, clinical diagnosis), we treated each group as a separate experiment. If a group of participants were randomly assigned to subgroups receiving different treatments (e.g., placebo vs. drugs) and if this between-subjects manipulation was unrelated to affect or congruence manipulation, we treated each subgroup as a separate experiment. We used the following criteria to select an experiment.

First, we focused on experiments that probed in response interference effects with flanker/Stroop/Simon tasks. Therefore, we excluded an experiment if it did not use flanker/Simon/Stroop tasks or if it used emotional Stroop tasks (e.g., a drug Stroop task, emotional Stroop match-to-sample task; see, e.g., Williams et al., 1996) that are irrelevant to response interference or (extrinsic) affective Simon tasks (De Houwer, 2003b), which assessed implicit evaluation/attitude. We also excluded an experiment if it did not include both response-incongruent and response-congruent trials.

Second, we focused on task-irrelevant affect that is manipulated with emotional stimuli in a trial-by-trial manner. Therefore, we excluded experiments in which no affect was manipulated at all; excluded experiments manipulating emotional states with interventions like reappraisal and meditation instead of concrete emotional stimuli; and excluded experiments focusing on single-valence (either negative or positive) stimuli, tonic affect/mood, or affect contingent on performance or responses.

Third, we focused on healthy human beings, therefore we excluded experiments that tested patients only or nonhuman species.

Data Collection

We wrote to the authors of the articles that met the inclusion criteria to ask for the following data: (a) means and standard deviations of CEs in individual affective conditions; (b) Pearson correlation coefficients of CEs between different affective conditions; and (c) Pearson correlation coefficients of RTs (accuracies [ACCs]/error rates [ERs]) between congruent and incongruent conditions.

Usually, an article included two or more experiments and an experiment of a between-subjects design involves two or more groups of participants that were featured by demographic characters or experimental manipulation. We asked the authors to summarize data separately for individual experiments and in case of between-subjects experiments, separately for individual groups (Borenstein et al., 2009). Besides, when a potential moderator of interest (as elaborated in the "Moderators Characterizing Emotional Modulation of Control" part) was manipulated by the design employed (e.g., arousal was a variable of interest and manipulated in a study) or when a manipulation of irrelevant variables (e.g., type of negative words [emotion-lable vs. emotion-laden]) leads to changes in a potential moderator of interest (e.g., arousal), we also asked authors to code data separately for each level of that moderator (arousal) or manipulation (type of negative words).[2] For convenience, we constructed a particular table for each article; what the authors did was only to fill in the table. All tables we had provided the authors were uploaded to the Open Science Framework (Zhang et al., 2023).

Coding of Moderators

Coding methods of all moderators were presented in Table 2. Moderators were coded by the first author, and all authors discussed coding when there were ambiguities.

Analysis

Summarizing Data

When studies provided raw data, we aggregated RTs and ERs for each participant and each Affect × Congruence condition. Before aggregating RTs, we excluded error trials and outliers (beyond 2.5 *SD*s of cell means). After aggregation, we summarized (a) *M*s and *SD*s of CEs for each affective condition, (b) Pearson correlation coefficients of CEs (r) between affective conditions, and (c) Pearson correlation coefficients of RTs and ERs (r') between congruent and incongruent trials.

Computing Effect Sizes

Given that affect and congruence were manipulated within subjects in *all* experiments of the present meta-analysis, we computed Cohen's d_z as the measure of effect size. The way to compute d_z depended on the type of data we had. Optimally, d_z can be computed with the mean (M_{diff}) and the standard deviation (SD_{diff}) of raw differences in CE between affective conditions (Cracco et al., 2018; Lakens, 2013).

$$d_z = \frac{M_{\text{diff}}}{SD_{\text{diff}}}. \tag{2}$$

For effects of emotion in general, raw differences in CE were computed by subtracting the CEs in neutral conditions from affective conditions. A positive (negative) score means the CE is larger (smaller) in emotional versus neutral conditions. For valence-specific effects, raw differences in CE were computed by subtracting the CE in positive conditions from negative

[2] Some moderators were added to the database after we contacted authors.

Table 2
Coding Methods and Features of Moderators

Moderator	Value	Coding method	Description: Emotion versus neutral	Description: Negative versus positive
Properties of emotional stimuli				
Valence	N P	A categorical moderator representing valence of emotional stimuli. N = negative; P = positive.	N: $n = 180$ P: $n = 76$	/
D_v	Continuous	A continuous variable representing standardized differences in valance ratings between emotional stimuli. Mathematically, it equals absolute values of raw differences divided by pooled standard deviations (SD_{pool}). For the contrast between emotional and neutral stimuli, we coded *absolute values* of the standardized differences in valence rating. $SD_{pool} = \sqrt{(SD^2_{emo} + SD^2_{neu})/2}$, in which SD_{emo} and SD_{neu} represent the standard deviations of valence ratings for emotional conditions and neutral conditions, respectively. For the contrast between negative stimuli and positive stimuli, we coded *values* of the standardized differences in valence rating. $SD_{pool} = \sqrt{(SD^2_{neg} + SD^2_{pos})/2}$, in which SD_{neg} and SD_{pos} represent the standard deviations of valence ratings for negative conditions and positive conditions, respectively.	$n = 91$ $M = 5.67$ $SD = 5.45$ Range: 0.21–35.00	$n = 66$ $M = -7.59$ $SD = 5.20$ Range: −30.86 to −2.26
D_a_1	Continuous	A continuous variable representing standardized differences in arousal ratings between emotional stimuli.	$n = 101$ $M = 2.99$ $SD = 1.80$ Range: −0.03–8.63	$n = 62$ $M = 0.93$ $SD = 1.72$ Range: −2.87–5.09
D_a_2	T F	A categorical variable indicating whether difference in arousal is statistically significant (T) or nonsignificant (F) between emotional stimuli.	T: $n = 122$ F: $n = 15$	T: $n = 47$ F: $n = 19$
Thr	T F	A categorical variable indicating whether negative stimuli are threatening (T) or unthreatening (F). When negative stimuli are designed to be threatening or angry/fearful faces, negative stimuli are threatening. When negative stimuli are designed to be unthreatening or sad/disgusting, negative stimuli are unthreatening.	T: $n = 68$ F: $n = 32$	T: $n = 39$ F: $n = 28$
Sti	F W P A-S R S V D	A categorical variable specifying emotional stimulus type, for example, face pictures (F), word stimuli (W), pictures of emotional scenes (P), anticipation of shock (A-S), random reward (R), sounds (S), video (V), disfluency of processing (D).	F: $n = 85$ W: $n = 22$ P: $n = 98$ R: $n = 28$ V: $n = 10$ D: $n = 8$ A-S: $n = 3$	F: $n = 43$ W: $n = 9$ P: $n = 59$ R: $n = 16$ S: $n = 4$
Dur	Continuous	A continuous variable indicating exposure duration (in millisecond) of an emotional stimulus in each trial, specifically, the duration from onset to end of an emotional stimulus. When the mean of RTs terminates before the designed end of an emotional stimulus, counting of real exposure duration is from onset to the end of the mean RT. If it was variable in an experiment, we coded the mean.	$n = 203$ $M = 603$ $SD = 877$ Range: 50–6,000	$n = 119$ $M = 663$ $SD = 444$ Range: 50–3,000
Properties of experimental procedure				
Att	1 2 3 4 5	A categorical variable specifying whether emotional information is presented (a) as part of conflict task-relevant and -irrelevant stimuli, (b) part of the conflict task-relevant stimulus only, (c) part of the conflict task-irrelevant stimulus only, (d) spatially overlapping, or (e) spatially distinct with conflict task-relevant and -irrelevant stimuli. RT task is an abbreviation for response interference tasks. Conflict task-irrelevant stimuli evoke responses conflicting with conflict task-relevant stimuli, such as semantic words in a color–word Stroop task or flanking letters in a letter-flanker task.	1: $n = 44$ 2: $n = 21$ 3: $n = 18$ 4: $n = 151$ 5: $n = 22$	1: $n = 9$ 2: $n = 18$ 3: $n = 16$ 4: $n = 68$ 5: $n = 20$
Rep	Continuous	A continuous variable indicating how many times each emotional stimulus is repeated in an experiment.	$n = 205$ $M = 8.28$	$n = 121$ $M = 29.39$

(*table continues*)

Table 2 (*continued*)

Moderator	Value	Coding method	Description: Emotion versus neutral	Description: Negative versus positive
			SD = 11.20 Range: 1–70	*SD* = 58.79 Range: 1–240
Num	Continuous	A continuous variable representing how many trials in the *smallest* cell conditioned by emotion (negative, positive, neutral) and congruence (congruent, incongruent).	*n* = 242 *M* = 85.22 *SD* = 59.86 Range: 20–280	*n* = 127 *M* = 92.74 *SD* = 61.74 Range: 12–280
Des	B M	A categorical variable representing whether different valence conditions are blocked (B) or mixed within blocks (M).	B: *n* = 33 M: *n* = 215	B: *n* = 32 M: *n* = 99
ISI	Continuous	A continuous variable representing interval in millisecond from offset of emotional stimuli till onset of conflict task-relevant stimuli. If it was changeable in an experiment, we coded the mean.	*n* = 195 *M* = 57 *SD* = 712 Range: −1,026–2,500	n = 119 *M* = −53 *SD* = 627 Range: −1,026–1,450
Task	S F M	A categorical variable representing whether the conflict task refers to a Stroop-like task (S), a flanker task (F), or a Simon task (M).	S: *n* = 90 F: *n* = 140 M: *n* = 26	S: *n* = 31 F: *n* = 76 M: *n* = 28
Mod	S D	A categorical variable representing whether emotional stimuli and conflict task-relevant/-irrelevant stimuli are presented in the same (S) or different modalities (D).	S: *n* = 237 D: *n* = 9	S: *n* = 131 D: *n* = 4
RT	Continuous	A continuous variable representing the mean reaction time (RT) in millisecond for a task. Mathematically, the mean RT (RT) was calculated in this way, RT = W_{inc} * RT_{inc} + W_{con} * RT_{con} W_{inc} *and* W_{con} refer to weights/proportions of incongruent trials and congruent trials in a task, respectively. When congruent and incongruent trials were equally frequent, $W_{inc} = W_{con} = 0.5$. RT_{inc} and RT_{con} refer to mean reaction times for incongruent trials and congruent trials, respectively.	Range: 388–1,124 *n* = 252 *M* = 626 *SD* = 150	Range: 356–1,021 *n* = 130 *M* = 591 *SD* = 142
Individual differences				
Sample	United States China Germany England Israel Korea	A categorical variable representing which country participants are from.	United States: *n* = 75 Austria: *n* = 2 Bangladesh: *n* = 2 Canada: *n* = 8 China: *n* = 21 England: *n* = 17 Germany: *n* = 91 Israel: *n* = 21 Korea: *n* = 3 Netherlands: *n* = 8 Poland: *n* = 2 Switzerland and Germany: *n* = 6	United States: *n* = 39 Austria: *n* = 2 Canada: *n* = 8 China: *n* = 5 England: *n* = 6 Germany: *n* = 68 Korea: *n* = 3 Netherlands: *n* = 4
Age	Continuous	A continuous variable indicating the average of participants' ages.	*n* = 170 *M* = 23.43 *SD* = 8.8 Range: 5.30–69.4	*n* = 100 *M* = 23.79 *SD* = 5.52 Range: 5.30–32.56
F	Continuous	A continuous variable indicating the proportion of female participants.	*n* = 192 *M* = 0.59 *SD* = 0.17 Range: 0.16–1.00	*n* = 110 *M* = 0.64 *SD* = 0.16 Range: 0.16–1.00
Publication bias				
N	Continuous	A continuous variable indicating the number of subjects in an experiment.	*n* = 248 *M* = 29	*n* = 135 *M* = 43

(*table continues*)

Table 2 (*continued*)

Moderator	Value	Coding method	Description: Emotion versus neutral	Description: Negative versus positive
			SD = 14 Range: 8–101	SD = 35 Range: 13–215
Env	B E F	A categorical variable indicating whether an experiment is a behavioral (B), ERP/EEG(E), or fMRI (F) experiment.	B: n = 130 E: n = 67 F: n = 59	B: n = 82 E: n = 30 F: n = 23
PY	Continuous	A continuous variable indicating publication year of an experiment.	n = 244 Range: 2006–2019	n = 121 Range: 2006–2019

Note. D_v = difference in valence rating between emotional stimuli and neutral stimuli; D_a_1 = difference in arousal rating between emotional stimuli and neutral stimuli; D_a_2 = statistical significance of arousal difference between affective and neutral stimuli; Thr = threat of negative stimuli (threatening, unthreatening); Sti = affect-stimulus format; Dur = exposure duration of the emotional stimuli; Att = attentional status toward the emotional stimuli; Rep = the number of times the emotional stimuli were repeatedly presented; Num = the number of trials of the smallest cell defined by affect and congruency in the experiment; Des = procedure of presenting emotional stimuli in the experiment; ISI = interstimulus interval measured from the offset of emotional stimuli to the onset of conflict task-relevant stimuli; Mod = compatibility of perception modalities between emotional stimuli and conflict-task stimuli; RT = mean reaction time for the experiment task; Env = experiment environment; PY = publication year of the experiment; ERP = event-related potential; EEG = electroencephalogram; fMRI = functional magnetic resonance imaging.

conditions. A positive (negative) score suggests the CE is larger (smaller) in negative versus positive conditions. For general emotional effect,

$$SD_{\text{diff}} = \sqrt{SD_{\text{emo}}^2 + SD_{\text{neu}}^2 - 2 \times r \times SD_{\text{emo}} \times SD_{\text{neu}}}, \quad (3)$$

and for valence-specific effect,

$$SD_{\text{diff}} = \sqrt{S_{\text{neg}}^2 + SD_{\text{pos}}^2 - 2 \times r \times SD_{\text{neg}} \times SD_{\text{pos}}}. \quad (4)$$

SD_{emo}, SD_{neu}, SD_{neg}, and SD_{pos} represent the standard deviations of the CEs in emotional conditions, neutral conditions, negative conditions, and positive conditions, respectively. r is the Pearson correlation coefficient of CEs between affective conditions.

Unfortunately, r was usually inaccessible. In that case, we searched for t score of the difference in CE between affective conditions or F score of a Valence (2) × Congruence (2) interaction effect (Cracco et al., 2018; Lakens, 2013). Then,

$$d_z = \frac{t}{\sqrt{N}} = \frac{\sqrt{F}}{\sqrt{N}}, \quad (5)$$

where N represents the number of participants. With this method, direction of the difference in CE had to be coded. For instance, when results of a study demonstrated that a larger CE occurred in emotional versus neutral conditions, d_z (computed by subtracting the CE in neutral conditions from emotional conditions) must be positive.

When r was missing and when t and F values were not reported as well, we replaced r with an estimate. The estimate was achieved by performing an additional meta-analysis of rs in experiments included in the main meta-analysis. Details of estimating r were presented in Supplemental Materials. The estimate of r was 0.60 (95% CI [0.48, 0.69]) for the contrast between emotional and neutral conditions and was 0.51 (95% CI [0.40, 0.62]) for the contrast between negative and positive conditions.

In addition to r, standard deviations of CEs were usually missing. Then,

$$SD_{\text{CE}} = \sqrt{SD_{\text{incon}}^2 + SD_{\text{con}}^2 - 2 \times r' \times SD_{\text{incon}} \times SD_{\text{con}}}. \quad (6)$$

SD_{incon} and SD_{con} represent the standard deviations of RTs (ACCs/ERs) of incongruent trials and of congruent trials, respectively. They were usually available from the main text or published tables/figures. r' represents the Pearson correlation coefficient of RTs (ACCs/ERs) between congruent and incongruent conditions. r' was usually not published and we replaced it with an estimate we achieved by performing another meta-analysis of r's in experiments included in the main meta-analysis. Details of the meta-analysis of r' were presented in Supplemental Materials. The estimate of r' was 0.83 (95% CI [0.80, 0.86]).

d_z was corrected with Hedges' method (Hedges, 1982). The correction parameter (J) can be approximated by $1 - \frac{3}{4 \times (N-1) - 1}$. Consequently,

$$g_z = d_z \times \left(1 - \frac{3}{4 \times (N - 1) - 1}\right). \quad (7)$$

Sampling variance (v; Cracco et al., 2018),

$$v = \frac{1}{N} + \frac{g_z^2}{2N}. \quad (8)$$

Meta-Analytic Procedure

Analyses were conducted in R (R Core Team, 2018) using the metafor package (Viechtbauer, 2010). The meta-analytical models were conducted as multilevel random-effects models (MREM) because effects sizes computed from the same experiment (e.g., RTs and accuracy) violate the assumption of independence of effect sizes. Application of MREM addresses dependency of effect sizes by higher order clustering that allows to account for correlations between multiple effect sizes from the same study and between multiple effect sizes from the same experiment. Therefore, the present meta-analysis used a three-level random-effects models (Assink & Wibbelink, 2016) to fit g_z values across studies and experiments. Level 1 represents the sampling variance (v_{ij}); Level 2 represents the variance between effect sizes estimates within experiments (u_i); and Level 3 represents the variance between experiments (τ^2):

$$y_{ij} = \beta_0 + \tau^2 + u_i + v_{ij}, \quad (9)$$

where y_{ij} represents the jth estimate of the effect in the ith experiment and β_0 represents the mean of true effect sizes across experiments.

We fitted data to an *intercept-only* model to achieve an overall estimate, namely β_0. Regarding the heterogeneity across observations, we examined the proportion of variance situated at each level (for more details of specific methods, see Harrer et al., 2019). If the sampling variance was less than 75% of the total variance, then we further assessed the modifying influences of moderators; otherwise, we concluded that there was no need to do so (Hunter & Schmidt, 1990). To examine the influences of moderators and interaction effects between moderators, we entered each moderator and each interaction effect separately into a metaregression model. We restricted analysis of more complex models to a possible interaction between the task employed and other moderator variables. To test the possibility of publication bias, funnel plots were plotted with X-axis indicating the magnitudes of effect sizes and Y-axis indicating standard errors (Sterne & Egger, 2001) and we conducted a regression test to test funnel plot asymmetry by entering standard error as a moderator in a metaregression model (Egger et al., 1997). If results of the regression test demonstrated asymmetry of the funnel plot, we drew a contour-enhanced funnel plot (Peters et al., 2008) to help to detect publication bias due to the suppression of nonsignificant results. We performed sensitivity analysis by replacing estimates of correlations (r and r') with other candidate values in their 95% CI, more exactly, boundary values to test if results depended on correlations of CEs between affective conditions. Results of sensitivity analysis were similar to the primary analysis; therefore, we included them in the Supplemental Materials.

Apparatus

Data summary was completed in IBM SPSS Statistics 25. d_z and its sampling variance (v) were computed with *escalc* function (the argument *Measure* = "SMCC", which represents raw change divided by standard deviation of change scores) in the R package metafor (Viechtbauer, 2010). Throughout the present meta-analysis, we fitted models via restricted maximum-likelihood estimation, which was generally recommended by Viechtbauer (2005). The criterion for statistical significance remained $p < .05$. We used GetData Graph Digitizer 2.26 to measure data from figures.

Results

Results of Literature Search and Data Collection

Figure 1 shows a schematic overview of the search results. We identified 3,292 records in total; after a filtering procedure based on our exclusion criteria and data collection, data from 71 articles were included in the present meta-analyses (another 25 articles were excluded because of lacking relevant statistics and a list of these articles was included as a Supplemental Materials). To specify, we received from authors (a) summarized data of 19 experiments in 14 articles; (b) aggregated RTs and ACCs/ERs of 18 experiments in 13 articles; and (c) raw data of 19 experiments in seven articles, one under review article, and three unpublished studies; furthermore, we collected (d) necessary statistics from 33 articles including a sum of 47 experiments. Thus, we considered data from 103 experiments of 71 studies. Hereinafter, we counted the number of participant groups in between-/within-subjects studies as the number of experiments. All the studies were included in the reference list and marked with an asterisk.

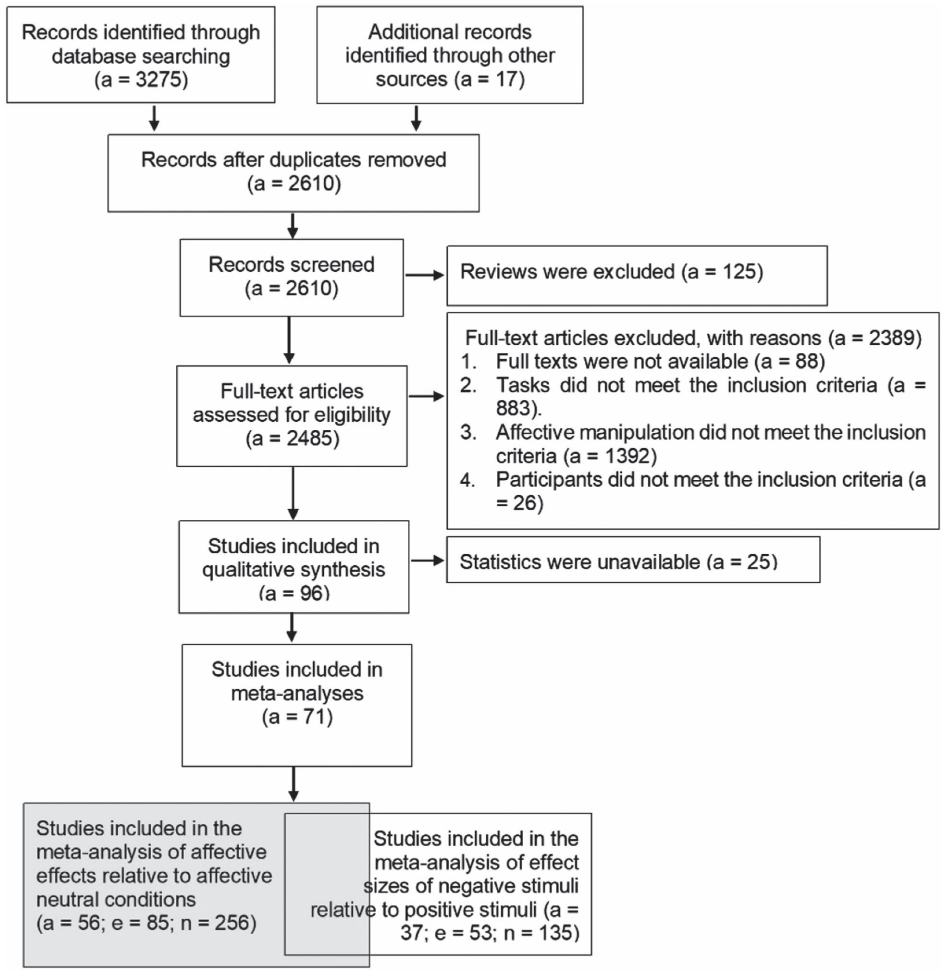
Results of Coding Moderators

Coding results of individual studies and observations were included in Supplemental Materials. Information on moderator features (e.g., means, standard deviations; range) were summarized in Table 2. Here, we presented a brief overview of moderators related to participants included in the present meta-analyses. Hereinafter, the lowercase letters "a," "e," and "n" in parenthesis refer to the number of studies (articles), experiments (participant groups), and observations (estimates), respectively.

Fifty-six of 71 studies provided a total of 256 estimates for the meta-analysis of affective relative to neutral conditions. Two hundred forty-four of 256 estimates were from studies published in 2006 through 2018 and the remaining 12 estimates were from unpublished studies. Those studies were conducted in America ($n = 75$), Australia ($n = 2$), Bangladesh ($n = 2$), China ($n = 21$), Canada ($n = 8$), England ($n = 17$), Israel ($n = 21$), Korea ($n = 3$), Netherlands ($n = 8$), Poland ($n = 2$), and Switzerland and Germany (cooperation: $n = 6$; Germany alone: $n = 91$). A sum of 2,314 participants of 85 experiments were involved, with the sample size of individual experiment ranging from 8 to 101. Percentages of female participants were available for 192 estimates and ranged from 0.16 to 1, with a mean of 0.59 (SD = 0.17). Mean ages were available for 170 estimates and ranged from 5.3 to 69.4 years old, with a mean of 23.4 years (SD = 8.8).

Thirty-seven of 71 studies provided a total of 135 estimates for the meta-analysis of effect sizes of negative stimuli relative to positive stimuli. One hundred twenty-one of 256 estimates were from studies published in 2006 through 2018 and the remaining 14 estimates were from unpublished studies. Those studies were conducted in America ($n = 39$), Australia ($n = 2$), Canada ($n = 8$), China ($n = 5$), England ($n = 6$), Germany ($n = 68$), Korea ($n = 3$), and Netherlands ($n = 4$). A sum of 2,046 participants of 53 experiments were involved, with the

Figure 1
Flow of Studies Into the Meta-Analyses



Note. Flow of studies into the meta-analyses as they faced each filter. Seventy-one studies were included in the present meta-analyses. The lowercase letters *a*, *e*, and *n* in parenthesis represent the numbers of articles (i.e., studies), experiments, and estimates, respectively. Fifty-six of 71 articles provided 256 estimates of 85 experiments for the meta-analysis of affective effects relative to affective neutral conditions. Thirty-seven of 71 articles provided 135 estimates of 53 experiments for the meta-analysis of effect sizes of negative stimuli relative to positive stimuli. Some studies provided estimates for both meta-analyses. The number of experiments was counted as the number of participant groups in between-/within-subjects studies.

sample size of individual experiment ranging from 13 to 215. Percentages of female participants were available for 110 estimates and ranged from 0.16 to 1, with a mean of 0.64 ($SD = 0.16$). Mean ages were available for 100 estimates and ranged from 5.3 to 32.6 years old, with a mean of 23.4 years ($SD = 5.5$ years).

Difference in Congruence Effect Between Affective and Neutral Conditions

Overall Estimate

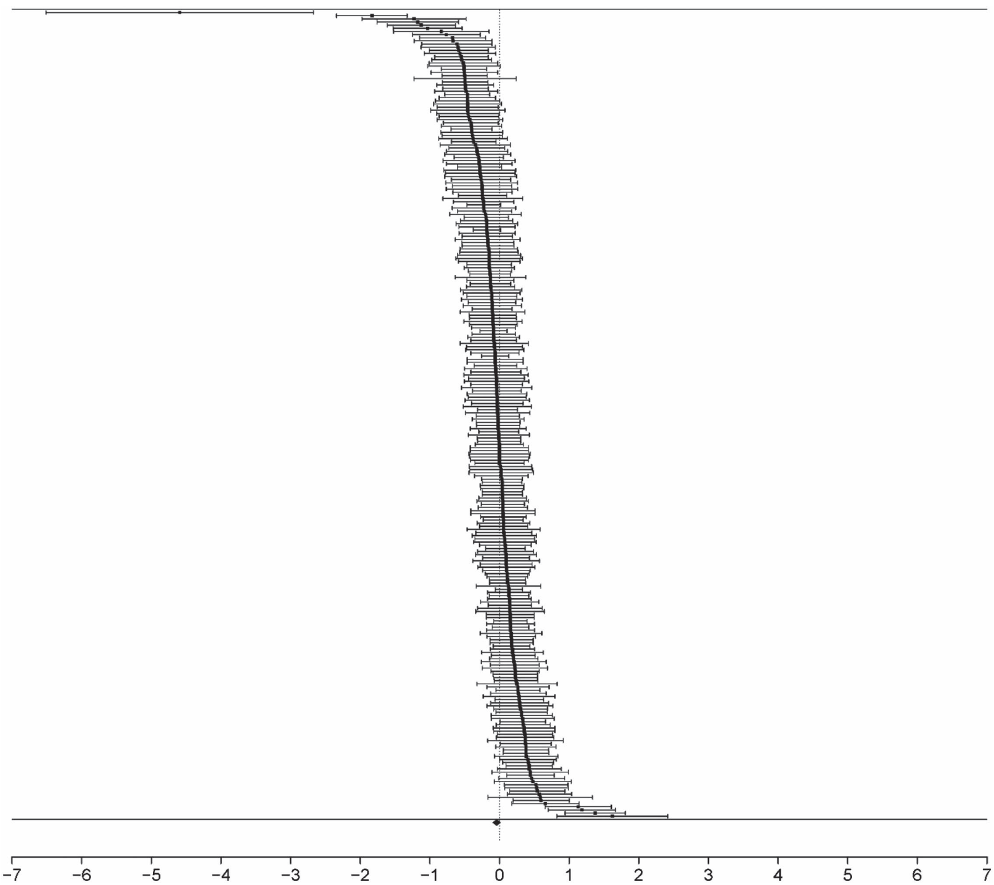
The overall estimate of difference in CE between emotional and neutral conditions was −0.04 (95% CI [−0.09, 0.01]; $n = 256$, $a = 56$, $e = 85$; see Figure 2, for a forest plot) and statistically nonsignificant against zero ($t = -1.61$, $p = .11$).

Effect Size Heterogeneity

The sampling variance (0.036) occupied nearly 36% of the total variance; the within-experiments/between-estimates variance (0.042) occupied around 42% of the total variance; the between-experiments variance (0.022) occupied nearly 22% of the total variance. According to the 75% rule proposed by Hunter and Schmidt (1990), it was worthy of investigating modifying influences of potential moderators.

Figure 2

Forest Plot of Individual Effect Sizes of Emotional (Relative to Neutral) Effects



Note. Individual effect sizes are ordered by effect size. The overall estimate with 95% confidence intervals is represented with a diamond.

Significant Moderator

Here, we presented results of significant moderators only. See Table 3, for details of other nonsignificant moderators.[3] Besides, we also presented results of attention for emotional stimuli because results of sensitivity analyses showed it was a significant moderator (see Supplemental Materials, for results of sensitivity analyses).

Stimulus Format. Results demonstrated that stimulus format was a significant moderator, $F(6, 247) = .38$, $p < .001$; $e = 84$, $n = 254$. The overall difference in CE between emotional and neutral conditions reached statistical significance for word stimuli ($\beta = -0.23$, 95% CI [−0.37, −0.08]; $t = -3.12$, $p < .01$; $e = 12$, $n = 22$; see Figure 3), for video stimuli ($\beta = -0.29$, 95% CI [−0.50, −0.08]; $t = -2.72$, $p < .01$; $e = 5$, $n = 10$), and when emotion was evoked with disfluency of processing ($\beta = 0.35$, 95% CI [0.10, 0.61]; $t = 2.70$, $p < .01$; $a = 1$, $e = 2$, $n = 8$). Negative overall differences in CE for word stimuli and video stimuli indicate smaller CEs in emotional versus neutral conditions. The overall difference was positive when emotion was evoked with disfluency of processing; however, individual observations were from two experiments reported in single article ($a = 1$). The overall difference in congruence effect was statistically nonsignificant for face stimuli ($t = -0.04$, $p = .97$; $e = 23$, $n = 85$), emotional pictures ($t = 0.10$, $p = 92$; $e = 32$, $n = 98$), random reward ($t = -0.52$, $p = .60$; $e = 8$, $n = 28$), or for anticipation of shock ($t = -1.87$, $p = .06$; $e = 2$, $n = 3$).

Arousal Difference. Results demonstrated that difference in arousal between emotional and neutral stimuli was a significant moderator, $F(1, 135) = 3.94$, $p = .049$; $e = 52$, $n = 137$; see Figure 4. Specifically, the overall estimate of affective effects reached statistical significance when arousal of emotional stimuli was not different ($p > .05$) from neutral stimuli ($\beta = -0.23$, 95% CI [−0.41, −0.04]; $t = -2.37$, $p = .02$; $e = 9$, $n = 15$); a negative overall estimate suggested a smaller CE for emotional versus neutral stimuli. The overall estimate of affective effects was statistically nonsignificant when arousal of emotional stimuli differed ($p < .05$) from neutral stimuli ($t = -0.70$, $p = .49$; $e = 44$, $n = 122$).

[3] As suggested by a reviewer, we also examined influences on affective effects from specific emotional categories. After coding specific emotional categories, we fitted affective effects into a model with emotional category as one moderator. The results showed that specific emotional category (sad [$e = 5$, $n = 8$], happy [$e = 11$, $n = 21$], fearful [$e = 16$, $n = 35$], angry [$e = 14$, $n = 32$]) was not a significant moderator, $F(3, 92) = 2.05$, $p = .11$; $e = 29$, $n = 96$.

Table 3
Results of the Metaregression Analyses With One Moderator Only for the Comparison Between Emotional and Neutral Conditions

Moderator	*df*	*F*	*p*	*e*	*n*	β	95% CI	Intercept	σ_1	σ_2
Properties of emotional stimuli										
Valence	1, 254	0.53	.47	85	256				0.210	0.149
Negative				78	180	−0.03	[−0.09, 0.02]			
Positive				40	76	−0.06	[−0.14, 0.02]			
D_v	1, 89	0.12	.73	31	91	−0.002	[−0.02, 0.01]	−0.02	0.260	0.000
D_a_1	1, 95	0.41	.52	33	97	−0.01	[−0.05, 0.03]	0.04	0.269	0.000
D_a_2	1, 135	3.94	.05*	52	137				0.280	0.091
Nonsignificant				9	15	−0.23*	[−0.41, −0.04]			
Significant				44	122	−0.02	[−0.09, 0.05]			
Thr	1, 98	0.69	.41	38	100				0.183	0.209
Unthreatening				15	32	−0.06	[−0.20, 0.07]			
Threatening				28	68	0.001	[−0.10, 0.10]			
Sti	6, 247	4.38	<.001***	84	254				0.209	0.113
Face				23	85	−0.002	[−0.08, 0.08]			
Emotional picture				32	98	0.004	[−0.07, 0.08]			
Random reward				8	28	−0.03	[−0.16, 0.09]			
Video				5	10	−0.29**	[−0.50, −0.08]			
Word				12	22	−0.23**	[−0.37, −0.08]			
Anticipation of shock				2	3	−0.36	[−0.75, 0.02]			
Disfluency of processing				2	8	0.35**	[0.09, 0.61]			
Dur[a]	1, 201	0.57	.45	65	203	−0.03	[−0.11, 0.05]	−0.01	0.235	0.138
Properties of experimental procedure										
Att	4, 251	2.21	.07	85	256				0.201	0.159
1				20	44	−0.18**	[−0.29, −0.06]			
2				6	21	−0.02	[−0.18, 0.15]			
3				4	18	0.11	[−0.08, 0.29]			
4				53	151	−0.01	[−0.08, 0.05]			
5				7	22	−0.04	[−0.20, 0.13]			
Rep	1, 203	0.47	.49	71	205	1.70	[−3.21, 6.61]	−0.08	0.204	0.144
Num[a]	1, 240	1.20	.27	82	242	0.50	[−0.40, 1.41]	−0.09	0.193	0.167
Des	1, 246	3.60	.06	83	248				0.191	0.159
Blocked				10	33	0.08	[−0.06, 0.23]			
Mixed				59	215	−0.06*	[−0.12, −0.01]			
ISI[a]	1, 193	0.23	.63	63	195	0.02	[−0.05, 0.09]	−0.04	0.222	0.110
Task	2, 253	2.53	.08	85	256					
Flanker				42	140	0.004	[−0.06, 0.07]		0.209	0.145
Simon				10	26	−0.17*	[−0.32, −0.02]			
Stroop				33	90	−0.07	[−0.15, 0.01]			
Mod	1, 244	0.02	.89	80	246				0.204	0.144
Incompatible				4	9	−0.01	[−0.25, 0.22]			
Compatible				77	237	−0.03	[−0.08, 0.02]			
RT[a]	1,250	0.02	.88	83	252	0.03	[−0.31, 0.37]	−0.05	0.212	0.147
Individual differences										
Sample	11, 244	1.76	.06	85	256				0.206	0.147
America				21	75	−0.03	[−0.13, 0.06]			
China				7	21	−0.12	[−0.30, 0.05]			
England				7	17	0.13	[−0.04, 0.30]			
Germany				29	91	−0.10*	[−0.18, −0.02]			
Israel				9	21	−0.02	[−0.19, 0.16]			
Australia				1	2	−0.28	[−0.82, 0.27]			
Bangladesh				1	2	−0.35	[−0.84, 0.13]			
Canada				2	8	0.06	[−0.22, 0.35]			
Korea				2	3	0.64**	[0.19, 1.09]			
Netherlands				2	8	0.02	[−0.26, 0.30]			
Poland				1	2	−0.03	[−0.47, 0.40]			
Switzerland and Germany				3	6	0.01	[−0.29, 0.30]			
Age[a]	1, 168	2.63	.11	63	170	−4.77	[−10.57, 1.03]	0.03	0.263	0.029
F	1, 190	0.43	.51	65	192	0.11	[−0.22, 0.44]	−0.13	0.228	0.131
Publication bias										
N[a]	1, 254	1.36	.24	85	256	2.01	[−1.38, 5.40]	−0.10	0.209	0.151
Env	2, 253	3.98	.02*	85	256				0.208	0.142
Behavioral				38	130	−0.01	[−0.07, 0.06]			

(*table continues*)

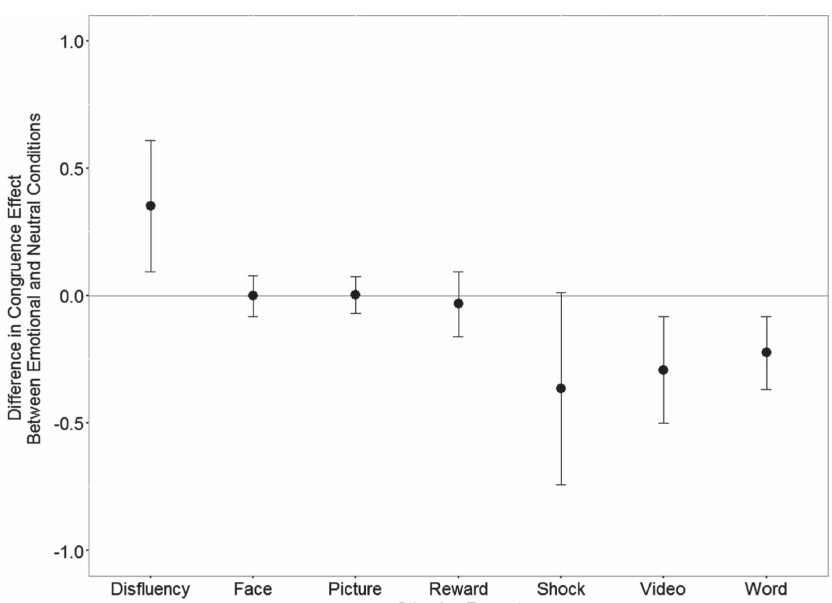
Table 3 (*continued*)

Moderator	*df*	*F*	*p*	*e*	*n*	β	95% CI	Intercept	σ_1	σ_2
ERP				25	67	−0.15**	[−0.25, −0.06]			
fMRI				22	59	0.02	[−0.08, 0.12]			
PY	1, 242	1.51	.22	82	244	0.01	[−0.01, 0.03]	−21.79	0.223	0.156

Note. βs of continuous variables represent regression coefficients and of categorical variables represent overall estimates of effect sizes at individual levels. σ_1 and $\sigma_2$represent residual variance between estimates and between experiments, respectively. *e* = number of experiments; *n* = number of estimations; 95% CI = confidence interval at the 95% confidence level; Valence = valence of emotional stimuli (negative, positive); D_v = difference in valence rating between emotional stimuli and neutral stimuli; D_a_1 = difference in arousal rating between emotional stimuli and neutral stimuli; D_a_2 = statistical significance of arousal difference between affective and neutral stimuli (significant [$p < .05$]; nonsignificant); Thr = threat of negative stimuli (threatening, unthreatening); Sti = affect-stimulus format (face = emotional face photos; word = emotional words; emotional picture = emotional pictures; video = emotional videos; anticipation of shock = stimuli conditioned with electro shock; sound = sounds; random reward = random reward being independent from task performance; disfluency = trigger of disfluent processing); Dur = exposure duration of the emotional stimuli; Att = attentional status toward the emotional stimuli (1 = affective information was presented as part of conflict task-relevant and -irrelevant stimuli; 2 = affective information was presented as part of conflict task-relevant stimuli; 3 = affective information was presented as part of the conflict task-irrelevant stimuli; 4 = affective information was spatially overlapping with conflict task-relevant and -irrelevant stimuli; 5 = affective information was spatially distinct from conflict task-relevant and -irrelevant stimuli); Rep = the number of times the emotional stimuli were repeatedly presented; Num = the number of trials of the smallest cell defined by affect and congruency in the experiment; Des = procedure of presenting emotional stimuli in the experiment (blocked = emotional stimuli of different valence were presented in different blocks; mixed = emotional stimuli of different valence were intermixed within blocks); ISI = interstimulus interval measured from the offset of emotional stimuli to the onset of conflict task-relevant stimuli; Mod = compatibility of perception modalities between emotional stimuli and conflict task stimuli (compatible, incompatible); Task = conflict task in the experiment (Stroop task, Simon task, flanker task); RT = mean reaction time for the experiment task; Age = mean age of the experiment participants; F = ratio of female participants in the experiment; *N* = number of the experiment participants; Env = experiment environment (behavioral experiment, ERP experiment, fMRI experiment); ERP = event-related potential; fMRI = functional magnetic resonance imaging; PY = publication year of the experiment.
[a] Each value of the moderator was divided by 1,000 before analysis, which did not change results.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Attention for Emotional Stimuli. Results demonstrated that the modifying influence of attention for emotional stimuli was marginally significant (*e* = 85, *n* = 256; see Figure 5), $F(4, 251) = 2.21$, $p = .07$. The overall difference in CE between emotional and neutral conditions was statistically significant when emotional information is presented as part of task-relevant and -irrelevant stimuli (β = −0.18, 95% CI [−0.29, −0.06]; $t = -3.05$, $p \leq .01$; $e = 20$, $n = 44$); a negative overall difference indicated a smaller CE in emotional versus neutral conditions. In other situations, the overall difference in congruence effect became statistically nonsignificant: when emotional information

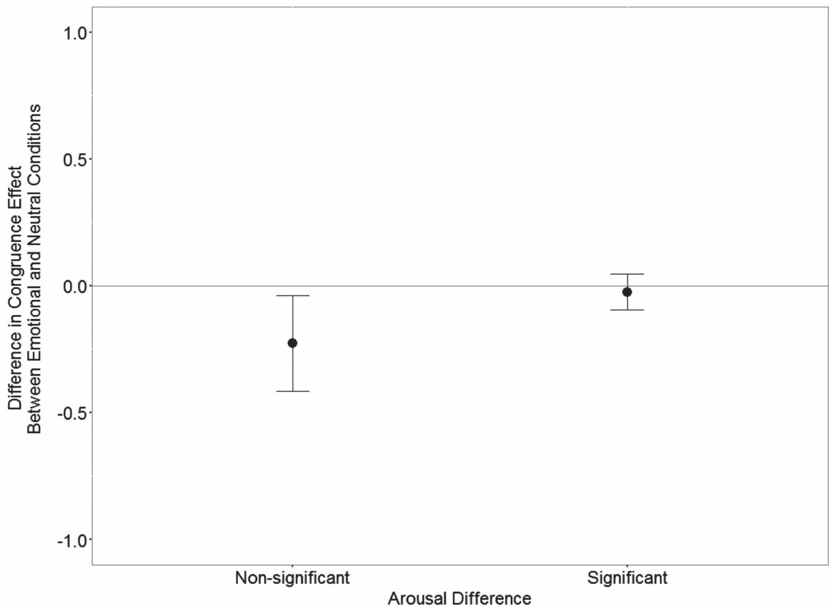
Figure 3
Affective Effects Across Stimulus Formats



Note. Overall estimates of effect sizes of the difference in congruence effect for emotional relative to neutral stimuli when emotion was invoked with disfluency of processing, face photos, emotional pictures, random reward, anticipation of shock, video, and word stimuli. Error bars indicate 95% confidence intervals.

Figure 4

Affective Effects Across Different Conditions of Arousal Difference Between Emotional and Neutral Stimuli



Note. Overall estimates of effect sizes of the difference in congruence effect for emotional relative to neutral stimuli across different conditions of arousal difference between emotional and neutral stimuli. Nonsignificant = arousal difference between emotional stimuli and neutral stimuli did not reach statistical significance ($p > .05$); Significant = arousal difference between emotional and neutral stimuli was statistically significant ($p \leq .05$). Error bars indicate 95% confidence intervals.

was presented as part of the task-relevant stimulus only ($e = 6$, $n = 21$) or task-irrelevant stimulus only ($e = 4$, $n = 18$), $t = -0.18$, $p = .86$, and $t = 1.13$, $p = .26$, respectively; when emotional stimuli spatially overlap with conflict task-relevant and -irrelevant stimuli ($e = 53$, $n = 151$), $t = -0.42$, $p = .67$; for others ($e = 7$, $n = 22$), $t = -0.45$, $p = .65$.

Experiment Environment. Results demonstrated that experiment environment was a significant moderator, $F(2, 253) = 3.98$, $p = .02$; $e = 85$, $n = 256$; see Figure 6. The overall difference in CE between emotional and neutral conditions was statistically significant for event-related potential experiments ($\beta = -0.15$, 95% CI [−0.25, 0.06]; $t = -3.23$, $p < .01$; $e = 25$, $n = 67$), and the CE was smaller in emotional versus neutral conditions. The overall difference was statistically nonsignificant for behavioral studies ($t = -0.15$, $p = .88$; $e = 38$, $n = 130$) or functional magnetic resonance imaging studies ($t = 0.34$, $p = .73$; $e = 22$, $n = 59$).

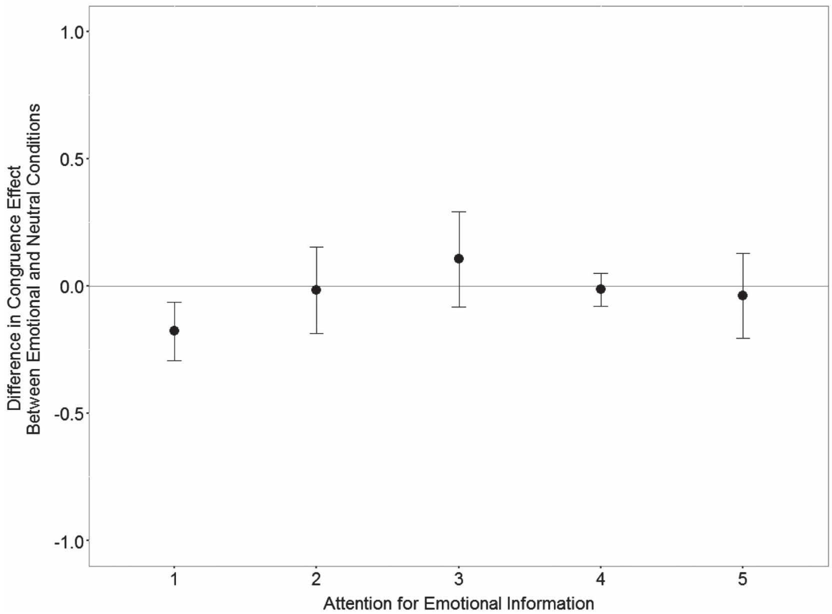
Interaction Effects Between Task and the Other Moderators

Only significant interaction effects are discussed. See Table 4, for an overview of all interaction results.

Interaction Between Task and Stimulus Format. Results demonstrated significant affective effects for different formats of emotional stimuli in different tasks, see Figure 7; $F(6, 239) = 3.81$, $p < .01$; $e = 84$, $n = 254$. Specifically, the overall estimate of affective effects in Stroop tasks was statistically significant for face stimuli ($t = -2.65$, $p = .01$; $\beta = -0.19$, 95% CI [−0.33, −0.05]; $e = 5$, $n = 18$), video stimuli ($t = -3.08$, $p < .01$; $\beta = -0.29$, 95% CI [−0.48, −0.10]; $e = 5$, $n = 10$), and neutral stimuli conditioned with electronic shock ($t = -2.13$, $p = .03$; $\beta = -0.38$, 95% CI [−0.72, −0.03]; $e = 2$, $n = 3$); the overall estimate of affective effects in Simon tasks was statistically significant for face stimuli ($t = -2.69$, $p < .01$; $\beta = -0.34$, 95% CI [−0.58, −0.09]; $e = 2$, $n = 5$) and word stimuli ($t = -2.64$, $p < .01$; $\beta = -0.46$, 95% CI [−0.81, −0.12]; $e = 3$, $n = 3$); and the overall estimate of affective effects in flanker tasks was statistically significant for face stimuli ($t = 2.14$, $p = .03$; $\beta = 0.08$, 95% CI [0.01, 0.15]; $e = 16$, $n = 62$), word stimuli ($t = -2.33$, $p = .02$; $\beta = -0.17$, 95% CI [−0.32, −0.03]; $e = 7$, $n = 16$), and disfluent processing ($t = 4.29$, $p < .01$; $\beta = 0.65$, 95% CI [0.35, 0.95]; $e = 1$, $n = 4$). Overall estimates of affective effects were statistically nonsignificant for other combinations of task and stimulus format (ps $> .36$).

Interaction Between Task and the Number of Repetitions of Emotional Stimuli. The interaction effect between task and the number of repetitions of emotional stimuli was statistically significant, see Figure 8; $F(2, 199) = 6.97$, $p < .01$; $e = 71$, $n = 205$. Specifically, the overall estimate of affective effects in Stroop tasks varied with the amount of repetitions of emotional stimuli ($t = -3.62$, $p < .01$; $e = 26$, $n = 70$). More specifically, a negative regression coefficient suggested that the CE for emotional stimuli relative to neutral stimuli decreased as the amount of repetitions of emotional stimuli increased ($\beta = -0.03$, 95% CI [−0.06, −0.01]). The modifying influence of repetitions of emotional stimuli was not statistically significant for Simon tasks ($t = -1.13$, $p = .26$; $e = 10$, $n = 26$) or flanker tasks ($t = 0.42$, $p = .68$; $e = 35$, $n = 109$).

Figure 5
Affective Effects Across Various Attentional Status to Emotional Stimuli



Note. Overall estimates of effect sizes of the difference in congruence effect for emotional relative to neutral stimuli when emotional stimuli were presented (a) as part of conflict task-relevant and -irrelevant stimuli (i.e., attention for emotional information = "1"), (b) as part of conflict task-relevant stimuli only (i.e., attention for emotional information = "2"), (c) as part of conflict task-irrelevant stimuli only (i.e., attention for emotional information = "3"), (d) spatially overlapping with conflict task-relevant and -irrelevant stimuli (i.e., attention for emotional information = "4"), and (e) spatially distinct from conflict task-relevant and -irrelevant stimuli (i.e., attention for emotional information = "5"). Error bars indicate 95% confidence intervals.

Interaction Effect Between Task and Modality Compatibility. The interaction effect between task and modality compatibility was statistically significant, see Figure 9; $F(1, 241) = 8.66$, $p < .01$; $e = 80$, $n = 246$. Specifically, the overall estimate of affective effects in Simon tasks was statistically significant when emotional stimuli and conflict task stimuli were compatible in perceptual modality ($t = -3.21$, $p < .01$; $e = 9$, $n = 20$) and the overall estimate of affective effects ($\beta = -0.25$, 95% CI [−0.41, −0.10]) indicated a smaller CE for affective versus neutral stimuli. Besides, results of sensitivity analysis also showed a marginally significant effect size in Stroop tasks when emotional stimuli and conflict task stimuli were different in perceptual modality ($t = -1.99$, $p = .05$; $\beta = -0.35$, 95% CI [−0.71, −0.00]; $e = 2$, $n = 3$). Affective effects were not statistically significant for other combinations of task and modality compatibility (ps > .06).

Publication Bias

Most observations were crowded at the top of the funnel plot (see Figure 10) because of infrequent extreme effects with large standard errors. Results of metaregression analyses showed that standard error was a significant moderator, $F(1, 254) = 13.55$, $p < .001$, suggesting asymmetry of the funnel plot. Visually, there were some missing effect sizes on the right side of the funnel (see Figure 10), and those values were mostly located in areas with large effect sizes (areas with $p < .05$). Accordingly, there seems no issue of hiding nonsignificant results; instead, the funnel plot asymmetry might arise from other factors such as variable qualities of studies (Peters et al., 2008).

Differences in Congruence Effect Between Negative and Positive Conditions

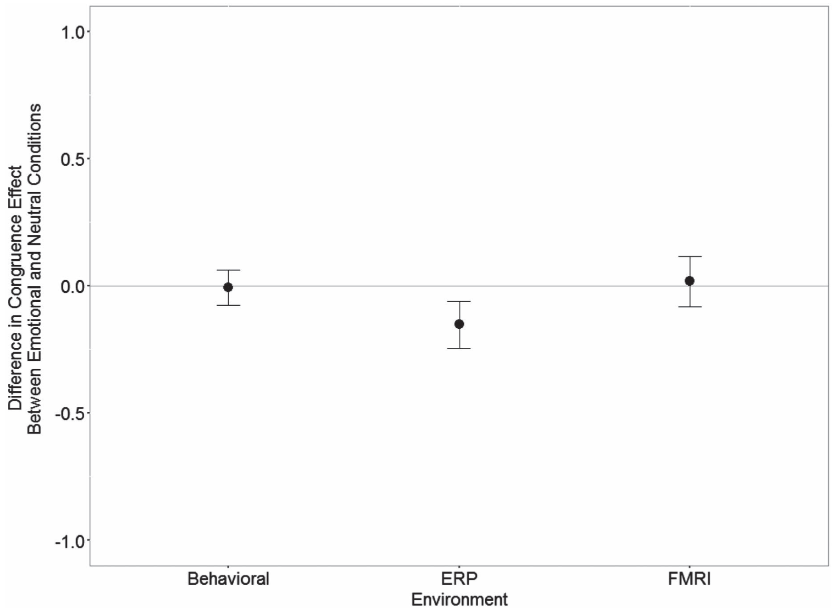
Overall Difference

The overall difference in CE between negative and positive conditions was 0.03 (95% CI [0.001, 0.06]; $n = 135$, $a = 37$, $e = 53$; see Figure 11, for a forest plot) and statistically significant against zero ($t = 2.05$, $p = .04$). This suggested a larger CE for negative versus positive stimuli.

Effect Size Heterogeneity

The sampling variance (0.024) occupied nearly 90% of the total variance; the within-experiments/between-estimates variance (0.003) occupied around 10% of the total variance; the between-experiments variance (2.73e-11) occupied nearly zero of the total variance. According to the 75% rule proposed by Hunter and Schmidt (1990), there is no need to investigate modifying influences of potential moderators.

Figure 6
Affective Effects Across Experiment Environments



Note. It depicts overall estimates of effect sizes of the difference in congruence effect for emotional relative to neutral stimuli in behavioral experiments, ERP experiments, and fMRI experiments. ERP = event-related potential; fMRI = functional magnetic resonance imaging. Error bars indicate 95% confidence intervals.

Significant Moderators

For completeness, we conducted metaregression analyses with one moderator only. In line with the results of heterogeneity analysis, almost all moderators failed to reach significance, except for overall RT and publication year. Besides, sensitivity analysis showed threat relevance was a significant moderator. Here, we presented results of those three moderators. See Table 5, for details of nonsignificant moderators.

Threat Relevance. Results demonstrated that the modifying influence of threat relevance was not significant, $F(1, 65) = 3.86$, $p = .054$; $e = 26$, $n = 67$; see Figure 12. We decided to present this result although it failed to reach the level of significance, since results from the sensitive analysis corroborated this effect. There was a trend of a larger CE for threatening negative stimuli than for positive stimuli ($\beta = 0.06$, 95% CI [−0.01, 0.13]; $t = 1.81$, $p = .07$; $e = 14$, $n = 39$), and this trend was absent when negative stimuli were not threatening ($t = -1.04$, $p = .30$; $e = 14$, $n = 28$).

Overall RT. Results demonstrated that overall RT was a significant moderator, $F(1, 128) = 7.06$, $p < .01$; $e = 50$, $n = 130$; see Figure 13. Specifically, a positive regression coefficient ($\beta = 0.31$, 95% CI [0.08, 0.55]) suggested that the CE for negative stimuli relative to positive stimuli tended to increase as the mean RT for conflict tasks increased.

Publication Year. Results demonstrated that publication year was a significant moderator, $F(1, 119) = 8.88$, $p < .01$; $e = 48$, $n = 121$; see Figure 14. Specifically, a positive regression coefficient ($\beta = 0.01$, 95% CI [0.005, 0.02]) suggests that the overall difference in CE between negative and positive conditions should increase year by year.

Interaction Effects Between Task and the Other Moderators

None of the interaction effects between task and the other moderators reached statistical significance. See Table 6, for a summary of results.

Publication Bias

Visually, the funnel plot (see Figure 15) seemed symmetric in reference to the midline ($x = 0.03$). Results of metaregression analyses showed that standard error was *not* a significant moderator, $F(1, 133) = 0.13$, $p = .71$, confirming the symmetry of funnel plots.

General Discussion

The present research tested whether emotional stimuli change cognitive control in conflict tasks and asked how this effect is modulated by variables that might mitigate a possible link between affect and control. Emotion theories have described affect with respect to two dimensions, valence and arousal. Based on this distinction, theoretical accounts regarding the impact of emotion on cognitive control make diverse predictions how valence or arousal should modulate cognitive control. Therefore, we conducted two meta-analyses that compared the impact of (a) emotional stimuli against neutral and (b) positive against negative stimuli on the size of the CE. We focused on conflict tasks to assess the degree of conflict resolution as an indicator of cognitive control. Results of both meta-analyses indicate that across all studies, the impact

Table 4
Results of Metaregression Analysis of Emotional (Relative to Neutral) Effects With Interaction Between Task (Flanker Task, Simon Task, Stroop Task) and the Other Moderators

Moderator	*df*	*F*	*p*	*e*	*n*	*a*	β	95% CI	σ_1	σ_2
Valence	2, 250	0.74	.48	85	256	59			0.2121	0.1382
Flanker: negative				38	93	26	0.03	[−0.05, 0.10]		
Flanker: positive				23	47	17	−0.04	[−0.13, 0.06]		
Simon: negative				8	20	5	−0.14	[−0.30, 0.03]		
Simon: positive				4	6	4	−0.27	[−0.55, 0.01]		
Stroop: negative				32	67	25	−0.08	[−0.17, 0.01]		
Stroop: positive				13	23	9	−0.04	[−0.18, 0.10]		
D_v	2, 85	0.46	.63	31	91	22			0.264	0.000
Flanker: D_v				11	38	8	−0.002	[−0.01, 0.01]		
Simon: D_v				3	7	2	−0.02	[−0.04, 0.01]		
Stroop: D_v				17	46	12	−0.004	[−0.03, 0.02]		
D_a_1	2, 95	0.31	.74	34	101	23			0.271	0.000
Flanker: D_a_1				15	48	9	0.01	[−0.02, 0.04]		
Simon: D_a_1				3	7	2	−0.05	[−0.12, 0.02]		
Stroop: D_a_1				16	46	12	−0.01	[−0.04, 0.02]		
D_a_2	1, 136	0.16	.69	53	141	38			0.270	0.132
Flanker: nonsignificant				3	4	2	−0.15	[−0.54, 0.24]		
Flanker: significant				18	54	12	−0.02	[−0.14, 0.09]		
Simon: significant				8	18	5	−0.15	[−0.35, 0.05]		
Stroop: nonsignificant				6	11	5	−0.25*	[−0.48, −0.01]		
Stroop: significant				19	54	15	−0.02	[−0.14, 0.10]		
Thr	2, 94	1.04	.36	38	100	24			0.182	0.136
Flanker: unthreatening				11	22	8	0.03	[−0.10, 0.17]		
Flanker: threatening				16	44	9	0.14*	[0.03, 0.25]		
Simon: unthreatening				2	4	2	−0.35*	[−0.67, −0.02]		
Simon: threatening				1	2	1	−0.05	[−0.47, 0.37]		
Stroop: unthreatening				2	6	2	−0.18	[−0.46, 0.09]		
Stroop: threatening				11	22	9	−0.26***	[−0.40, −0.11]		
Sti	6, 239	3.86	.00**	84	254	58			0.214	0.000
Flanker: disfluency				1	4	1	0.65***	[0.35, 0.95]		
Flanker: face				16	62	9	0.08*	[0.01, 0.15]		
Flanker: picture				10	32	7	−0.04	[−0.14, 0.06]		
Flanker: random reward				7	24	5	−0.02	[−0.12, 0.08]		
Flanker: word				7	16	6	−0.17*	[−0.32, −0.03]		
Simon: face				2	5	2	−0.34**	[−0.58, −0.09]		
Simon: picture				4	14	2	0.01	[−0.15, 0.16]		
Simon: random reward				1	4	1	−0.13	[−0.42, 0.17]		
Simon: word				3	3	2	−0.46**	[−0.80, −0.12]		
Stroop: anticipation of shock				2	3	2	−0.37*	[−0.71, −0.02]		
Stroop: disfluency				1	4	1	0.07	[−0.21, 0.36]		
Stroop: face				5	18	4	−0.19**	[−0.33, −0.05]		
Stroop: picture				18	52	13	0.04	[−0.05, 0.12]		
Stroop: video				5	10	4	−0.29**	[−0.48, −0.10]		
Stroop: word				2	3	2	−0.08	[−0.40, 0.24]		
Dur[a]	2, 197	2.14	.12	65	203	44			0.230	0.137
Flanker: Dur				39	134	27	0.01	[−0.10, 0.12]		
Simon: Dur				10	26	7	−0.57**	[−0.95, −0.19]		
Stroop: Dur				16	43	13	−0.03	[−0.10, 0.04]		
Att	5, 244	1.08	.37	85	256	59			0.203	0.153
Flanker: 1				8	20	7	−0.07	[−0.24, 0.11]		
Flanker: 2				4	18	2	0.03	[−0.17, 0.22]		
Flanker: 3				2	10	1	0.15	[−0.08, 0.39]		
Flanker: 4				28	78	19	0.02	[−0.06, 0.11]		
Flanker: 5				5	14	3	−0.10	[−0.30, 0.10]		
Simon: 1				6	10	4	−0.34**	[−0.58, −0.10]		
Simon: 4				2	8	2	−0.22	[−0.50, 0.07]		
Simon: 5				2	8	1	0.11	[−0.18, 0.39]		
Stroop: 1				6	14	5	−0.21*	[−0.40, −0.01]		
Stroop: 2				2	3	2	−0.13	[−0.52, 0.26]		
Stroop: 3				2	8	1	0.06	[−0.24, 0.36]		
Stroop: 4				23	65	18	−0.04	[−0.14, 0.06]		

(*table continues*)

Table 4 (*continued*)

Moderator	*df*	*F*	*p*	*e*	*n*	*a*	β	95% CI	σ_1	σ_2
Rep	2, 199	6.97	.00**	71	205	50			0.201	0.105
Flanker: Rep				35	109	24	0.00	[−0.00, 0.01]		
Simon: Rep				10	26	7	0.02	[−0.01, 0.04]		
Stroop: Rep				26	70	21	−0.03*	[−0.06, −0.01]		
Num	2, 236	0.92	.40	82	242	57			0.194	0.162
Flanker: Num				41	136	28	0.00	[−0.00, 0.00]		
Simon: Num				10	26	7	−0.00*	[−0.00, −0.00]		
Stroop: Num				31	80	25	−0.00	[−0.00, 0.00]		
Des	1, 243	0.85	.36	83	248	58			0.191	0.155
Flanker: blocked				6	24	4	0.07	[−0.10, 0.24]		
Flanker: mixed				36	116	25	−0.01	[−0.08, 0.06]		
Simon: mixed				10	26	7	−0.18*	[−0.33, −0.02]		
Stroop: blocked				4	9	4	0.12	[−0.13, 0.34]		
Stroop: mixed				27	73	21	−0.10*	[−0.20, −0.01]		
ISI[a]	2, 189	0.50	.61	63	195	43			0.215	0.132
Flanker: ISI				38	130	26	−0.00	[−0.09, 0.08]		
Simon: ISI				10	26	7	−0.00	[−0.20, 0.19]		
Stroop: ISI				15	39	12	0.09	[−0.08, 0.27]		
Mod	1, 241	8.66	.00**	80	246	55			0.204	0.119
Flanker: Compatible				42	140	29	0.01	[−0.05, 0.07]		
Simon: Incompatible				2	6	1	0.15	[−0.13, 0.42]		
Simon: Compatible				9	20	7	−0.25**	[−0.41, −0.10]		
Stroop: Incompatible				2	3	2	−0.36	[−0.73, 0.02]		
Stroop: Compatible				26	77	20	−0.02	[−0.10, 0.07]		
RT[a]	2, 246	0.65	.52	83	252	57			0.211	0.145
Flanker: RT				42	140	29	0.02	[−0.09, 0.13]		
Simon: RT				10	26	7	−0.28*	[−0.54, −0.03]		
Stroop: RT				31	86	24	−0.09	[−0.20, 0.03]		
Sample[b]	3, 247	2.05	.11	85	256	59			0.211	0.138
Flanker: American				8	32	5	0.01	[−0.13, 0.15]		
Flanker: Asian				11	29	8	−0.08	[−0.22, 0.06]		
Flanker: European				23	79	16	0.03	[−0.05, 0.12]		
Simon: Asian				3	9	2	0.02	[−0.23, 0.28]		
Simon: European				7	17	5	−0.27**	[−0.45, −0.08]		
Stroop: American				15	51	11	−0.04	[−0.16, 0.07]		
Stroop: Asian				5	9	4	0.03	[−0.23, 0.29]		
Stroop: Australian				1	2	1	−0.28	[−0.81, 0.26]		
Stroop: European				12	28	10	−0.12	[−0.25, 0.02]		
Age	2, 164	0.69	.51	63	170	46			0.257	0.038
Flanker: Age				26	74	19	−0.00	[−0.01, 0.001]		
Simon: Age				8	18	6	−0.01*	[−0.02, −0.00]		
Stroop: Age				29	78	23	−0.00	[−0.01, −0.00]		
F	2, 186	0.78	.46	65	192	47			0.225	0.123
Flanker: F				29	95	21	−0.05	[−0.17, 0.06]		
Simon: F				8	18	6	−0.36**	[−0.60, −0.12]		
Stroop: F				28	79	22	−0.08	[−0.22, 0.06]		
N	2, 250	0.69	.50	85	256	59			0.208	0.149
Flanker: N				42	140	29	0.00	[−0.00, 0.00]		
Simon: N				10	26	7	−0.01*	[−0.01, −0.00]		
Stroop: N				33	90	26	−0.00	[−0.00, 0.00]		
Env	4, 247	1.45	.22	85	256	59			0.211	0.122
Flanker: Behavioral				24	91	14	0.02	[−0.05, 0.10]		
Flanker: ERP				14	42	12	−0.04	[−0.15, 0.07]		
Flanker: fMRI				14	42	12	0.04	[−0.20, 0.29]		
Simon: Behavioral				5	18	3	−0.08	[−0.25, 0.10]		
Simon: ERP				4	7	4	−0.31*	[−0.58, −0.04]		
Simon: fMRI				4	7	3	−0.46	[−1.11, 0.20]		
Stroop: Behavioral				9	21	8	−0.06	[−0.21, 0.10]		
Stroop: ERP				7	18	6	−0.34***	[−0.52, −0.17]		
Stroop: fMRI				17	51	13	0.02	[−0.08, 0.13]		
PY[c]	2, 238	1.39	.25	82	244	57			0.221	0.149
Flanker: PY				39	128	27	0.00	[−0.00, 0.01]		

(*table continues*)

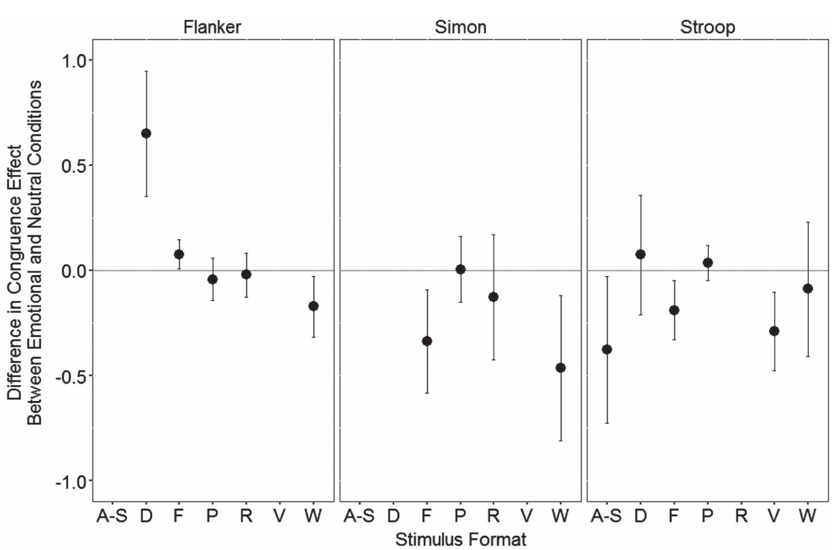
Table 4 (*continued*)

Moderator	*df*	*F*	*p*	*e*	*n*	*a*	β	95% CI	σ_1	σ_2
Simon: PY				10	26	7	−0.01	[−0.02, 0.00]		
Stroop: PY				33	90	26	−0.00	[−0.01, 0.00]		

Note. βs of continuous variables represent regression coefficients and of categorical variables represent overall estimates of effect sizes at individual levels. σ_1 and σ_2 represent residual variance between estimates and between experiments, respectivelye = number of experiments; *n* = number of estimations; *a* = number of articles; 95% CI = confidence interval at the 95% confidence level; Valence = valence of emotional stimuli (negative, positive); D_v = difference in valence rating between emotional stimuli and neutral stimuli; D_a_1 = difference in arousal rating between emotional stimuli and neutral stimuli; D_a_2 = statistical significance of arousal difference between affective and neutral stimuli (significant [$p < .05$]; nonsignificant); Thr = threat of negative stimuli (threatening, unthreatening); Sti = affect-stimulus format (face = emotional face photos; word = emotional words; emotional picture = emotional pictures; video = emotional videos; anticipation of shock = neutral stimuli conditioned with electro shock; sound = emotional sounds; random reward = random reward being independent from task performance; disfluency = trigger of disfluent processing); Dur = exposure duration of the emotional stimuli; Att = attentional status toward the emotional stimuli (1 = affective information was presented as part of conflict task-relevant and -irrelevant stimuli; 2 = affective information was presented as part of conflict task-relevant stimuli; 3 = affective information was presented as part of the conflict task-irrelevant stimuli; 4 = affective information was spatially overlapping with conflict task-relevant and -irrelevant stimuli; 5 = affective information was spatially distinct from conflict task-relevant and -irrelevant stimuli); Rep = the number of times the emotional stimuli were repeatedly presented; Num = the number of trials of the smallest cell defined by affect and congruency in the experiment; Des = procedure of presenting emotional stimuli in the experiment (blocked = emotional stimuli of different valence were presented in different blocks; mixed = emotional stimuli of different valence were intermixed within blocks); ISI = interstimulus interval measured from the offset of emotional stimuli to the onset of conflict task-relevant stimuli; Mod = compatibility of perception modalities between emotional stimuli and conflict task stimuli (compatible, incompatible); RT = mean reaction time for the experiment task; Age = mean age of the experiment participants; F = ratio of female participants in the experiment; *N* = number of the experiment participants; Env = experiment environment (behavioral experiment, ERP experiment; fMRI experiment); ERP = event-related potential; fMRI = functional magnetic resonance imaging; PY = publication year of the experiment.
[a] Values of the moderator were divided by 1,000 before analysis, which did not change the results. [b] Countries were grouped in accordance with geographical continents (American continent, Asian continent, European continent, African continent, Australian continent). [c] 2000 was subtracted from each value of the moderator before analysis, which did not change the results.
* $p < .05$. ** $p < .01$. *** $p < .001$.

of emotional (negative and positive) stimuli on the CEs was very small (if at all existent). Specifically, the overall effect of emotional (compared to neutral) stimuli on the CE was not statistically significant against zero ($p = .11$). The overall effect of negative (compared to positive) stimuli on the CE reached significance ($p = .04$). This could suggest that positive relative to negative stimuli enhance the CE. Regardless, due to a very small effect size ($g_z = 0.03$, 95% CI [0.001, 0.06]) and a direction of the effect not

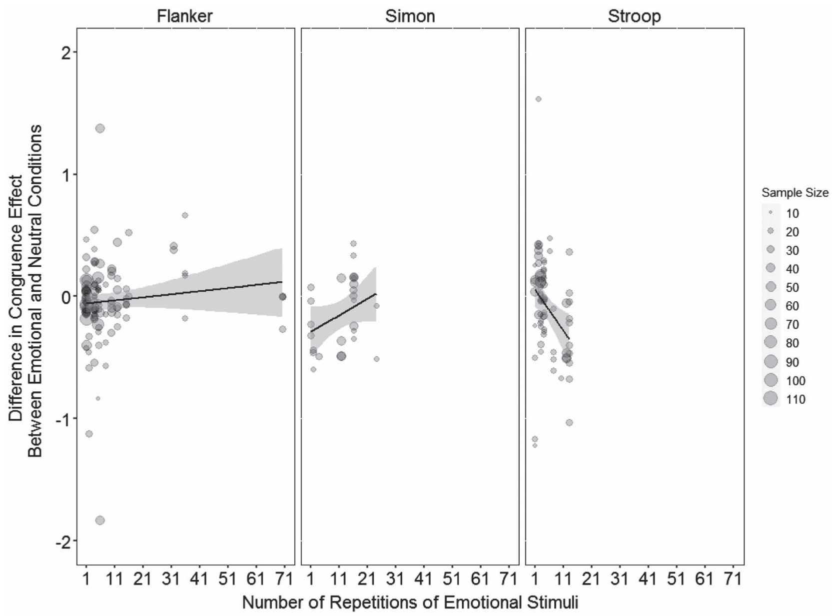
Figure 7
Affective Effects Across Different Combinations of Emotional-Stimulus Format and Conflict Task



Note. It depicts overall estimates of effect sizes of the difference in congruence effect between emotional and neutral stimuli across different combinations of task (flanker task, Simon task, Stroop task) and stimulus format of emotional stimuli. A-S = anticipation of shock; D = trigger of disfluency of processing; *F* = emotional face photos; *P* = pictures of emotional scenes; R = random reward; *V* = emotional videos; W = emotional words. Error bars indicate 95% confidence intervals.

Figure 8

Affective Effects Varying With the Number of Repetitions of Emotional Stimuli in Different Tasks



Note. It depicts standardized difference in congruence effect between affective and neutral stimuli varying with the amount of repetitions of emotional stimuli in different conflict tasks (flanker task, Simon task, Stroop task). A bubble represents an observation. Size of bubbles is proportional to sample size. One bubble in the Stroop condition is close to −5 in the caption and was not displayed.

predicted by theoretical accounts, we refrain from an interpretation of this surprising outcome.[4]

Since theoretical models predict variation of the impact of emotional stimuli under different circumstances, multiple metaregression models tested whether the effect size of emotionally biased control varies as a function of characteristics of the emotional stimuli, the experimental procedure, influences of individual differences, and effects of publication bias. Furthermore, an exploratory analysis tested possible interaction effects between the specific conflict task and other moderator variables. In the remainder of this article, we will discuss findings of the moderator analysis, before we lay out possible implications for theoretical models, discussion consequences for the empirical assessment of emotion–control interactions, and point out possible limitations.

The Role of Emotional Stimuli, Task Procedure, and Context Factors

The moderator analyses (see Figures 3–6, for a graphical description) suggested that characteristic of emotional stimuli (e.g., stimulus format, attention to stimuli, and arousal difference) and context factors (e.g., EEG data collection) modulated how arousal reduced the size of CEs. Furthermore, task characteristics (overall RT) modulated the impact of valence on the CE (see Figure 13). We discuss these findings in turn.

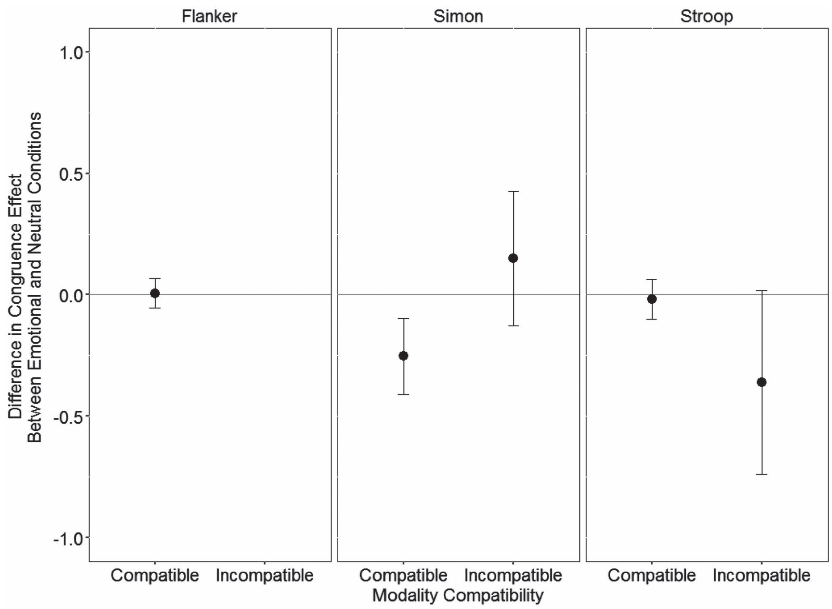
First, moderator analysis of stimulus format showed that emotional words and video stimuli decreased CEs. Interestingly, emotional pictures, which have been the most frequently used emotional stimulus format ($n = 98$, $e = 32$, $a = 22$) in the present meta-analysis, did not modulate CEs. Differences between emotional stimuli have been frequently discussed in the literature and it has been suggested that emotional pictures produce larger changes in arousal relative to words (Carretié et al., 2008; De Houwer & Hermans, 1994; Hinojosa et al., 2009; Keil, 2006; Kensinger & Schacter, 2006), which is true for the present meta-analysis (see Figure 16). Yet, exploratory follow-up analysis that considered the arousal difference of picture stimuli as a continuous predictor failed to find more direct evidence for a modulatory influence on CEs, $F(1, 64) = 1.58$, $p = .21$; $e = 21$, $n = 66$.

Second, the factor "attention to emotional stimuli" showed a marginally significant impact on the CE. More specifically, only emotional stimuli that were part of the relevant and irrelevant stimulus dimension decrease the size of CEs ($n = 44$, $e = 20$, $a = 15$), but not if emotional stimuli are presented before or after the conflict task, even if they share the same relevant spatial coordinates (see Figure 5). This finding indicates that attention allocated to emotional stimuli is a necessary condition in order to influence the size of CEs. It contributes to an ongoing discussion whether processing of emotional stimuli is obligatory (e.g., Öhman et al., 2001; Vuilleumier et al., 2001) or biased by top-down influences (see Pessoa et al., 2002). By showing that only attended (but task-irrelevant) emotional stimuli affect cognitive control, the present findings corroborate the hypothesis that processing of emotional stimuli is "automatic" in the sense that "it does not require conscious

[4] Additional sensitive analysis for both meta-analysis accounting for possible biases in correlations between measures within designs corroborated these findings (see Supplemental Material).

Figure 9

Affective Effects Across Different Conditions of Modality Compatibility in Different Tasks



Note. It depicts overall estimates of effect sizes of the difference in congruence effect between emotional and neutral stimuli across different conditions of modality compatibility in different tasks (flanker task, Simon task, Stroop task). Error bars indicate 95% confidence intervals.

monitoring, but it may require sufficient attentional resources and consciousness" (Okon-Singer et al., 2007, p. 147). Furthermore, the results are in line with the notion that only attended emotional stimuli can feed into cognitive control processes (Kanske, 2012).

Third, results showed that arousal differences between emotional and neutral stimuli moderated the impact of emotional stimuli on the CE ($e = 52$, $n = 137$; see Figure 4). More specifically, studies which presented emotional stimuli that did *not* differ significantly from neutral stimuli in terms of arousal ratings reduced CEs, but not emotional stimuli that have been rated significantly more arousing compared to neutral stimuli.[5] Relatedly, moderator analysis of "threat relevance" indicated a marginal significant moderatorion when comparing negative and positive stimuli, suggesting that negative threating stimuli (but not negative, nonthreating stimuli) increased CEs compared to positive stimuli. Both observations are compatible with Pessoa (2009) view that highly significant stimuli, which threatening and highly arousing stimuli are, can strain central resources needed for control and therefore increase CEs.

Fourth, moderator analysis showed that experiments that also recorded EEG showed stronger reduction of CE for emotional relative to neutral stimuli, compared to experiments that recorded functional magnetic resonance imaging or focused on behavior as a primary measure (see Figure 6). This finding is surprising, since it has been suggested that secondary outcomes (i.e., behavioral results in an EEG experiment) yield overall smaller effect sizes, because nonsignificant effects are more likely to be published (Suchotzki et al., 2017). Clearly, testing conditions differ widely between behavioral and EEG experiments. One possible explanation could be that EEG experiments often require more trials and therefore show stronger effect sizes also in behavioral responses. Nonetheless, as Figure 17 shows, in the present meta-analysis, behavioral studies contained even more trials per design cell than EEG studies and additional analysis also found no effect of the number of trials on the modulation of the CE effect in event-related potential ($e = 24$, $n = 57$), $F(1, 55) = 1.92$, $p = .17$; in behavioral ($e = 38$, $n = 126$), $F(1, 124) = 0.14$, $p = .71$; or in fMRI studies ($e = 20$, $n = 51$), $F(1, 49) = 1.08$, $p = .30$.

Finally, for the comparison between positive and negative valence stimuli on the CE, moderator analysis showed that negative (compared to positive) stimuli enhanced the CE more strongly for overall longer RTs. If we assume that controlled processing take time to built up (e.g., Ridderinkhof, 2002), positive emotional stimuli seem to enhance control for relatively to negative stimuli. Furthermore, for the same comparison of valence on the CE, we observed that the effect size of the modulatory impact of valence on the CE increased over time with larger effect sizes for more recent studies. This finding is incompatible with the decline effect (Schooler, 2011). Rather it could reflect an effort to test increasingly larger samples sizes in recent years.

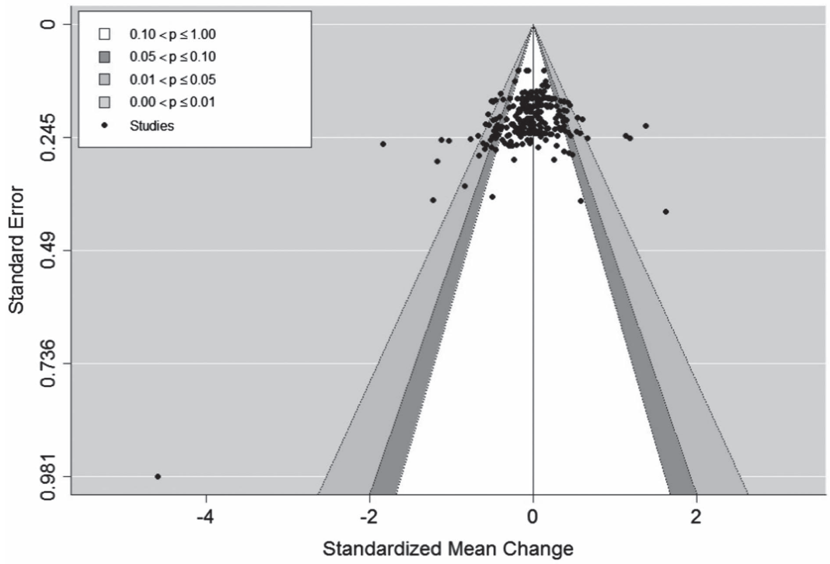
Implications for Models of Emotion–Control Interaction

Overall, the effects of emotional stimuli on the CEs were very small (if at all existing; see Tables 3–6). One conclusion from the primary meta-analysis is that the impact of emotional stimuli on cognitive

[5] Interestingly, this effect of arousal differences was not corroborated when arousal differences were entered as a continuous predictor ($p = .52$ in main analysis; $p = .48$ and $.56$ in sensitivity analysis), possibly due to a small set of studies included in this analysis.

Figure 10

The Contour-Enhanced Funnel Plot of Emotional (Relative to Neutral) Effects Across Standard Errors



Note. It signifies levels of statistical significance of the observed difference in congruence effect between emotional and neutral conditions. Each black point represents an observation. The funnel is centered at 0 (the null hypothesis of no difference). The criterion of statistical significance is $p \leq .05$. Therefore, a black point located at the white region ($p > .1$) or the dark gray-shaded region ($.05 < p \leq .1$) indicates the corresponding effect is statistically nonsignificant.

control in conflict tasks is less general and subtler than previously thought. This seems inconsistent with claims about universal effects of emotional stimuli on cognitive control and questions the generalizability of emotion–cognition interactions in conflict tasks.

Many models allow more specific predictions, considering different situations in which emotional stimuli should be more or less likely to impact on cognitive control. Indeed, moderator analysis showed that the effect size of emotional-biased CEs varies as a function of characteristics of the emotional stimuli and the experimental setup (see above; also see Table 3). What we found noteworthy is that results from almost all significant metaregression models showed decreased CEs for emotional (positive and negative) relative to neutral stimuli (see Table 3). Therefore, a conclusion from the moderator analysis is that negative and positive stimuli exert a facilitatory influence on cognitive control.

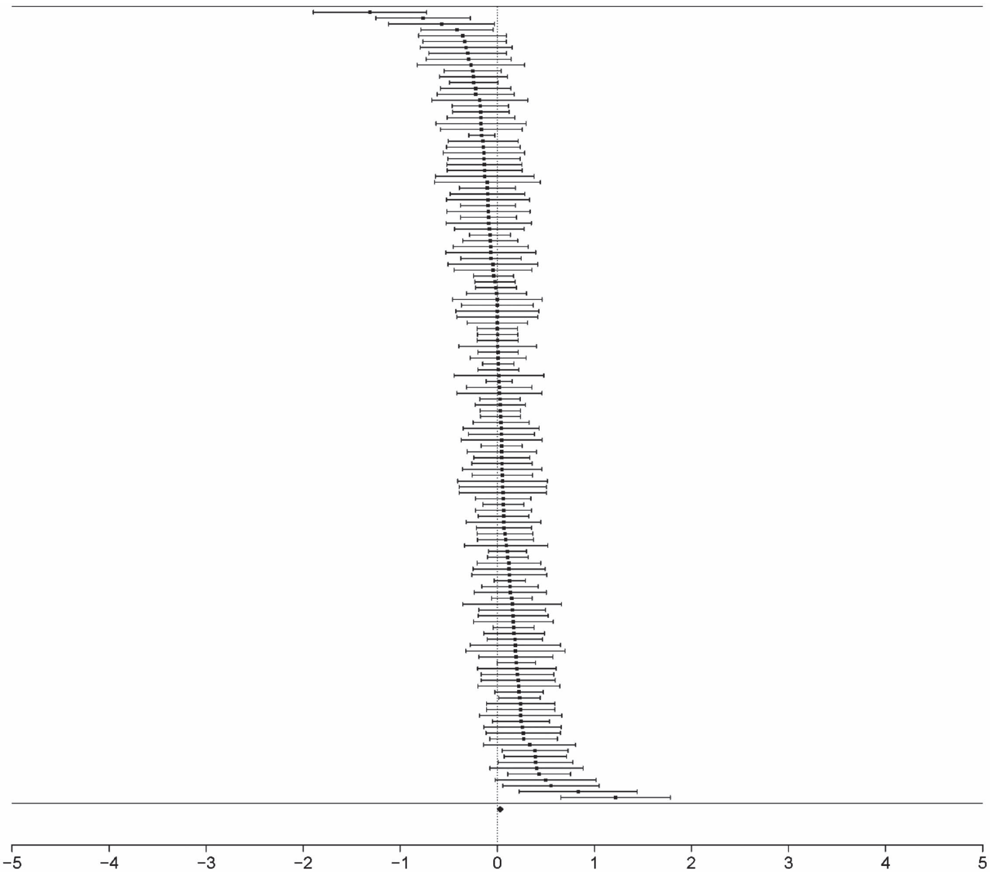
This is consistent with the attention account (e.g., Chajut & Algom, 2003; Easterbrook, 1959), suggesting that emotional stimuli should compete with irrelevant distractor information and therefore reduce CEs. While target feature receive full attention, distractor features are only processed to the degree of available additional "spare" resources. Consequently, irrelevant emotional stimuli attract attention away from distractor processing and therefore reduce CEs. Decreased CEs for negative and higher arousing stimuli are also compatible with the catalyst view (e.g., Dignath et al., 2020; Mather et al., 2016), suggesting that emotional stimuli change the weighting between target and distractors. According to the biased competition account (Mather et al., 2016), arousal of emotional stimuli increases the gain of relevant target features, favoring target selection over distractor processing. According to recent versions of the conflict-monitoring model (Verguts & Notebaert, 2008, 2009), arousal of emotional stimuli facilitates bindings between active task sets and all the other task-relevant representations (especially, those currently active representations) and thereby increases the weights for target relative to distractor information.

The results are also relevant for the evaluation of capacity models that relate cognitive control and processing of emotional stimuli. While the findings do not support as strong version of the capacity view, which predict increased CEs for arousing and negative stimuli in general (for a dicusssion, see Schimmack, 2005), other versions of the capacity view might be more compatible with the present results. For instance, the dual competition model (Pessoa, 2009) predicts facilitation of target processing if the emotional stimulus is part of the relevant dimension, which is in line with the moderator analysis in the present research. Furthermore, the model assumes that more extreme emotional stimuli can impair control, a prediction that is also supported by the moderator analysis of arousal differences and threat relevance. Together, these findings might indicate that a mild level of arousal facilitates control (as suggested by the attentional view and proponents of the biased competition view), while more extreme emotional stimuli can impair performance (as suggested by proponents of the capacity view).

Finally, the findings do not support the idea that emotional stimuli act as cues for attentional tuning (see Phaf, 2015; Schwarz & Clore, 2003) or cognitive flexibility and stability (e.g., Goschke, 2014), which predict larger CEs for positive versus negative stimuli. Instead, the primary meta-analysis comparing the effect of negative and positive stimuli found increased CEs for negative stimuli as compared with positive stimuli (see Figure 11). This result is also incompatible with

Figure 11

A Forest Plot of Individual Effect Sizes of Emotional (Negative Relative to Positive) Effects



Note. Individual effect sizes were ordered by effect size. The overall estimate with their 95% confidence intervals was represented with a diamond.

the idea that negative valence of stimuli facilitates control (Dignath et al., 2020; Dreisbach & Fischer, 2015; Van Steenbergen, 2015), which would have predicted reduced CE with negative stimuli. Furthermore, the finding that positive stimuli reduce CEs more strongly for longer overall RT (see Table 5 and Figure 13) is also incompatible with this valence-specific perspective. If one assumes that longer RT allows for a built up of control, this account would have predicted the opposite effect, that is, stronger reduction of CE for longer RTs with negative stimuli. Instead, this moderator effect could be related to observations that resolving conflict is positive and that "the rewarding value of resolving an incongruent stimulus may motivate a person to enhance the task focus that drove him/her to that response" (Schouppe et al., 2015, p. 259). Speculatively, inducing positive affect by presenting emotional stimuli boosts the positive evaluation of reward of conflict resolution (which probably is more likely with longer RT) and thereby increases control.

Implications for Usage of Conflict Tasks to Probe Emotion–Control Interactions

Although the conflict tasks selected in the present research are structurally similar, it remains unclear whether they share a common control processes or rather reflect separable control processes. A task-general view is implied by theoretical accounts (H. C. Barrett & Kurzban, 2006) and computational models (Botvinick et al., 2001; Ulrich et al., 2015), and it receives support from empirical data suggesting a common latent variable (e.g., Miyake et al., 2000; see also Gyurkovics et al., 2020) and experimental designs showing a generalization of control across different tasks (e.g., Freitas et al., 2007; Kunde & Wühr, 2006). A task-specific view is compatible with conceptual analysis of conflict tasks (e.g., Kornblum et al., 1990; Schuch et al., 2019) and empirical observations showing that control in conflict tasks differs in terms of their temporal dynamics (e.g., Pratte et al., 2010), neurophysiological correlates (e.g., Liu et al., 2004), and mechansims (e.g., Chajut et al., 2009). In this meta-analysis, the main effect of task was not a significant moderator (see Table 3), but exploratory analysis showed significant two-way interactions between task-type and three different moderator variables (see Table 4). More specifically, results suggested that the format, the number of repetitions, and the modality emotional stimuli modulated the impact in a task-specific way (see Figures 7–9). We found that (a) overall emotional stimulus decreased CEs (except for facial and disfluent stimuli in the flanker task), but presentation formats were differently effective in the three tasks; (b) repetition of emotional stimuli enhanced a reduction of CEs in the Stroop task (but not flanker or Simon); and (c) emotional stimuli presented in the same modality as the conflict stimuli lead to a reduction of CEs in the Simon task (but not flanker or Stroop). Both accounts could explain such differences. For instance, the diffusion model of conflict tasks assumes that the same mechanisms can explain control in different tasks (Ulrich et al., 2015). More precisely, the race between irrelevant and relevant information is critical for control and the CE, and task-specific effects can be attributed to timing differences (e.g., Hübner et al., 2019). Task-specific account could explain the difference by assuming differences in control processes that might more or less penetrable for affective responses.

In the present meta-analysis, control was measured with CEs difference scores (incongruent minus congruent). Congruency

Table 5

Results of Metaregression Analysis With One Moderator Only for the Comparison of Congruence Effects Between Negative and Positive Conditions

Moderator	*df*	*F*	*p*	*e*	*n*	β	95% CI	Intercept	σ_1	σ_2
Properties of emotional stimuli										
D_v	1, 64	0.24	.63	66	26	−0.00	[−0.01, 0.01]	0.02	0.000	0.000
D_a_1	1, 62	< 0.001	.98	26	64	−0.00	[−0.02, 0.02]	0.04	0.000	0.000
D_a_2	1, 64	2.47	.12	28	66				0.020	0.000
Nonsignificant				10	19	−0.00	[−0.06, 0.06]			
Significant				22	47	0.06*	[0.01, 0.10]			
Thr	1, 65	3.86	.054	26	67				0.135	0.000
Unthreatening				14	28	−0.04	[−0.13, 0.04]			
Threatening				14	39	0.06	[−0.01, 0.13]			
Sti	4, 126	0.46	.76	52	131				0.061	0.020
Face				15	43	0.05	[−0.01, 0.11]			
Emotional pictures				23	59	0.03	[−0.01, 0.07]			
Random reward				8	16	−0.02	[−0.10, 0.06]			
Sound				2	4	0.03	[−0.23, 0.29]			
Word				4	9	0.03	[−0.10, 0.16]			
Dur[a]	1, 117	0.93	.34	44	119	0.04	[−0.04, 0.12]	−0.00	0.061	0.019
Properties of experimental procedure										
Att	4, 126	1.31	.27	51	131				0.040	0.000
1				5	9	0.06	[−0.08, 0.20]			
2				8	18	0.11*	[0.02, 0.20]			
3				7	16	−0.02	[−0.11, 0.06]			
4				27	68	0.03	[−0.00, 0.07]			
5				8	20	0.02	[−0.07, 0.11]			
Rep	1, 119	< 0.01	.97	49	121	−0.01	[−0.54, 0.52]	0.03	0.021	0.033
Num[a]	1, 125	1.86	.18	49	127	0.31	[−0.14, 0.75]	0.01	0.026	0.000
Des	1, 129	0.39	.53	51	131				0.022	0.037
Blocked				10	32	0.05	[−0.01, 0.11]			
Mixed				41	99	0.02	[−0.01, 0.06]			
ISI[a]	1, 117	2.13	.15	44	119	−0.04	[−0.10, 0.01]	0.03	0.056	0.030
Task	2, 132	0.07	.93	53	135				0.055	0.028
Flanker				28	76	0.03	[−0.01, 0.07]			
Simon				8	28	0.02	[−0.03, 0.07]			
Stroop				17	31	0.03	[−0.05, 0.11]			
Mod	1, 133	< 0.01	.99	53	135				0.059	0.000
Incompatible				2	4	0.03	[−0.23, 0.29]			
Compatible				51	131	0.03*	[0.00, 0.06]			
RT[a]	1, 128	7.06	.01**	50	130	0.31**	[0.08, 0.55]	−0.14	0.039	0.000
Individual differences										
Sample	7, 127	1.59	.14	53	135				0.053	0.000
America				20	39	0.01	[−0.05, 0.06]			
Australia				1	2	−0.01	[−0.20, 0.18]			
Canada				4	8	0.13	[−0.03, 0.29]			
China				3	5	0.09	[−0.09, 0.27]			
England				3	6	0.08	[−0.05, 0.21]			
Germany				18	68	0.04*	[0.00, 0.07]			
Korea				2	3	0.09	[−0.19, 0.37]			
Netherland				2	4	−0.22*	[−0.41, −0.04]			
Age	1, 98	0.22	.64	39	100	−0.00	[−0.01, 0.01]	0.08	0.000	0.000
F	1, 108	0.48	.49	41	110	−0.07	[−0.28, 0.14]	0.09	0.043	0.000
Publication bias										
N[a]	1, 133	0.25	.62	53	135	−0.14	[−0.72, 0.43]	0.04	0.060	0.000
Env	2, 132	1.49	.23	53	135				0.059	0.000

(*table continues*)

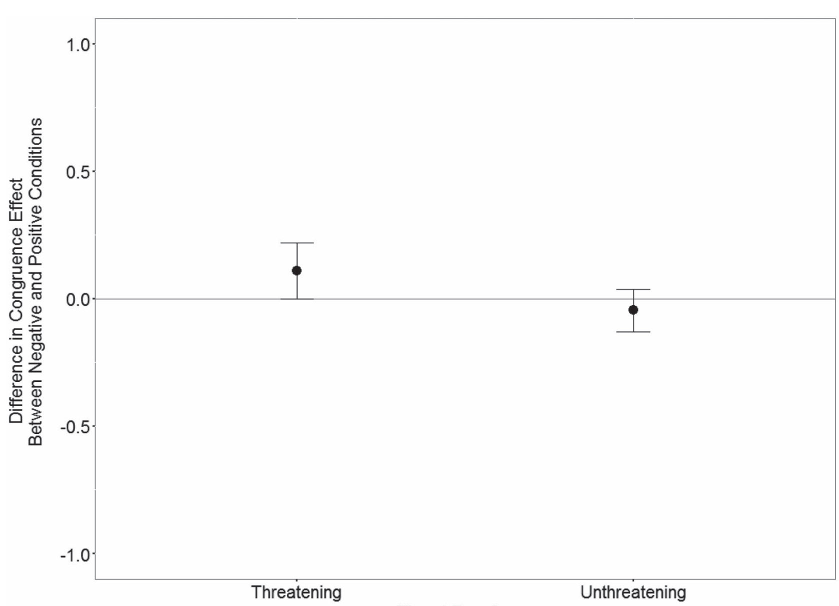
Table 5 (*continued*)

Moderator	*df*	*F*	*p*	*e*	*n*	β	95% CI	Intercept	σ_1	σ_2
Behavioral				26	82	0.04*	[0.01, 0.07]			
ERP				14	30	−0.04	[−0.11, 0.04]			
fMRI				13	23	0.04	[−0.05, 0.13]			
PY	1, 119	8.92	<.01**	48	121	0.01	[0.00, 0.02]	−29.73	0.050	0.001

Note. βs of continuous variables represent regression coefficients and of categorical variables represent overall estimates of effect sizes at individual levels. σ_1 and σ_2 represent residual variance between estimates and between experiments, respectively; *e* = number of experiments; *n* = number of estimations; 95% CI = confidence interval at the 95% confidence level; D_v = difference in valence rating between emotional stimuli and neutral stimuli; D_a_1 = difference in arousal rating between emotional stimuli and neutral stimuli; D_a_2 = statistical significance of arousal difference between affective and neutral stimuli (significant [$p < .05$]; nonsignificant); Thr = threat of negative stimuli (threatening, unthreatening); Sti = affect-stimulus format (face = emotional face photos; word = emotional words; emotional picture = emotional pictures; video = emotional videos; anticipation of shock = neutral stimuli conditioned with electro shock; sound = emotional sounds; random reward = random reward being independent from task performance; disfluency = trigger of disfluent processing); Dur = exposure duration of the emotional stimuli; Att = attentional status toward the emotional stimuli (1 = affective information was presented as part of conflict task-relevant and -irrelevant stimuli; 2 = affective information was presented as part of conflict task-relevant stimuli; 3 = affective information was presented as part of the conflict task-irrelevant stimuli; 4 = affective information was spatially overlapping with conflict task-relevant and -irrelevant stimuli; 5 = affective information was spatially distinct from conflict task-relevant and -irrelevant stimuli); Rep = the number of times the emotional stimuli were repeatedly presented; Num = the number of trials of the smallest cell defined by affect and congruency in the experiment; Des = procedure of presenting emotional stimuli in the experiment (blocked = emotional stimuli of different valence were presented in different blocks; mixed = emotional stimuli of different valence were intermixed within blocks); ISI = interstimulus interval measured from the offset of emotional stimuli to the onset of conflict task-relevant stimuli; Mod = compatibility of perception modalities between emotional stimuli and conflict task stimuli (compatible, incompatible); Task = conflict task in the experiment (Stroop task, Simon task, flanker task); RT = mean reaction time for the experiment task; Age = mean age of the experiment participants; F = ratio of female participants in the experiment; *N* = number of the experiment participants; Env = experiment environment (behavioral experiment, ERP experiment; fMRI experiment); ERP = event-related potential; fMRI = functional magnetic resonance imaging; PY = publication year of the experiment.
[a] Each value of the moderator was divided by 1,000 before analysis, which did not change results.
* $p < .05$. ** $p < .01$.

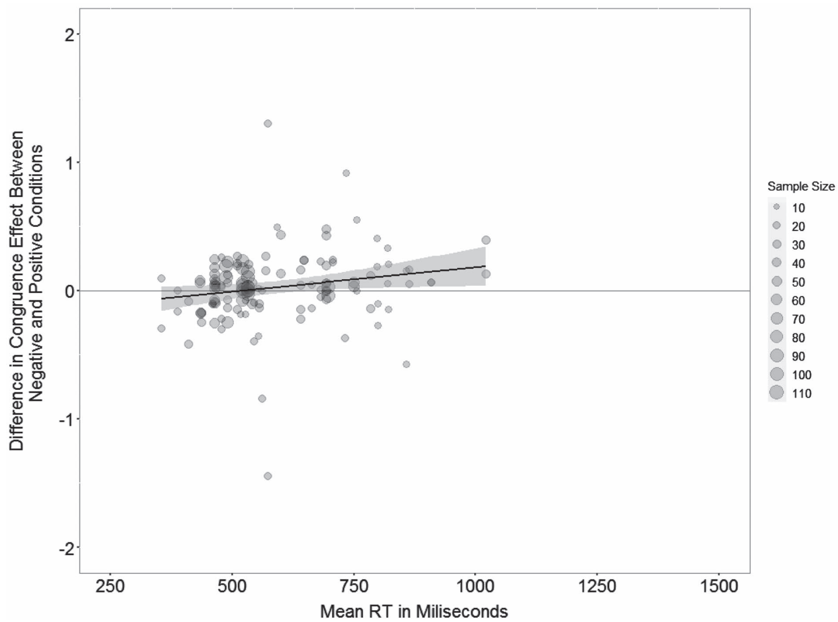
effects can be driven by interference and facilitation. While performance in incongruent trials suffers from a conflict between irrelevant and relevant information, performance during congruent trials is enhanced by irrelevant, but helpful information. Research aimed to separate both components by presenting neutral trials that are supposed to have neither interfering nor facilitative effect on performance (e.g., Kalanthroff et al., 2015). In theory, performance in neutral trials subtracted from performance in incongruent trials should result in a measure of interference, while performance in congruent trials subtracted from performance in neutral trials should produce a measure of facilitation (for a critique of various neutral stimulus configurations, see Brown, 2011). In the present meta-

Figure 12
Affective Effects Across Threat Relevance



Note. It depicts overall estimates of effects sizes of the difference in congruence effect between negative and positive stimuli across threat relevance. Error bars indicate 95% confidence intervals.

Figure 13
Affective Effects Varying With Mean Reaction Time in Conflict Tasks



Note. It depicts standardized difference in congruence effect between negative and positive stimuli varying with mean reaction times (RTs in millisecond) for conflict tasks. A bubble represents an observation. The size of bubbles is proportional to sample size.

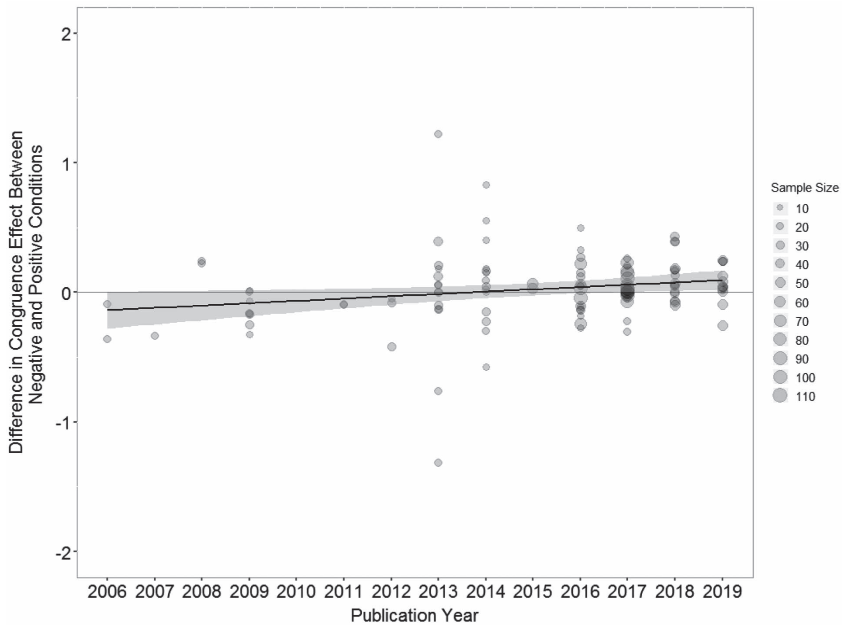
analysis, a subset of experiments ($e = 9$; $n = 21$; $a = 6$) included neutral trials. Aggregating effect sizes in a way similar to the main analysis described above showed no significant effect of emotional stimuli on interference and facilitation scores (for details, see Zhang et al., 2023). Nevertheless, this exploratory analysis is limited due to the relatively small number of observations and due to the observation that the estimated effect size depended upon specific assumptions about the correlation between repeated measures.

Relatedly, in the Stroop task, neutral trials can instigate a specific type of conflict related to the parallel activation of two tasks (Goldfarb & Henik, 2007; MacLeod & MacDonald, 2000). For instance, neutral (color-unrelated) words (but not arbitrary symbols) have been found to engage word reading, which is incongruent with the instructed task to name the ink color in the color-word Stroop task and therefore impair performance (e.g., Goldfarb & Henik, 2007; Kalanthroff et al., 2015; also see Brown, 2011). While it is not possible to estimate the effect of task conflict in this meta-analysis using behavioral data, future research could also investigate physiological measures. For instance, it has been found that task conflict quickly increases pupil dilation (Hershman & Henik, 2019). Interestingly, a similar effect on the pupil has been documented for arousing stimuli (for an overview, see Steinhauer et al., 2022), suggesting that emotional stimuli could modulate task conflict in particular. Here, more experimental work is needed to test these speculations.

Furthermore, while the size of CE is often taken as an index of cognitive control, other processes unrelated to control, could also influence CEs. For instance, research on the so-called "Stroop dilution effect" found that additional stimuli (e.g., presentation of a task-unrelated word next to a Stroop color-word) can under some circumstances reduce CEs (Kahneman & Chajczyk, 1983), possibly because the additional word impairs processing of the distractor dimension (see Chajut et al., 2010, for an emotional version of this effect). This explanation is not incompatible with some of the theoretical positions described earlier. For instance, the attentional view suggests that emotional stimuli reduce CEs because emotional stimuli absorb resources, which then limits processing of task-irrelevant distractor information. In any case, researcher should remain cautions to unquestioningly equate CEs with control.

Furthermore, it has been suggested that congruency sequence effects (CSE) provide a more direct measure of control, because they are supposed to reflect an upregulation of control based on previous conflict (Botvinick et al., 2001). Therefore, some studies investigated how emotional stimuli modulate the CSE (for an overview, see Dignath et al., 2020, Table 3). Here, results have been heterogeneous, with studies reporting increased CSEs for negative stimuli (van Steenbergen et al., 2012), decreased CSE for negative stimuli (Padmala et al., 2011), or null effects (Dignath et al., 2017). Still, for many studies, alternative explanations, unrelated to cognitive control, have been suggested for the CSE (e.g., Davelaar & Stevens, 2009; Hommel et al., 2004; see Dignath et al., 2019, for a hybrid account). More recent studies that circumvent these limitations observed that both negative and positive stimuli relative to neutral stimuli enhance the CSE (e.g., Landman & van Steenbergen, 2020; Zeng et al., 2017), which could suggest that arousal increases control across trials. The present research did not consider congruency in the previous trial but focused on CE in the current trial. Although it is debated how CEs in the previous and the current trial are related (e.g., Weissman et al., 2014; Wendt et al., 2014), some accounts describe the CSE as a carryover effect due to

Figure 14
Affective Effects Across Publication Year



Note. Effects sizes of the difference in congruence effect between negative and positive stimuli as a function of publication year. A bubble represents an observation. The size of bubbles is proportional to sample size.

within-trial control as indexed by the CE (Nigbur et al., 2015; Pastötter et al., 2013; Scherbaum et al., 2011). More systematic research is needed to understand how emotional stimuli impact on control across multiple timescales.

Limitations of Results

It has been indicated that study quality makes a difference to effect sizes and should be considered in research synthesis (Valentine, 2019). We assessed certain methodological aspects such as sample size and number of trials administered to test whether larger samples and more precise measurements influence the overall effect (we observed no moderation). However, much of what might matters (e.g., subject instructions) are currently not reported systematically to allow a more detailed analysis. Future studies and meta-analyses may directly investigate how and whether effects of emotional stimuli on cognitive control change with (dimensions of) study quality. The present meta-analysis focused exclusively on behavioral effects in conflict tasks. Although these tasks are very popular among experimental and clinical psychologists to assess cognitive control, they reflect only a subset of specific control mechanisms. Therefore, we cannot exclude that other tasks or measures might have been more sensitive to capture emotional modulation of control. Future overviews could adopt a more integrated approach by using a wider range of tasks and measures of control. Furthermore, we restricted our analysis to task-irrelevant emotional stimuli and did not consider longer lasting mood states induced by specific procedures or instructions. Clearly, this focus constrains generalization beyond clearly controlled experimental tasks. Furthermore, according to many theories, processing of emotional stimuli is highly cultural (e.g., L. F. Barrett, 2006; Fiske, 2020). Generalization of the present results is constrained by a mostly WEIRD (Henrich et al., 2010) sample tested in the included studies (127/135 estimates were from a WEIRD sample for the comparison between positive and negative stimuli; 230/256 estimates were from a WEIRD sample for the comparison between affective and neutral stimuli). Moreover, information on many other demographic variables and cultural factors that influence emotional processing, such as sociolinguistic factors (Fiske, 2020) and social rank (van Kleef & Lange, 2020), were not reported for participants involved in the present meta-analyses. Therefore, it remains unclear how observed effects are representative of broader populations. Finally, the present meta-analysis included studies only until 2018. Therefore, more recent studies investigating whether and how emotional stimuli influence cognitive control could not be considered. Interestingly, many recent studies investigated how specific moderator variables (e.g., social status, Fondevila et al., 2021; subjective relevance, Imbir et al., 2021; anxiety, Daches Cohen & Rubinsten, 2022; emotion regulation abilities, Khosravi et al., 2020) modulate the impact of emotional stimuli on cognitive control. This is compatible with the conclusion from the present work that emotional stimuli can facilitate control, but mostly under specific conditions.

Conclusions

Emotional stimuli modulate cognitive control in conflict task, but this effect is only weak and have been found only under specific circumstances. At an operational level, this means that researchers interested in studying such a modulation should (a) ensure that

Table 6

Results of Metaregression Analysis of Emotional (Negative Relative to Positive) Effects With Interaction Between Task (Flanker Task, Simon Task, Stroop Task) and the Other Moderators

Moderator	*df*	*F*	*p*	*e*	*n*	*a*	β	95% CI	σ_1	σ_2
D_v	2,60	0.35	.70	26	66	17			0.000	0.000
Flanker: D_v				12	29	8	−0.00	[−0.01, 0.00]		
Simon: D_v				3	18	2	−0.01	[−0.01, 0.00]		
Stroop: D_v				11	19	7	−0.01	[−0.03, 0.01]		
D_a_1	2,56	0.24	.79	25	62	16			0.000	0.000
Flanker: D_a_1				11	25	7	0.01	[−0.06, 0.08]		
Simon: D_a_1				3	18	2	0.00	[−0.02, 0.02]		
Stroop: D_a_1				11	19	7	0.05	[−0.03, 0.12]		
D_a_2	1, 61	0.07	.80	28	66	16			0.023	0.019
Flanker: nonsignificant				6	11	4	−0.00	[−0.12, 0.12		
Flanker: significant				7	12	4	0.07	[−0.04, 0.18]		
Simon: nonsignificant				4	8	2	0.00	[−0.06, 0.07]		
Simon: significant				3	14	2	0.05	[−0.01, 0.12]		
Stroop: significant				12	21	8	0.05	[−0.04, 0.15]		
Thr	2,61	0.55	.58	26	67	19			0.142	0.000
Flanker: unthreatening				10	20	7	−0.05	[−0.14, 0.05]		
Flanker: threatening				8	27	6	0.09*	[0.01, 0.18]		
Simon: unthreatening				2	4	2	−0.10	[−0.35, 0.16]		
Simon: threatening				1	2	1	−0.01	[−0.27, 0.25]		
Stroop: unthreatening				2	4	1	0.03	[−0.27, 0.32]		
Stroop: threatening				5	10	3	−0.02	[−0.18, 0.14]		
Sti	3,121	0.73	.54	52	131	36			0.054	0.046
Flanker: face				8	29	6	0.08*	[0.00, 0.16]		
Flanker: emotional picture				8	20	5	0.02	[−0.06, 0.11]		
Flanker: random reward				7	14	5	−0.02	[−0.11, 0.07]		
Flanker: word				4	9	3	0.03	[−0.11, 0.17]		
Simon: face				2	4	2	−0.04	[−0.21, 0.14]		
Simon: emotional picture				5	22	3	0.03	[−0.04, 0.10]		
Simon: random reward				1	2	1	−0.09	[−0.41, 0.22]		
Stroop: face				5	10	3	−0.02	[−0.16, 0.13]		
Stroop: emotional picture				10	17	7	0.06	[−0.05, 0.17]		
Stroop: sound				2	4	1	0.02	[−0.23, 0.28]		
Dur[a]	2,113	0.73	.48	44	119	31			0.054	0.049
Flanker: Dur				28	76	20	0.05	[−0.01, 0.11]		
Simon: Dur				8	28	6	0.02	[−0.06, 0.10]		
Stroop: Dur				8	15	5	0.09	[−0.04, 0.22]		
Att	5,119	0.63	.67	51	131	36			0.038	0.046
Flanker: 1				3	5	2	0.09	[−0.10, 0.28]		
Flanker: 2				5	12	4	0.12*	[0.01, 0.23]		
Flanker: 3				5	12	4	−0.01	[−0.11, 0.09]		
Flanker: 4				14	33	11	0.01	[−0.06, 0.08]		
Flanker: 5				5	14	3	0.02	[−0.10, 0.15]		
Simon: 1				2	4	2	0.01	[−0.24, 0.25]		
Simon: 4				3	18	2	0.04	[−0.01, 0.10]		
Simon: 5				1	2	1	−0.01	[−0.20, 0.18]		
Stroop: 2				3	6	2	0.07	[−0.10, 0.23]		
Stroop: 3				2	4	1	−0.20	[−0.46, 0.06]		
Stroop: 4				10	17	7	0.06	[−0.05, 0.17]		
Stroop: 5				2	4	1	0.03	[−0.22, 0.28]		
Rep	2,115	0.19	.83	49	121	34			0.010	0.052
Flanker: Rep				27	68	19	0.0001	[−0.0003, 0.0005]		
Simon: Rep				7	26	5	0.002	[−0.001, 0.0045]		
Stroop: Rep				15	27	10	0.001	[−0.002, 0.004]		
Num	2,121	0.18	.84	49	127	34			0.026	0.020
Flanker: Num				27	74	19	0.0003*	[0.0000, 0.0006]		
Simon: Num				7	26	5	0.0004	[−0.0001, 0.0008]		
Stroop: Num				15	27	10	0.0012	[−0.0006, 0.0029]		
Des	2,125	0.45	.64	51	131	36			0.019	0.044
Flanker: blocked				5	11	3	0.02	[−0.12, 0.16]		
Flanker: mixed				23	65	17	0.03	[−0.02, 0.08]		
Simon: blocked				2	16	1	0.05	[−0.01, 0.10]		
Simon: mixed				6	12	5	−0.01	[−0.09, 0.06]		
Stroop: blocked				3	5	2	0.15	[−0.10, 0.39]		
Stroop: mixed				12	22	8	0.04	[−0.05, 0.13]		

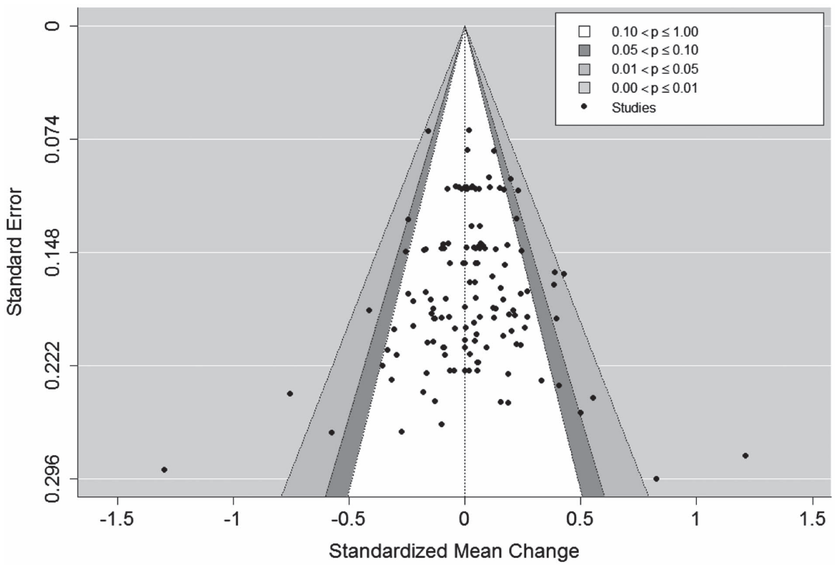
(*table continues*)

Table 6 (*continued*)

Moderator	*df*	*F*	*p*	*e*	*n*	*a*	β	95% CI	σ_1	σ_2
ISI[a]	2,113	1.57	.21	44	119	31			0.063	0.017
Flanker: ISI				28	76	20	−0.08*	[−0.14, −0.01]		
Simon: ISI				8	28	6	0.06	[−0.05, 0.16]		
Stroop: ISI				8	15	5	0.03	[−0.19, 0.25]		
Mod[b]	/	/	/	/	/	/			/	/
Flanker: compatible				28	76	20	0.03	[−0.02, 0.07]		
Simon: compatible				8	28	6	0.02	[−0.02, 0.07]		
Stroop: incompatible				2	4	1	0.01	[−0.40, 0.43]		
Stroop: compatible				15	27	10	0.03	[−0.12, 0.19]		
RT[a]	2,124	0.53	.59	50	130	35			0.044	0.000
Flanker: RT				28	76	20	0.08*	[0.01, 0.15]		
Simon: RT				6	24	5	0.07	[−0.03, 0.18]		
Stroop: RT				16	30	10	0.06	[−0.05, 0.16]		
Sample[c]	2,127	0.41	.67	53	135	37			0.053	0.050
Flanker: American				8	17	5	0.05	[−0.06, 0.15]		
Flanker: Asian				3	5	2	0.09	[−0.10, 0.27]		
Flanker: European				17	54	13	0.02	[−0.03, 0.07]		
Simon: American				2	4	1	−0.01	[−0.12, 0.11]		
Simon: Australian				1	2	1	−0.01	[−0.22, 0.21]		
Simon: European				5	22	4	0.03	[−0.05, 0.11]		
Stroop: American				14	26	9	0.02	[−0.07, 0.11]		
Stroop: European				3	5	2	0.08	[−0.11, 0.28]		
N	1,129	0.92	.40	53	135	37			0.056	0.028
Flanker: *N*				28	76	20	0.00	[−0.00, 0.00]		
Simon: *N*				8	28	6	0.00	[−0.00, 0.00]		
Stroop: *N*				17	31	11	0.00	[−0.00, 0.00]		
Age	2,94	1.24	.29	39	100	27			0.000	0.013
Flanker: Age				17	47	12	0.001	[−0.001, 0.003]		
Simon: Age				5	22	4	0.001	[−0.0004, 0.003]		
Stroop: Age				17	31	11	0.001	[−0.002, 0.004]		
F	2,104	1.52	.22	41	110	29			0.052	0.000
Flanker: F				18	55	13	0.06	[−0.01, 0.13]		
Simon: F				6	24	5	0.05	[−0.02, 0.12]		
Stroop: F				17	31	11	0.07	[−0.06, 0.20]		
Env	2,128	0.31	.73	53	135	37			0.062	0.000
Flanker: behavioral				18	54	12	0.05*	[0.00, 0.09]		
Flanker: ERP				10	22	8	−0.03	[−0.12, 0.05]		
Simon: behavioral				6	24	4	0.03	[−0.02, 0.08]		
Simon: ERP				2	4	2	−0.10	[−0.31, 0.12]		
Stroop: behavioral				2	4	1	−0.00	[−0.20, 0.19]		
Stroop: ERP				2	4	1	0.03	[−0.22, 0.27]		
Stroop: fMRI				13	23	9	0.04	[−0.05, 0.13]		
PY[d]	2,115	0.68	.51	48	121	34			0.056	0.000
Flanker: PY				23	62	17	0.00	[−0.00, 0.01]		
Simon: PY				8	28	6	0.00	[−0.00, 0.00]		
Stroop: PY				17	31	11	0.00	[−0.00, 0.01]		

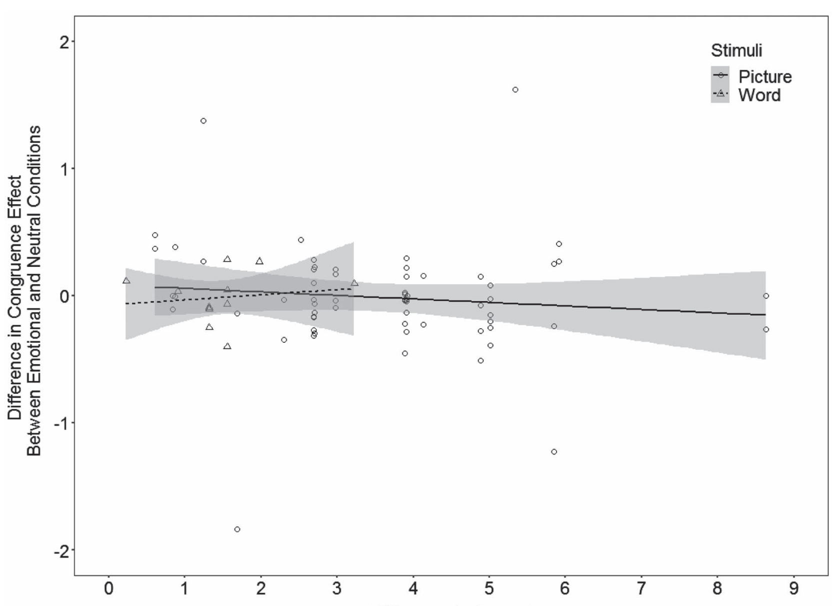
Note. βs of continuous variables represent regression coefficients and of categorical variables represent overall estimates of effect sizes at individual levels. σ_1 and σ_2 represent residual variance between estimates and between experiments, respectively; *e* = number of experiments; *n* = number of estimations; *a* = number of articles; 95% CI confidence interval at the 95% confidence level; Valence = valence of emotional stimuli (negative, positive); D_v = difference in valence rating between emotional stimuli and neutral stimuli; D_a_1 = difference in arousal rating between emotional stimuli and neutral stimuli; D_a_2 = statistical significance of arousal difference between affective and neutral stimuli (significant [$p < .05$]; nonsignificant); Thr = threat of negative stimuli (threatening, unthreatening); Sti = affect-stimulus format (face = emotional face photos; word = emotional words; emotional picture = emotional pictures; video = emotional videos; anticipation of shock = neutral stimuli conditioned with electro shock; sound = emotional sounds; random reward = random reward being independent from task performance; disfluency = trigger of disfluent processing); Dur = exposure duration of the emotional stimuli; Att = attentional status toward the emotional stimuli (1 = affective information was presented as part of conflict task-relevant and -irrelevant stimuli; 2 = affective information was presented as part of conflict task-relevant stimuli; 3 = affective information was presented as part of the conflict task-irrelevant stimuli; 4 = affective information was spatially overlapping with conflict task-relevant and -irrelevant stimuli; 5 = affective information was spatially distinct from conflict task-relevant and -irrelevant stimuli); Rep = the number of times the emotional stimuli were repeatedly presented; Num = the number of trials of the smallest cell defined by affect and congruency in the experiment; Des = procedure of presenting emotional stimuli in the experiment (blocked = emotional stimuli of different valence were presented in different blocks; mixed = emotional stimuli of different valence were intermixed within blocks); ISI = interstimulus interval measured from the offset of emotional stimuli to the onset of conflict task-relevant stimuli; Mod = compatibility of perception modalities between emotional stimuli and conflict task stimuli (compatible, incompatible); RT = mean reaction time for the experiment task; *N* = the number of participants in the experiment; Age = mean age of the experiment participants; F = ratio of female participants in the experiment; Env = experiment environment (behavioral experiment, ERP experiment; fMRI experiment); ERP = event-related potential; fMRI = functional magnetic resonance imaging; PY = publication year of the experiment.
[a] Values of the moderator were divided by 1,000 before analysis, which did not change the results. [b] Analysis of interaction effects between task and modality compatibility was impossible with the present data. [c] Countries were grouped in accordance with geographical continents (American continent, Asian continent, European continent, African continent, Australian continent). [d] 2,000 was subtracted from each value of the moderator before analysis, which did not change the results.
* $p < .05$.

Figure 15
The Contour-Enhanced Funnel Plot of Emotional (Negative Relative to Positive) Effects Across Standard Errors



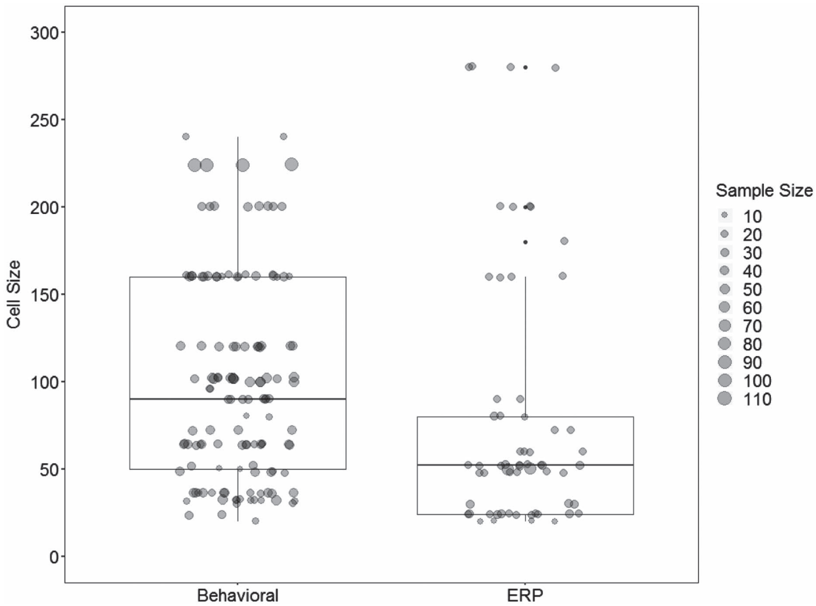
Note. It signifies levels of statistical significance of the observed difference in congruence effect between negative and positive conditions. Each black point represents an observation. The funnel is centered at 0 (the null hypothesis of no difference). The criterion of statistical significance is $p \leq .05$. Therefore, a black point located at the white region ($p > .1$) or the dark gray-shaded region ($.05 < p \leq .1$) indicates the corresponding effect is statistically nonsignificant.

Figure 16
Affective Effects Across Differences in Arousal for Emotional Pictures and Word Stimuli



Note. It illustrates the association between effect sizes (standardized difference in congruence effect for emotional relative to neutral stimuli) and difference in arousal (standardized difference in arousal rating of emotional relative to neutral stimuli) for emotional pictures and word stimuli separately. One bubble in the picture condition is close to −5 in the caption and was not displayed.

Figure 17
Cell Sizes Across Experiment Environment



Note. It depicts cell sizes (the number of trials in a cell conditioned by valence [negative, positive, neutral] and congruence [congruent, incongruent]) in behavioral experiments and ERP experiments. ERP = event-related potential. A bubble represents an observation. The size of bubbles indicates sample size (how many participants were involved in an observation), with a larger bubble indicating a larger sample size.

emotional stimuli are fully attended, (b) present stimuli preferably as words or videos, (c) control for arousal level, and (d) probe control processes with the appropriate conflict task of interest. At a theoretical level, this implies that the impact of emotional stimuli on cognitive control is less inevitable and universal, as suggested by many authors. Multiple moderator analysis converged on the observation that emotional stimuli relative to neutral stimuli decrease CEs, suggesting that (not extreme) emotional stimuli facilitate control. This finding supports a view in which attributes enhanced control either to overload of perceptual distractor processing or increase an amplification of target information and/or suppression of distractor information.

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