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Investigating the Interaction of Emotion and Cognition: Conflict Adaptation and the Impact of Emotionally-Salient Distraction

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Abstract

Individual differences in cognitive control have significant implications for a broad range of everyday functions, from driving a car to maintaining healthy relationships. In a world filled with salient, task-irrelevant information, it is imperative to investigate cognitive control in the context of distraction. The current study investigated the interference effect of emotional versus non-emotional distraction in a conflict adaptation paradigm. Forty-seven young adults completed several individual difference measures and an emotional flanker task. Results failed to support the hypothesis that distractor valence would interact with prior and current flanker congruency, but showed a trend toward an effect of distractor valence on conflict adaptation. Comparison of high- and low-reappraisers showed that greater emotion regulation ability may attenuate the interference effects of emotional distractors. The current study suggests that previous findings of a distractor valence effect may be contaminated by important differences in emotional and non-emotional image content.

Keywords

Cognitive control; conflict adaptation; distraction; emotion

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1. Introduction

Cognitive control, or executive function, refers to a set of general-purpose processes that are imperative to self-regulation (Miyake et al., 2000; Miyake & Friedman, 2012). Individual differences in cognitive control have significant implications for many aspects of day-to-day functioning, including self-perception and positive affect (e.g., Baumeister, 2002), romantic relationship success (e.g., Pronk et al., 2011), adherence to healthy lifestyle regimens (e.g., diet and exercise; Hall et al., 2008), and externalizing problems such as attention deficits and substance abuse (e.g., Young et al., 2009). Individual differences in cognitive control and self-regulation are known to be somewhat stable over development (e.g., Miyake & Friedman, 2012); however, they can also vary in the face of distracting stimuli – one may strictly adhere to a new diet while at home, but "cheat" when presented with decadent dessert options at a restaurant. Likewise, the cognitive processes required to drive a vehicle can be impaired by a distracting phone call or the sight of an accident on the side of the road, potentially leading to severe negative consequences. Thus, in a world filled with distracting information, it is important to investigate cognitive control in the context of task-irrelevant stimuli.

Cognitive control is typically defined and studied in terms of its component processes, namely working memory, set-shifting, and inhibitory control (Miyake et al., 2000). Inhibitory control, as one example, is commonly measured with stimulus-response compatibility tasks, wherein participants must follow specific attention-guiding rules and ignore distractors. This can prove very challenging, especially for incongruent trials, in which the information conveyed by salient distractors conflicts with the target (e.g., a target arrow pointing left with flanker arrows pointing right, or the word "blue" written in red ink). From a different theoretical perspective, cognitive control can be conceptualized as problem-solving, wherein successful cognitive performance requires an individual to appraise the problem, formulate and execute a plan, and evaluate its success (Luria, 1980; Zelazo et al., 1997). Distracting information can interfere with the effectiveness of any of these problem-solving steps, distancing the individual from successful achievement of their cognitive goal. Thus, regardless of the theoretical model one ascribes to, it is clear that distraction poses a threat to successful cognitive control.

1.1 Emotional Distraction and Cognitive Control

Interference from emotive stimuli forms a particularly interesting sub-class of distraction. Emotions signal potential harm or benefit; information conveyed by emotive distractors is potentially relevant to an individual's homeostasis, and therefore highly salient. Further, emotions are ubiquitous and imperative to almost all aspects of everyday human functioning, including cognition. The task of driving a vehicle, for example, requires a high degree of focus and attention, but is surrounded by emotionally-salient distractors that must be ignored in some circumstances (i.e., an incoming text message) and utilized in other circumstances to prioritize cognitive processes (i.e., a child having an asthma attack in the backseat; Blair & Dennis, 2010). Thus, understanding real-world cognitive functioning demands consideration of emotional factors (rather than adopting a strictly cognitive perspective, using abstract tasks such as the Flanker or Stroop task; Zelazo et al., 2010). In recent decades, researchers have begun to investigate cognitive control in the context of emotional signals (e.g., positive and negative images, rewards, punishers); however, characterizing the nature of this competitive emotion-cognition interaction remains a central theoretical challenge.

According to some studies, the introduction of emotionally-salient information can facilitate performance on cognitive tasks, *if* that information is task-relevant. Qu and Zelazo (2007), for example, found that three-year-olds performed significantly better on an emotional

Dimensional Change Card Sort (DCCS) task, where they were required to sort facial stimuli by gender (male/female) and emotion (happy/sad), than on the traditional DCCS. However, when emotionally-salient information is task-*irrelevant*, performance is significantly hindered. In Carlson et al.'s (2005) "Less Is More" task, children are presented two piles of candy and must point to the smaller one in order to receive the larger one as a reward. This task proved extremely difficult for young children; however, when they were distanced from the salient reward stimuli (by replacing the candy with random symbols), their performance improved significantly. Similarly, in the traditional Delay of Gratification task, children's wait times increase if the reward is removed from sight or if they are instructed to think about its abstract qualities, like shape, rather than its arousing qualities, like taste (Mischel & Baker, 1975; Mischel, Ebbesen, & Zeiss, 1972). In adults, a direct study of emotional distractors found increased response times (RTs) for simple auditory discrimination trials preceded by highly emotional stimuli (i.e., appetitive erotic images and aversive injurious images) relative to trials preceded by neutral stimuli (Buodo, Sarlo, & Palomba, 2002). Buodo et al. concluded that in the face of emotional distractors, attentional resources are drawn toward the emotion and away from the target task.

Indeed, many studies have replicated the interfering effect of emotional stimuli; however, the literature also reveals many inconsistencies, such that emotional stimuli hinder cognitive performance under some circumstances, but not others. In a follow-up experiment, Buodo et al. (2002) found that threatening images actually *decreased* RTs. They argued that in the face of threatening stimuli, humans are evolutionarily "hard-wired" to minimize the allocation of attentional resources to the stimulus, in favour of facilitating rapid action. To reconcile this finding with the attention-*drawing* effect of positive (e.g., erotic) and negative (e.g., injurious) stimuli, Buodo et al. proposed an early mechanism, in which the impact of emotional distractors on cognitive task performance may be moderated by the allocation of attentional resources.

More recently, studies have found that emotional stimuli impair performance on simple cognitive tasks, but not complex ones. Cohen et al. (2011) found that negative images hindered RTs on congruent flanker trials but not incongruent trials. Similarly, negative images increased RTs on easy trials of a bar orientation task but had no effect on difficult trials (Erthal et al., 2005), and increased search times for low-load search paradigms but had no effect on high-load paradigms (Gupta et al., 2016). Further, O'Toole et al. (2011) found that threatening facial expressions impaired performance (relative to non-threatening expressions) in the easy condition of an attention task, but not in the difficult condition. Thus, the impact of emotional distractors on cognitive performance may be moderated by the allocation of cognitive resources (e.g., attention, conflict monitoring), such that cognitively demanding tasks retroactively diminish distraction effects.

The allocation of cognitive resources to complex tasks may also have proactive effects on the processing of emotional stimuli. Cohen et al. (2011) investigated the impact of *prior* congruency on distraction from negative versus neutral images using an emotional flanker task. Interestingly, they found that when the previous (N–1) trial was incongruent, negative distractors had no effect (relative to neutral distractors) on RTs for the current (N) trial. In contrast, when the N–1 trial was congruent, there was a significant valence effect, such that RTs were slower for negatively-cued N trials relative to neutrally-cued N trials. In line with the previously discussed mechanism, Cohen et al. concluded that during complex (i.e., incongruent) trials, cognitive resources are allocated to resolving the conflict, leaving fewer resources available to process the distractor image and therefore attenuating its interference effect in the subsequent trial.

Cognitive neuroscience studies provide further evidence for a trade off between executive and emotional attention. Van Dillen et al. (2009) found that when executive activation was increased (i.e., by having participants solve complex arithmetic equations), neurophysiological and subjective responses to negatively-valenced stimuli were attenuated, while trials with low "executive load" (i.e., simple arithmetic equations) had no attenuating effect. Similarly, visual search trials with high perceptual load (i.e., high target-distractor similarity) attenuated amygdala responses to fearful stimuli, relative to trials with low perceptual load (Hsu & Pessoa, 2007). Physiological evidence also supports this mechanism: pupillary responses to negative images were attenuated following incongruent flanker trials but not congruent trials (Cohen et al., 2015).

Thus, there is considerable evidence that effortful executive tasks impact attention to emotional stimuli. These effects may represent a general instance of conflict adaptation.

1.2 Emotional Distraction and Conflict Adaptation

Conflict adaptation refers to the fact that in stimulus-response compatibility tasks, such as the flanker task, congruency effects are larger following congruent trials than they are following incongruent trials (refer to Figure 1). There are numerous theoretical perspectives from which conflict adaptation can be interpreted. Conflict monitoring theory (Botvinick et al., 2001) posits that completing an incongruent trial strengthens attention-guiding rules (e.g., to focus on the central arrow), which improves RTs on a second incongruent trial. An alternative view appeals to an "attentional lens" or spatial spotlight: an incongruent trial narrows focus to the target and limits processing of conflicting flankers. On a subsequent incongruent trial, this narrowed lens facilitates responding to the target; however, on a subsequent congruent trial, reduced processing of congruent flankers diminishes their helpful effect. Performance on a current congruent trial is therefore enhanced by prior *congruency*, which widens the attentional lens and increases processing of facilitative flankers. Despite some key differences, all prevailing accounts agree that conflict adaptation is a reflection of learning, in which prior experience adaptively calibrates current processing (Egner, 2014).

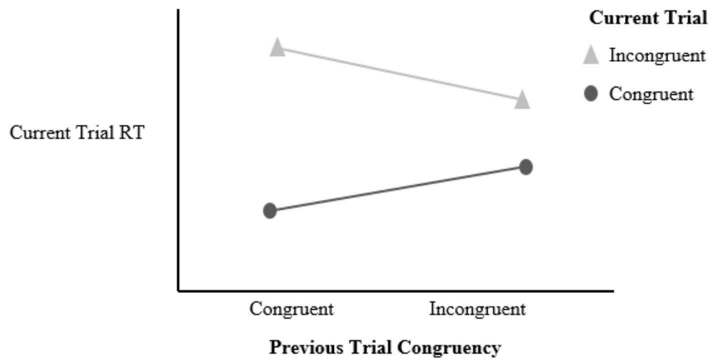

Figure 1. The conflict adaptation effect. RTs on current congruent trials are facilitated by prior congruency; RTs on current incongruent trials are facilitated by prior incongruency.

One interesting question concerns the possible impact of emotionally-salient distractors on conflict adaptation. Does the presence of an intervening distractor disrupt conflict adaptation? Are there differential interference effects for emotional versus non-emotional distractors?

Botvinick's (2001) conflict monitoring theory, for example, would posit that emotionally-salient distractors may disrupt the rule-strengthening process elicited by an incongruent trial, diminishing the facilitative effect of two consecutive incongruent trials. In this case, the congruency effect following incongruent trials would increase, while the congruency effect following congruent trials should remain the same (i.e., because no rule-strengthening is engaged by congruent trials), resulting in attenuated conflict adaptation overall. Alternatively, the attentional lens hypothesis would predict that emotionally-salient distractors have a particularly disruptive effect following congruent trials, as a widened lens and should lead to greater processing of a subsequent distractor. In this case, subsequent RTs should increase for both congruent and incongruent trials, diminishing the facilitative effect of two consecutive congruent trials. In contrast, the narrowed attentional lens instantiated by an incongruent trial should reduce processing of a subsequent distractor; however, it is possible that salient negative distractors may disrupt this narrowing and “re-widen” the attentional lens. The slightly widened lens should then increase processing of the distracting flankers, resulting in slightly slower RTs for subsequent incongruent trials and slightly faster RTs for subsequent congruent trials. Relative to the standard conflict adaptation effect, this would produce a slightly smaller congruency effect following congruent trials and a larger congruency effect following incongruent trials, attenuating conflict adaptation overall. On both theoretical accounts, neutral distractors should have no significant effect on conflict adaptation.

Cohen and colleagues (2011) conducted an emotional stimulus-response compatibility task and found that emotional distractors hindered flanker performance only when the preceding trial was congruent. They concluded that allocating resources to the complex incongruent trials diminished subsequent emotional distraction effects. These findings, while suggestive, demand more thorough investigation. Analyzing changes in the conflict adaptation effect as a function of intervening distractor valence may provide a more nuanced understanding of the mechanism through which emotional signals impair cognitive performance.

1.3 The Role of Individual Differences

Although conflict adaptation is a robust phenomenon, the degree of adaptation varies across individuals. Consideration of individual differences may therefore provide additional insight into the interaction of emotional and cognitive processing. Of particular interest in this study is individual differences in the ability to manage or regulate emotion. Core models of emotion regulation focus on the ability to down-regulate (i.e., reduce the impact of) negative emotions, emphasizing two strategies in particular: reappraisal and suppression (Gross & John, 2003). While both strategies possess adaptive value when employed in the appropriate context, there is substantial evidence supporting reappraisal as more effective overall, including associations with greater positive affect, social functioning, and general well-being (Gross, 2002; Gross & John, 2003). Thus, individual differences in reappraisal ability may be associated with the ability to complete cognitive tasks in the face of negatively-valenced distractors.

Currently, only one study has investigated emotion regulation in the context of an emotional distractor paradigm (Cohen, Henik, & Moyal, 2012). Each trial consisted of a flanker task, a distractor image, and a colour discrimination target task. Similar to previous studies, they found that negative distractors only impaired performance on the target task if the preceding flanker was congruent. Interestingly, however, this effect only occurred for individuals who scored highly on a measure of cognitive reappraisal (i.e., "high reappraisers"); for "low reappraisers", negative stimuli hindered performance on the target task, regardless of whether the preceding flanker trial was congruent or incongruent. Thus, allocating cognitive resources to complex task appears to protect against interference from emotional distractors, but only for individuals with good emotion regulation. In support of this finding, neurological studies have found that when viewing negative stimuli (e.g., disgusting film clips, sad or fearful facial expressions), employing either reappraisal or suppression increases executive activation (e.g., prefrontal cortex), but only reappraisal attenuates emotional activation (e.g., amygdala, insula; Drabant et al., 2009; Goldin et al., 2008). Thus, individual differences in emotion regulation ability appear to play a role in the relationship between executive and emotional functioning, and may also be associated with susceptibility to emotional interference during conflict adaptation.

1.4 The Current Study

The existing literature provides significant insight into the mechanism through which emotional stimuli impact cognitive performance; however, there are many remaining questions about the nature of this competitive interaction in the context of conflict adaptation and individual differences. The goal of the current study is to investigate changes in conflict adaptation as a consequence of interference from emotional and non-emotional distractors.

The first objective of the current study is to replicate the findings of Cohen et al. (2011) utilizing an emotional flanker task. It is hypothesized that there will be a significant effect of distractor valence, such that RTs will be significantly slower for trials preceded by negative images relative to neutral images. It is also hypothesized that there will be a significant interaction between distractor valence and current trial congruency, such that negative distractors hinder performance on congruent trials but not incongruent trials. Finally, distractor valence is expected to interact with prior trial congruency, such that negative distractors hinder performance on subsequent trials if the preceding trial was congruent, but have no effect if the preceding trial was incongruent.

Upon replication, the current study will investigate the impact of distractor valence on conflict adaptation. It is hypothesized that there will be a significant three-way interaction between prior congruency, current congruency, and distractor valence, such that negative and neutral stimuli will have differential effects on conflict adaptation. Specifically, given the spatial attention demands of a flanker paradigm, it is hypothesized that results will align with the attentional lens theory. Neutral distractors are expected to have no significant impact on conflict adaptation, while negative distractors are expected to attenuate conflict adaptation, such that congruency effects following congruent and incongruent trials are not significantly different.

The current study will also investigate the association between emotion regulation ability and performance on the emotional flanker task. Previous findings contrasting high- and low-reappraisers predict that individuals who engage more frequently in reappraisal will demonstrate reduced valence effects in the flanker paradigm. Additionally, it is hypothesized that there will be a four-way interaction between distractor valence, conflict adaptation (prior congruency and current congruency), and reappraisal ability. Consistent with the attentional lens hypothesis, negative distractors are expected to substantially disrupt (i.e., “re-widen”) the narrowed lens instantiated by incongruent trials for low reappraisers, completely disrupting conflict adaptation (such that current trial RTs are unaffected by prior congruency). In contrast, conflict adaptation is expected to be attenuated (but still evident) in high reappraisers, who are expected to regulate negative distractors more effectively, resulting in less disruption of the narrowed attentional lens.

Finally, the current study will employ an incidental learning paradigm to investigate the degree to which negative and neutral distractors are processed during the flanker task. It is hypothesized that there will be a significant valence effect, such that negatively-valenced images will be recalled with greater accuracy that neutral images. In line with the attentional lens account, it is also hypothesized that there will be a significant effect of prior congruency: the narrowed lens instantiated by an incongruent trial is expected to diminish distractor processing relative to the widened lens instantiated by a congruent trial. This hypothesis also aligns with existing mechanistic proposals: if incongruent flanker trials draw cognitive resources away from subsequent distractors (e.g., Cohen et al., 2011), images preceded by incongruent trials during the flanker task should be recalled with poorer accuracy than those preceded by congruent trials.

The current study will determine whether emotionally-salient distractors interfere with conflict adaption, providing more detailed insight into the relationship between emotional stimuli, cognitive resource allocation, and cognitive task performance. Results of this study will further our understanding of how emotional distractors interfere with task-related learning and clarify the specific conditions under which emotion hinders cognition.

2. Methods

2.1 Participants

Sixty-eight undergraduate students (48 females) were recruited from Western University to voluntarily participate in the study in exchange for course credit. Only participants who completed the emotional flanker task with at least 90% accuracy were included in the final sample. Seven participants who scored between 80% and 90% overall, but who scored above 90% on at least two of the four blocks in the flanker task remained in the final sample. Forty-seven participants (35 females) between the ages of 17- and 21-years-old (M = 18.47, SD = 0.856) completed all measures with sufficient accuracy and were included in the final sample. The majority of participants were right-handed (n = 44) and reported English as their first language or a fluent second language (n = 42).

2.2 Measures

2.2.1 Emotion Regulation Questionnaire (ERQ; Gross and John, 2003). Participants completed this ten item Likert-type scale assessing their use of emotion regulation strategies. Responses are made on a seven-point scale ranging from “1 (Strongly Disagree)” to “7 (Strongly Agree)”, with a response of “4” being neutral. Items are divided into two subscales, suppression and reappraisal, and include statements such as “I keep my emotions to myself” and “When I want to feel more positive emotion, I change what I’m thinking about”.

2.2.2 Positive and Negative Affect Schedule (PANAS; Watson et al., 1998). Participants completed a twenty item Likert-type scale assessing their current affective state. Participants read a series of twenty emotion words and indicated the degree to which they were currently experiencing each feeling using a five-point scale ranging from "1 (Very Slightly or Not At All)" to "5 (Extremely)". Items are divided into two subscales, positive affect and negative affect, and include both positive emotions (interested, excited, proud) and negative emotions (distressed, hostile, scared).

2.2.3 Behavioural Inhibition and Approach System Scales (BIS/BAS; Carver & White, 1994). Participants completed a twenty-four item Likert-type scale assessing their avoidance and approach tendencies. Responses are made on a four-point scale ranging from "very true for me" to "very false for me". Items are divided into one inhibition system subscale (inhibition) and three approach system subscales (drive, fun-seeking, and reward responsivity). The remaining four items are filler items. The scale includes statements such as "I go out of my way to get things I want", and "I feel worried or upset with I think or know somebody is angry at me".

2.2.4 Executive Functioning Tasks. Participants completed a series of three HTML-based executive functioning computer tasks. Digit Span assessed working memory, requiring participants to memorize a series of numeric codes which increased in length with each level. The task concluded when participants made three consecutive errors. Final scores corresponded to the maximum number of digits the participant correctly recalled. Spatial Search assessed spatial working memory, requiring participants to memorize a series of locations on the computer screen and select them in the correct order. The task concluded when participants made three consecutive errors within a single level. Final scores corresponded to the maximum number of locations the participant correctly recalled minus the total number of errors made throughout the task, and could therefore be either positive or negative. Finally, Verbal Reasoning presented participants with an image of two geometric shapes and a descriptive sentence such as “The circle is enclosed by the square”. In each trial, participants had to determine whether the sentence was a correct or incorrect description of the geometric image. Final scores corresponded to the participant’s total number of correct responses over the course of three minutes.

2.2.5 Emotional Flanker Task. The primary task in the current study was a modification of the Eriksen Flanker task (Eriksen & Eriksen, 1974) implemented in Python. Instructions were presented on the computer screen and given to participants verbally. In each individual trial (refer to Figure 2), participants were presented with a white fixation cross in the center of a black screen for 1,000ms. The fixation cross disappeared and was replaced with a negatively-valenced, neutral, or scrambled distractor image in the center of the screen for 100ms. The three distractor conditions were distributed evenly across the experiment, each accounting for one third of the total number of trials. Finally, participants were presented with the target stimulus – a horizontal line of five chevron arrows – which were centered on the screen and persisted for 1,500ms or until a response was made. Participants were required to indicate the direction of the center arrow as pointing left or right by pressing the left-most or right-most button, respectively, on a five-button Chronos response box with sub-millisecond temporal resolution. The target stimulus was congruent (all arrows pointing the same direction) in 50% of trials and incongruent (center arrow pointing the opposite direction) in 50% of trials.

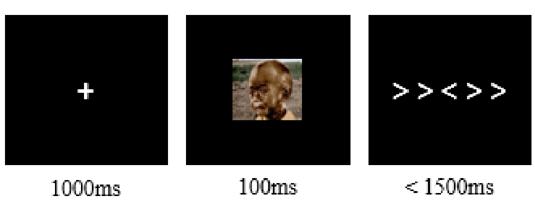

Figure 2. An individual trial from the emotional flanker task. Participants responded to the direction of the center arrow on the target screen.

Participants were instructed to respond as quickly and accurately as possible, and to focus on the fixation cross in between trials. The entire task consisted of 720 trials divided into four equal blocks. Participants were presented with a break screen after each block and instructed to resume the experiment when ready by pressing a “Continue” button. On average, the emotional flanker task required approximately 18 minutes to complete. Trial-by-trial performance, including accuracy and response time, was recorded and saved.

2.2.6 Image Stimuli. Twenty negative image and 20 neutral images were selected from the International Affective Picture System (IAPS; Lang et al., 2001) as distractors in the emotional flanker task. Images were selected using the standardized IAPS nine-point ratings of arousal (from “not arousing” to “very arousing”) and valence (from “very negative” to “very positive”). Negative images were selected based on extremely low valence ratings (M = 1.71) and high arousal ratings (M = 6.49). The final group of negative images was comparable to that of previous studies (Cohen et al., 2011; M_V = 1.67, M_A = 6.50). In contrast, neutral images were selected based on moderate valence ratings (M = 5.01) and extremely low arousal ratings (M = 2.80). Again, the final group of neutral images was comparable to Cohen et al. (M_V = 4.94, M_A = 2.49). Images were sized to 6.5cm x 9cm and presented in the center of the computer screen.

To minimize all other differences between negative and neutral images, the two groups were matched for content, such that both groups included exactly 2 animal-images, 3 object-images, 3 body-images, and 12 face-images. The two groups were also matched as best as possible on the spatial positioning of each image’s central feature(s). For example, if a negative image included a face positioned in the top-left corner, it was ensured that one of the neutral images also featured a face positioned in the top-left corner. The goal of this matching was to ensure any differences between negatively- and neutrally-cued trials could not be attributed to saccadic eye movements away from the center of the screen. Finally, the negative and neutral images were coarsely matched on colour and brightness, such that each group contained an approximately equal number of bright and dull images, and colourful and dark images.

Each group of images was further divided into four subsets of five images each. These subsets were matched on valence and arousal, such that all negative groups were approximately equal in valence and arousal, and all neutral groups were approximately equal in valence and arousal. The eight subsets (four negative, four neutral) were combined to create four images sets (A, B, C, and D) each containing five negative and five neutral images. Within these larger image sets, negative and neutral images were perfectly matched on content, and matched as best as possible on spatial displacement, brightness, and colour. Each image set was then yoked to one of the four possible flanker pair conditions, such that a congruent-congruent flanker pair was always interleaved with an image from Set A (for example), a congruent-incongruent pair was always interleaved with an image from Set B, an incongruent-congruent pair was always interleaved with an image from Set C, and an incongruent-incongruent pair was always interleaved with an image from D. The assignment of image sets to flanker pair conditions was counter-balanced across participants (refer to Appendix A, Table 2). This ensured any differences between negatively- and neutrally-cued flanker trials could be attributed to the valence, rather than the specific content or details of any particular images. It also enabled the employment of an incidental learning paradigm at the end of the experiment, as discussed below.

The 40 selected IAPS images (20 negative, 20 neutral) were used to create a scrambled version of each experimental image. Scrambled stimuli were created in Python by shrinking and then re-sizing the image, conserving the colour, brightness, and broad spatial frequencies of the image but distorting the content to be indecipherable. The emotional flanker task included negative, neutral, and scrambled distractor images with equal frequency. Each of the 20 negative images and 20 neutral images appeared in 12 of the 720 flanker trials. Each of the 40 scrambled images appeared in 6 trials.

2.2.7 Incidental Learning Paradigm. Participants completed a surprise recall test at the end of the experiment, programmed in Python and implemented on the computer. Instructions were presented on the computer screen and given to participants verbally. Participants completed the 100-trial paradigm, requiring a total of approximately 3 minutes. In each trial (refer to Figure 3), participants were presented with a fixation cross in the center of the screen for 1,000ms, following by a brief presentation (250ms) of a negative or neutral image. Participants were then presented with a blank screen until a response was made using the keyboard. Participants pressed the “D” key to indicate that the image was familiar and the “K” key to indicate that the image was unfamiliar. Forty trials featured a “real” image, selected from the groups of negative and neutral images utilized in the flanker paradigm. All 40 images from the flanker task were presented once during the incidental learning paradigm. Forty trials featured a “foil” image, selected from the IAPS but not included in the flanker task. Foil images were selected based on valence and arousal ratings, such that the 20 negative foils and 20 neutral foils were as comparable as possible to the real images. The final 20 trials of the incidental learning paradigm featured 20 positive images selected from the IAPS based on extremely high valence and arousal ratings, in order to elevate participants’ mood before concluding the experiment. These positive images were always the last 20 trials of the task and persisted on the screen for 500ms.

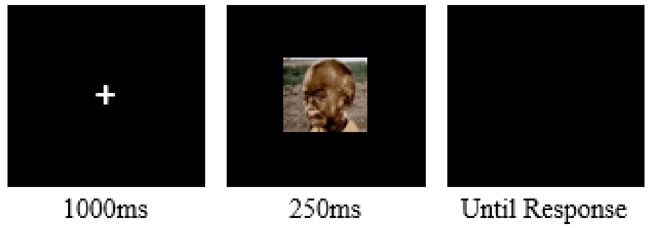

Figure 3. An individual incidental learning paradigm trial. Participants' response indicated whether the target image was familiar or unfamiliar.

2.3 Procedure

Participants were recruited through the psychology research participation pool (SONA) at Western University. The experiment was conducted in a testing room on Western campus in Westminster Hall. Upon providing consent to participate, participants began by completing the questionnaires, which were presented on a computer using a custom-programmed HTML platform. Participants completed a demographic questionnaire with items concerning age and gender, followed by the Emotion Regulation Questionnaire (ERQ), the Positive and Negative Affect Schedule (PANAS), and the Behavioural Inhibition and Approach System Scales (BIS/BAS), requiring a total of approximately 10 minutes. Participants then played the three HTML-based executive functioning tasks (Digit Span, Spatial Search, and Verbal Reasoning), requiring approximately 15 minutes to complete.

Next, participants completed the emotional flanker task. Participants were seated in a chair positioned approximately 60cm from the computer screen and asked to remain seated with their back against the chair throughout the entire task. In the absence of a chin rest, this helped to ensure all participants were approximately the same distance from the screen. The emotional flanker task took approximately 18-20 minutes to complete. Upon completion of the four flanker blocks, participants completed a second copy of the PANAS with pen and paper to allow for investigation of any changes in affect following the emotional flanker task. For both copies of the PANAS, participants were instructed to report how they were feeling in the exact current moment. Finally, participants completed the incidental learning paradigm on the computer, requiring approximately 3-5 minutes. Upon completion of the entire study, participants were given a verbal debriefing, provided an opportunity to ask any remaining questions, and compensated with 1.5 research credits through the research participation pool.

3. Results

The overall mean error rate in the emotional flanker task was 4.77%. To ensure data of the highest integrity, all error- and post-error trials were purged from the dataset. To confirm the flanker task was working as designed, two separate 2 (prior congruent, prior incongruent) X 2 (current congruent, current incongruent) repeated-measures ANOVAs were conducted, first using only the flanker trials preceded by scrambled distractors, and then collapsing across all distractor types.

As anticipated, when analyzing only the scrambled-distractor trials, there was a significant congruency effect, $F(1, 46) = 186.620$, $p < .001$, such that RTs were significantly slower on incongruent trials ($M = 515.65$, $SD = 63.858$) relative to congruent trials ($M = 466.87$, $SD = 63.414$; refer to Figure 4A). The congruency effect was replicated when analyzing across all flanker trials (including scrambled, negative, and neutral distractors), $F(1, 46) = 295.009$, $p < .001$, such that RTs were significantly slower on incongruent trials ($M = 525.18$, $SD = 66.558$) relative to congruent trials ($M = 471.48$, $SD = 62.162$; refer to Figure 4B).

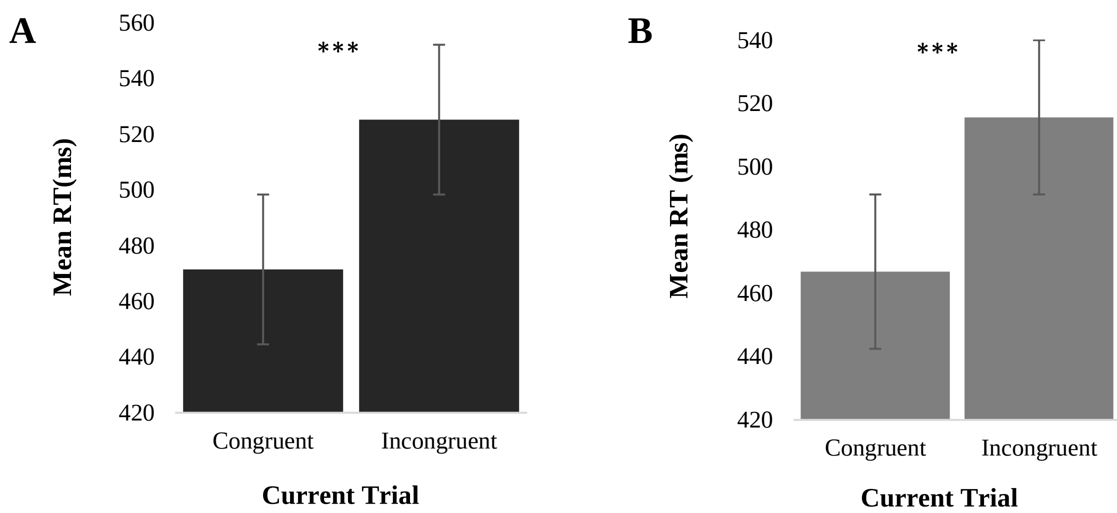

Figure 4. Mean RTs for (A) flanker trials preceded by scrambled distractors only and (B) across all flanker trials (preceded by all distractor types). Error bars denote standard error of the mean. Note: $*p < .05$; $**p < .01$; $***p < .001$.

Analysis of the scrambled-distractor trials also revealed a significant interaction between prior trial (N–1) congruency and current trial (N) congruency, $F(1, 46) = 8.082$, $p = .007$, referred to as the conflict adaptation effect (refer to Figure 5A). The conflict adaptation effect was replicated when analyzing across all flanker trials, $F(1, 46) = 13.091$, $p = .001$ (Figure 5B). Mean RTs for all sequential flanker conditions, across all trials and across trials with scrambled distractors only, are summarized in Table 1.

3.1 Replication

To investigate the study's primary hypotheses regarding the effect of distractor valence, a 2 (prior congruent, prior incongruent) X 2 (current congruent, current incongruent) X 2 (negative, neutral) repeated-measures ANOVA was conducted across all negatively- and neutrally-cued flanker trials. Contrary to expectations, the main effect of distractor valence was non-significant, $F(1, 46) = 1.639$, $p = .207$. Mean RTs were slightly, but not significantly, slower

Table 1.

Mean response times (ms) and associated standard deviations for sequential flanker pairs across all trials and across scrambled-distractor only trials.

N–1 Trial	N Trial	Distractor Type	*M*	*SD*
Congruent	Congruent	All	466.72	62.618
		Scrambled Only	460.72	63.969
	Incongruent	All	526.94	72.238
		Scrambled Only	518.45	70.018
Incongruent	Congruent	All	474.50	61.329
		Scrambled Only	474.19	64.418
	Incongruent	All	522.13	62.410
		Scrambled Only	513.21	61.035

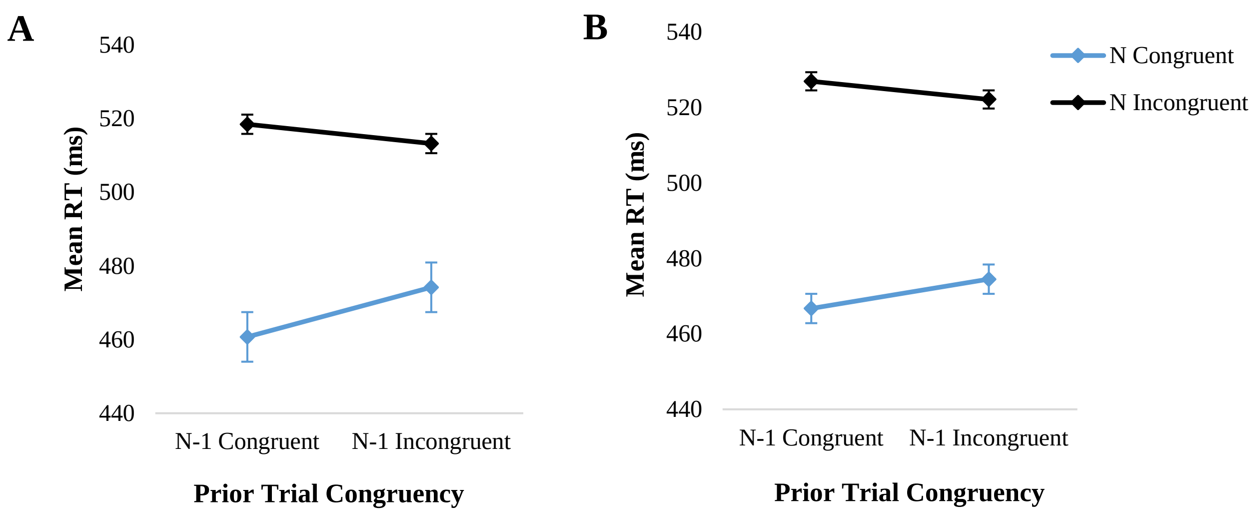

Figure 5. The significant interaction between prior trial congruency and current trial congruency on the emotional flanker task (A) across scrambled-distractor trials only and (B) across all trials.

on trials preceded by a negative image (*M* = 501.25, *SD* = 66.074) relative to trials preceded by a neutral image (*M* = 497.86, *SD* = 63.631; M_D = 3.38ms; refer to Figure 6). Mean RTs were significantly faster on scrambled trials (*M* = 493.08, *SD* = 62.507) relative to both negative (M_D = 8.171ms, $p < .001$) and neutral trials (M_D = 4.781ms, $p < .01$), $F(1, 46) = 18.193$, $p < .001$.

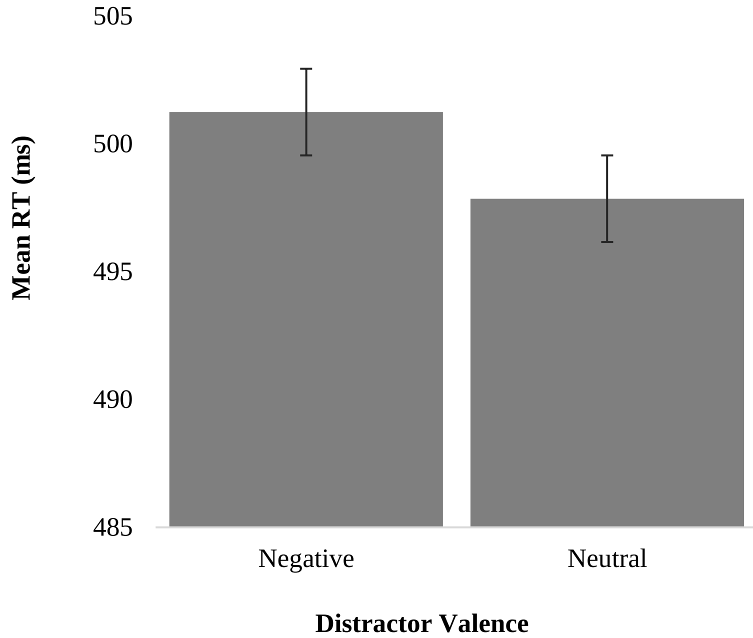

Figure 6. Mean response times on the current flanker trial when preceded by a negative distractor relative to a neutral distractor.

Also contrary to hypotheses, there was no significant interaction between preceding distractor valence and current flanker congruency, $F(1, 46) = 0.786$, $p = .380$ (refer to Figure 7). Mean RTs are summarized in Table 2. Interestingly, inclusion of trials preceded by scrambled distractors (as well as negative and neutral) did reveal a significant interaction, $F(1, 46) = 6.418$, $p = .015$, as well as a significant main effect of valence, $F(1, 46) = 32.214$, $p < .001$ (refer to Appendix A, Figure 1). Within congruent trials, RTs were significantly faster when preceded by scrambled distractors relative to negative distractors (M_D = 7.50ms), but there were no differences between negative and neutral distractors or between neutral and scrambled distractors. Within incongruent trials, RTs were significantly faster when preceded by scrambled distractors relative to both negative (M_D = 14.19ms) and neutral distractors (M_D = 12.85ms).

Table 2.

Mean response times (ms) and associated standard deviations for all pairings of preceding distractor valence and current trial (N) congruency in the emotional flanker task.

Distractor Valence	**N Congruency**	***M***	***SD***
Negative	Congruent	474.37	60.911
	Incongruent	529.84	73.742
Neutral	Congruent	470.07	63.584
	Incongruent	528.50	65.572
Scrambled	Congruent	466.87	63.414
	Incongruent	515.65	63.858

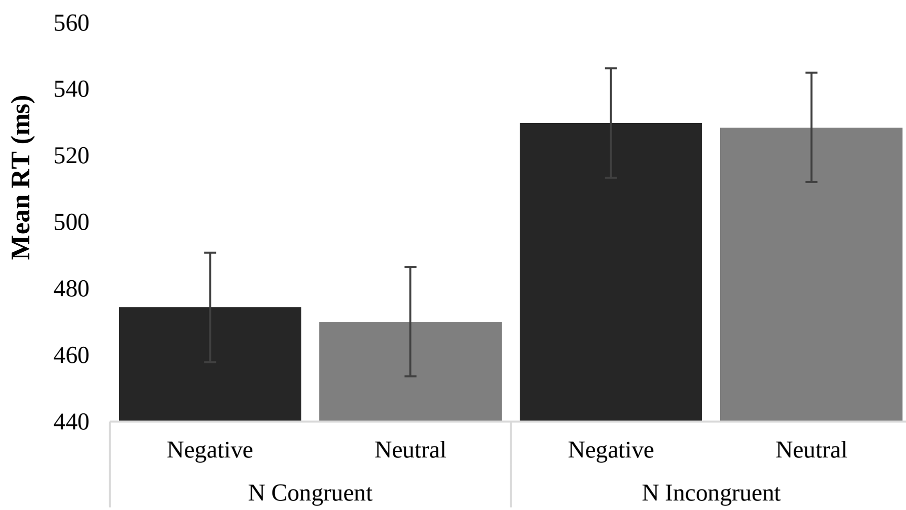

Figure 7. The non-significant interaction between preceding distractor valence and current (N) flanker trial congruency.

The current study also failed replicate findings of an effect of *prior* trial (N–1) congruency on current trial (N) distractor valence. Contrary to expectations, there was no significant interaction between prior congruency (congruent, incongruent) and distractor valence (negative, neutral), $F(1, 46) = 1.927$. $p = .172$ (refer to Figure 8). There were no significant differences in RTs for negatively-cued versus neutrally-cued trials, regardless of whether the preceding flanker trial was congruent or incongruent. Mean RTs are summarized in Table 3.

Table 3.

Mean response times (ms) and associated standard deviations for all pairings of prior flanker congruency and current distractor valence in the emotional flanker task.

N–1 Flanker Trial	**N Distractor Valence**	***M***	***SD***
Congruent	Negative	501.75	70.512
	Neutral	496.53	65.427
Incongruent	Negative	500.42	62.246
	Neutral	499.28	62.715

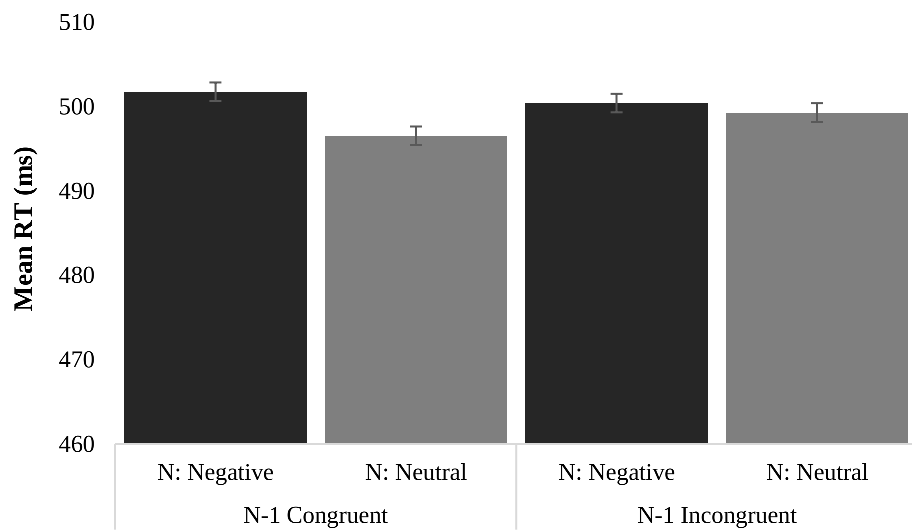

Figure 8. The non-significant interaction between flanker congruency in the previous (N–1) trial and distractor valence in the current (N) trial.

3.2 Extension

Despite replication failure, the current study investigated the effect of interfering distractor valence on the basic conflict adaptation effect. The three-way interaction between prior congruency, current congruency, and distractor valence was non-significant, $F(1) = 0.310$, $p = .580$ (refer to Figure 9). Interestingly, the conflict adaptation effect remained marginally significant in the neutral-image condition, $F(1) = 3.879$, $p = .055$ (Figure 9A), but was non-significant in the negative-image condition, $F(1) = 2.507$, $p = .120$ (Figure 9B). Mean RTs are summarized in Table 4.

Table 4.

Mean response times (ms) and associated standard deviations for all pairings of prior congruency, current congruency, and interfering distractor valence in the emotional flanker task.

Previous Trial	**Current Trial**	**Valence**	***M***	***SD***
Congruent	Congruent	Negative	473.71	64.009
		Neutral	465.93	63.828
	Incongruent	Negative	532.97	80.786
		Neutral	530.33	71.267
Incongruent	Congruent	Negative	475.22	59.389
		Neutral	474.07	65.114
	Incongruent	Negative	526.73	68.490
		Neutral	526.87	62.760

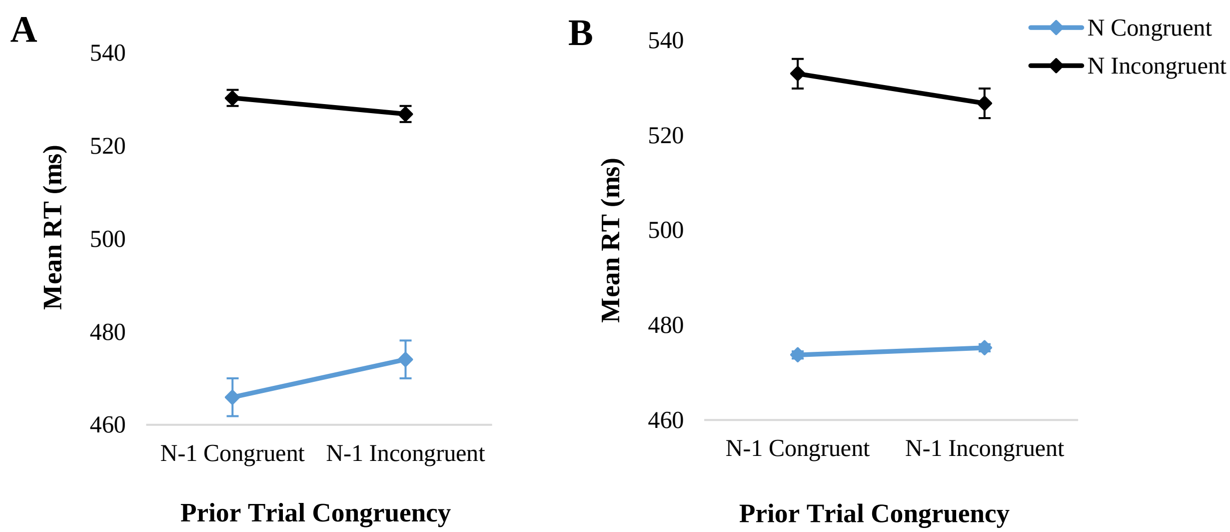

Figure 9. The non-significant interaction between prior congruency, current congruency, and distractor valence, comparing (A) trials interleaved with neutral images to (B) trials interleaved with negative images.

Despite the non-significant three-way interaction, it was hypothesized that flanker task performance would be associated with individual differences in emotion regulation. Of particular interest was participants' use of cognitive reappraisal as an emotion regulation strategy, and how reappraisal ability interacts with the basic valence effect and the three-way interaction between valence and conflict adaptation. The sample was divided into high- and low-reappraisers based on the median reappraisal score (4.833). A 2 (prior congruent, prior incongruent) X 2 (current congruent, current incongruent) X 2 (negative, neutral) X 2 (high reappraisers, low reappraisers) mixed-model ANOVA was conducted. The interaction between distractor valence and reappraisal ability was marginally significant, $F(1, 45) = 3.196$, $p = .081$, providing partial support for hypotheses (Figure 10). In contrast, the four-way interaction between prior congruency, current congruency, distractor valence, and reappraisal ability was non-significant, $F(1, 45) = 0.262$, $p = .611$. Mean RTs for high- and low-reappraisers are summarized in Table 5.

Exploratory correlational analyses were conducted to investigate individual difference factors potentially associated with performance on the emotional flanker task (as well as the incidental learning paradigm, which will be discussed), including scores on the reappraisal and suppression subscales of the Emotion Regulation Questionnaire (ERQ), scores on the four subscales of the Behavioural Inhibition and Approach Systems (BIS/BAS) Scales, changes in positive affect according to the Positive and Negative Affect Schedule (PANAS), and performance on the three executive functioning tasks (for descriptive statistics, refer to Tables 6 and 7). Individual difference variables were created for several aspects of flanker task performance, including an individual congruency effect and valence effect, three conflict adaptation effects (overall CAE, negative- distractor CAE, and neutral-distractor CAE), and a three-way interaction effect, subtracting the negative CAE from the neutral CAE.

Table 5.

Mean response times (ms) and associated standard error for negatively-cued and neutrally-cued trials in the emotional flanker task, for high- and low-reappraisers.

Distractor Valence	**Low Reappraisers**		**High Reappraisers**	
	M	***SE***	***M***	***SE***
Negative	504.40	13.914	498.22	13.621
Neutral	497.01	13.413	498.67	13.131

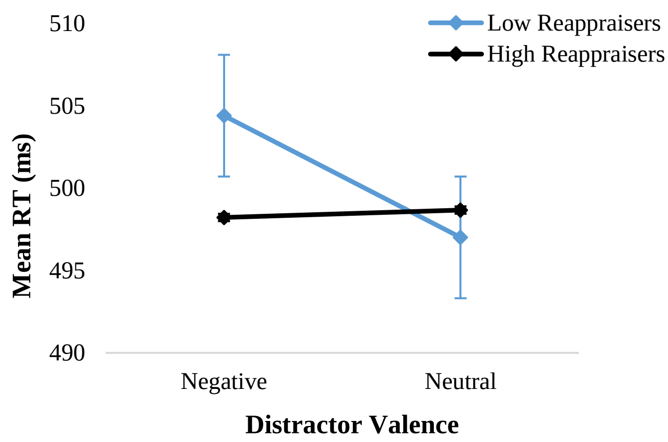

Figure 10. The marginally significant interaction between distractor valence and individual reappraisal ability. The difference between negatively- and neutrally-cued RTs was marginally larger for low reappraisers than high reappraisers.

There were no significant correlations between individual difference variables and flanker task performance, with the exception of a marginally significant negative correlation between scores on the BIS/BAS inhibition subscale and the three-way flanker interaction, $r(46) = -.25$, $p = .090$ (refer to Table 8). Neither reappraisal nor suppression was correlated with performance on the emotional flanker task; however, more frequent use of reappraisal was associated with smaller changes in positive affect over the course of the flanker experiment, $r(46) = -.25$, $p = .091$. There was significant variability in all individual difference measures of flanker task performance (refer to Appendix A, Table 1).

Table 6.

Mean scores and associated ranges and standard deviations for scores on the Emotion Regulation Questionnaire (ERQ), Positive and Negative Affect Schedule (PANAS1 and PANAS2), and Behavioural Inhibition and Approach System (BIS/BAS) Scales.

Subscale	**Possible Range**	***M***	***SD***
ERQ Reappraisal[a]	1 – 7	4.62	1.004
ERQ Suppression[a]	1 – 7	3.86	1.103
PANAS1 Positive[b]	10 – 50	24.85	6.801
PANAS1 Negative[b]	10 – 50	13.74	4.296
BIS Inhibition[c]	1 – 4	1.84	0.531
BAS Drive[d]	1 – 4	2.36	0.552
BAS Fun Seeking[d]	1 – 4	2.02	0.520
BAS Reward Responsiveness[d]	1 – 4	1.58	0.428
PANAS2 Positive[e]	10 – 50	21.02	7.344
PANAS2 Negative[e]	10 – 50	14.34	4.949

[a] Higher scores indicate more frequent use of reappraisal/suppression.
[b] PANAS completed at onset of experiment; higher scores indicate higher levels of positive/negative emotion.
[c] BIS/BAS Scales include one inhibition system subscale; higher scores indicate greater inhibitory behaviour.
[d] BIS/BAS Scales include three approach system subscales; higher scores indicate greater approach behaviour.
[e] PANAS completed following flanker task; higher scores indicate higher levels of positive/negative emotion.

Table 7.

Mean scores and associated ranges and standard deviations for scores on the executive functioning tasks.

Task	***n***	**Actual Range**	***M***	***SD***
Digit Span	41	5 – 9	7.61	1.093
Spatial Search	47	-9 – 35	1.85	12.750
Verbal Reasoning	47	8 – 30	22.45	4.916

Table 8.

Cross-correlations between response time effects on the emotional flanker task (FT; valence effect, congruency effect, conflict adaptation effect, negative-distractor conflict adaptation effect, neutral-distractor conflict adaptation effect, three-way interaction effect) and all individual difference measures of interest, including scores on the ERQ (reappraisal, suppression), PANAS (change in positive affect), and BIS/BAS Scales (inhibition, drive, fun-seeking, reward responsivity), and performance on the executive functioning tasks (Digit Span, Spatial Search, Verbal Reasoning).

	ERQ Reapp	ERQ Supp	PANAS PosChng	BIS Inhib	BAS Drive	BAS FunSeek	BAS RewResp	Digit Span	Spat Srch	Vrb Reas	FT Val Eff	FT Con Eff	FT CAE	FT NegCAE	FT NeuCAE	FT 3way
Reapp																
Supp	.08															
PANAS	-.25~	.12														
Inhibition	.06	-.04	.05													
Drive	-.23	.25~	.10	.16												
FunSeek	-.14	.38**	.17	.19	.54**											
RewResp	-.21	.36*	.37*	.37**	.62**	.72**										
Digit Span	-.03	-.07	-.02	-.01	.04	.15	.24									
Spat Srch	.00	-.06	-.05	-.08	-.03	-.34*	-.27~	.06								
Vrb Reas	-.20	-.36*	-.23	.03	-.24	-.35*	-.32*	-.03	.15							
FT ValEff	.00	-.11	.07	.15	.13	-.09	.10	.02	-.06	.04						
FT ConEff	-.12	.08	.00	.03	.21	.03	.05	-.10	.10	.02	-.10					
FT CAE	-.01	.09	-.19	.04	.04	.07	.07	-.08	-.06	-.08	.28~	.54**				
FT NegCAE	.04	-.03	-.07	.16	-.10	.06	.11	.12	-.22	-.10	.36*	.29*	.60**			
FT NeuCAE	.01	.20	-.14	-.16	.19	.09	.16	.22	.18	-.17	-.04	.34*	.59**	.19		
FT 3way	-.02	.20	-.07	-.25~	.24	.04	.06	.10	.31*	-.07	-.29*	.08	.08	-.55**	.72**	

Note: ~p < .10; *p < .05; **p < .01.

Finally, the current study employed an incidental learning paradigm (ILP) to investigate participants' recall of the negative and neutral images from the emotional flanker task. Positive-image trials were included only as a method of mood elevation and were excluded from all analyses. Percent accuracy was calculated for seven ILP outcome measures: all images (total accuracy), real images, foil images, negative images, neutral images, images preceded by congruent trials in the flanker experiment, and images preceded by incongruent trials in the flanker experiment (refer to Tables 9 and 10). Within subjects, images in the flanker experiment were yoked to specific conditions, such that half of all images consistently followed congruent trials and the other half consistently followed incongruent trials. Yoking of image subsets was counter-balanced across participants (refer to Appendix A, Table 2) and a between-subjects ANOVA confirmed that accuracies for the seven outcome measures did not significantly differ across conditions (although differences for the negative-image accuracy was marginally significant, $p = .080$; refer to Appendix A, Table 3).

A paired-samples t-test revealed a significant difference in percent accuracy between real-image trials and foil-image trials, $t(45) = -5.439$, $p < .001$, such that participants were significantly more accurate in identifying the foil images than the real images. A 2 (prior congruent, prior incongruent) X 2 (negative, neutral) repeated measures ANOVA was conducted. Contrary to expectations, there was no significant difference in recall of negative versus neutral images, $F(1, 45) = 0.830$, $p = .367$. Similarly, there was no significant difference in percent accuracy for images yoked to congruent versus incongruent flankers, $F(1, 45) = 0.081$, $p = .777$. The two-way interaction between prior flanker congruency and image valence was also non-significant, $F(1, 45) = 0.648$, $p = .425$. There were no significant differences in percent accuracy for negative versus neutral images, regardless of whether the yoked preceding flanker trial was congruent or incongruent.

Table 9.

Mean percent accuracies for all basic image conditions of the incidental learning paradigm.

Outcome Variable (% Accuracy)	**Actual Range**	***M***	***SD***
Total (All Images)	45 – 96.25	71.28	11.536
Real	20 – 95	61.03	17.253
Foil	32.5 – 100	81.52	17.171
Negative	40 – 95	71.85	12.807
Neutral	45 – 97.5	70.71	11.957

Table 10.

Mean percent accuracies for all pairings of prior flanker congruency and image valence in the incidental learning paradigm.

Prior Flanker Trial	**Image Valence**	**Actual Range**	***M***	***SD***
Congruent	All	15 – 95	60.76	19.002
	Negative	10 – 100	63.26	23.763
	Neutral	10 – 100	58.26	24.157
Incongruent	All	10 – 95	61.30	17.840
	Negative	0 – 100	62.39	23.493
	Neutral	10 – 100	60.22	22.656

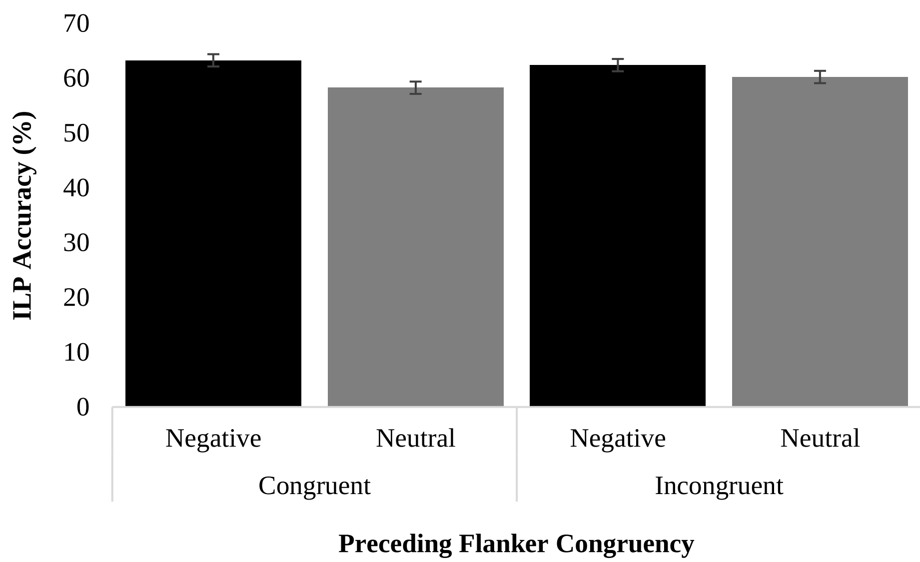

Figure 11. The non-significant interaction between image valence in the incidental learning paradigm and associated prior flanker congruency.

Exploratory correlational analyses were conducted to investigate potential individual difference factors associated with five of the incidental learning paradigm (ILP) outcome measures (total accuracy, negative images, neutral images, prior-congruent images, prior-incongruent images). Performance on the ILP was significantly correlated with scores on the Spatial Search executive functioning task only (refer to Appendix A, Table 4). Performance on the ILP was not associated with individual differences in any response time effects from the emotional flanker task (refer to Appendix A, Table 5).

4. Discussion

4.1 General Discussion

The successful completion of any cognitive control task – from focusing on a flanker target to driving a motor vehicle – is susceptible to interference from distraction. The hindering effects of emotionally-salient distraction, in particular, have been reliably established in the existing literature (e.g., Buodo et al., 2002; Carlson et al., 2005; Mischel & Baker, 1975). Building on recent findings of an interaction between distractor valence and subsequent task complexity (Cohen et al., 2011; Erthal et al., 2005; Gupta et al., 2016, O'Toole et al., 2011), and between distractor valence and *preceding* task complexity (Cohen et al., 2011), the purpose of the present study was to investigate the impact of emotionally-salient distractors on conflict adaptation.

4.1.1 Replication

It was hypothesized that the emotional flanker task would reveal a significant valence effect, such that response times (RTs) would be slower on negatively-cued trials relative to neutrally-cued trials. Results did not support this hypothesis: negatively-valenced distractors did not significantly hinder performance on subsequent flanker trials. This finding contrasts a large body of literature suggesting that emotionally-salient images, especially when negatively-valenced, hinder performance on cognitive tasks (e.g., Buodo et al., 2002). Interestingly though, RTs were significantly slower on both negatively- and neutrally-cued trials relative to trials preceded by scrambled images. This finding indicates that there is something particularly salient about distractors that contain meaningful information relative to distractors that are nonsensical, and suggests that the mere presence of an intervening distractor stimulus may not be sufficient for disrupting cognitive performance (although this is speculative, as the current study did not include no-distractor control trials).

One possible explanation for the null effect of negative versus neutral distractors is the fact that almost all images in the current study contained people: of the twenty images in each group (negative and neutral), twelve contained human faces and three contained human bodies. For typically developing adults, stimuli containing people and faces are known to be significantly more salient or attention-drawing than stimuli containing objects or landscapes (e.g., Borji et al., 2013; Cerf, et al., 2009). Although the neutral face- and body-images in the current study were selected using normed IAPS valence and arousal ratings, their probable salience raises questions about their true “neutrality”. This may be particularly problematic in the context of a distractor paradigm, such as the emotional flanker task, where the images are presented very briefly. Normed IAPS ratings are based on viewing times significantly longer than 100ms; in the context of very brief exposure, many of the neutral person-images may have been perceived as having greater arousal and slightly positive or negative valence. In contrast, the image stimuli utilized by Cohen and colleagues (2011), who *did* find an effect of distractor valence, included primarily person-images for the negative group (i.e., mutilated bodies) but primarily object-images for the neutral group (i.e., household items). Thus, results of the current study suggest that previous findings of a valence effect may be more accurately reflecting a content effect; when controlling for content in the negative and neutral distractor groups, the valence effect disappears. This finding is still surprising, however, as it was hypothesized that even when the images were matched for content, the negative images would be more salient due to their extremely low valence and disturbing nature. Further, many previous studies have utilized exclusively face-focused images, contrasting angry and neutral faces for example, and found evidence for a valence effect on current or subsequent cognitive tasks (e.g., Gupta et al., 2016; O'Toole et al., 2011; Solomon et al., 2014).

Also contrary to expectations, the current study found no significant interaction between distractor valence and current trial congruency; there was no effect of distractor valence on either congruent or incongruent trials. This result conflicts with previous findings that negatively-valenced distractors hinder performance on simple tasks but not complex ones (e.g., Cohen et al., 2011; Erthal et al., 2005; Gupta et al., 2016; O'Toole et al., 2011). As previously discussed, one possible explanation is the frequency of person-images included in the neutral distractor group, which may have diminished the overall effect of valence. Similarly, relative to Cohen et al. (2011), the overall congruency effect was fairly small in the current study (i.e., 53.7ms in the current study relative to 107.6ms in Cohen et al.), with significantly faster mean RTs on both congruent and incongruent trials. Although the current study shows a slight trend toward the valence-congruency interaction found in previous studies, its non-significance may be partly attributed to diminished main effects overall.

Similarly, there was no significant interaction between prior congruency and distractor valence; RTs for negatively- versus neutrally-cued trials did not differ for trials preceded by congruent and incongruent flanker stimuli. Again, this finding contradicts previous research and fails to support the mechanism currently proposed in the current literature, in which allocating cognitive resources to a complex task, such as an incongruent flanker trial, attenuates the subsequent impact of an emotionally-salient distractor (e.g., Cohen et al., 2011; Hsu & Pessoa, 2007; Van Dillen et al., 2009). As discussed, this may be partly explained by smaller overall congruency effects, which suggest that incongruent flanker trials may not have been sufficiently "complex" in the current study. This may be the result of possible practice effects facilitated by the very long duration of the flanker paradigm (although robust congruency and conflict adaptation effects indicate reliable differences in congruent versus incongruent trial difficulty).

4.1.2 Extension

Despite failure to replicate previous findings, the primary goal of the current study was to investigate the three-way interaction between distractor valence and conflict adaptation. It was hypothesized that conflict adaptation would be unaffected by neutral intervening stimuli, but would be attenuated by negative intervening stimuli. Contrary to expectations, the three-way interaction was non-significant, indicating no significant differences in the impact of negative versus neutral distractors on conflict adaptation.

In order to verify that the overall conflict adaptation effect observed in the data was not entirely due to the scrambled-distractor trials, the negative- and neutral-distractor trials were analyzed independently. Interestingly, conflict adaptation remained significant (though only marginally) in the neutral-distractor condition, but was non-significant in the negative-distractor condition. Although no conclusions can be drawn due to the lack of statistical significance, qualitative interpretation of the two conflict adaptation effects suggests a trend toward greater attenuation in the face of negative distractors relative to neutral distractors. Further, looking at conflict adaptation in the negative-distractor (Figure 9B) and scrambled-distractor (Figure 5A) conditions suggests that any attenuation of conflict adaptation in the negative condition is driven by a diminished facilitative effect of two consecutive congruent trials; in contrast, there appears to be minimal change in the effect of the prior trial on current incongruent trials. If statistically significant, this trend would provide potential support for the attentional lens hypothesis: prior congruent trials instantiate a widened attentional lens, enabling greater interference from negative distractors and hindering performance on subsequent congruent trials, in particular.

However, despite this apparent trend, results of the incidental learning paradigm indicate no statistically significant differences in distractor processing after congruent versus incongruent trials; participants did not recall images yoked to prior congruent trials with greater accuracy than images yoked to prior incongruent trials. Accuracy for these “real” images (i.e., actually included in the flanker experiment) was low but above chance (approximately 61%), therefore this null finding may provide support for the idea that the narrowed attentional lens instantiated by an incongruent trial is disrupted (i.e., widened) by the introduction of a salient distractor. However, contrary to hypotheses, there was no difference in recall accuracy for negative versus neutral images. A non-significant interaction confirmed a null valence effect regardless of prior congruency. Thus, any disruption of the narrowed attentional lens was not specific to negatively-valenced images. Participants recalled both negative and neutral images with reasonable accuracy (approximately 71%); thus, the non-significant difference may provide further support for the argument that both the negative and neutral distractors were highly salient, and that similarities in image salience may have contaminated any effects of differing valence.

Finally, it was hypothesized that individual differences in emotion regulation would interact with distractor valence, such that negatively-valenced stimuli would produce greater interference effects for low-reappraisers than high-reappraisers. A marginally significant interaction provided partial support for this hypothesis: there was no significant effect of negative versus neutral distractors for high reappraisers, but a significant hindering effect of negative distractors for low reappraisers. In line with previous research (Cohen et al., 2012), this finding suggests a trending association between stronger emotion regulation skills and greater inhibition of emotionally-salient distractors during cognitive task performance.

It was also hypothesized that emotion regulation ability would interact with the relationship between distractor valence and conflict adaptation. Results of a four-way interaction incorporating high and low reappraisal ability failed to support this hypothesis, indicating that the impact of negative and neutral distractors on conflict adaptation did not differ between individuals with good emotion regulation (high reappraisers) and poor emotion regulation (low reappraisers). Surprisingly, performance on the emotional flanker task was not significantly correlated with any individual difference measures, including use of reappraisal and suppression, trait approach and avoidance tendencies, affective changes over the course of the flanker task, or performance on the executive functioning tasks. Given the robust congruency and conflict adaptation effects observed in the flanker paradigm, these null findings point to possible methodological limitations in the measurement of individual difference variables.

4.2 Implications

The current study failed to replicate findings of an effect of emotional versus non-emotional distraction on flanker task performance. Null findings may be partly attributed to methodological limitations, as will be discussed. Results of the current study also point to possible confounds in the significant findings from previous studies. After controlling for the content of the negative and neutral images, such that the neutral group also included a large number of person- and face-images (rather than household objects, as used in previous studies; Cohen et al. 2011), the valence effect was non-significant. Thus, given the known salience of images containing people and faces, previous findings of a valence effect may be more accurately interpreted as a content effect.

Distractor valence also showed no significant interaction with conflict adaptation, failing to support the hypothesis that neutral and negatively-valenced images would have distinctly different effects on the learning processes underlying conflict adaptation. However, results did reveal a trend toward greater conflict adaptation in the negative-distractor condition relative to the neutral condition. As previously discussed, it is possible that the brief presentation of distractors, coupled with the high frequency of person- and face-images, may have obscured key arousal and valence differences between the negative and neutral distractor groups. Replication of this study with longer distractor exposure may facilitate larger valence effects and strengthen the trending effect of distractor valence on conflict adaptation. Stronger evidence for the observed trend would also suggest that in the context of a flanker paradigm, the attentional lens hypothesis may be a plausible explanation for the interference effects of emotional distractors.

The current study also observed a marginally-significant interaction between distractor valence and individual differences in emotion regulation, such that the valence effect was larger for low reappraisers than high reappraisers. Again, prolonged distractor exposure may strengthen this effect, and could reveal an interaction between emotion regulation ability and other aspects of emotional flanker task performance, including conflict adaptation. The impact of reappraisal ability on emotional interference suggests that improving emotion regulation skills may have positive implications for distractor management in real-life cognitive tasks, such as driving a car amidst salient social distractors or adhering to a diet amidst salient dessert distractors.

4.3 Limitations and Future Directions

The null findings in the current study may be partly attributed to methodological limitations. First, as discussed, there are important differences between the image sets selected in the current study and those used in previous studies (Cohen et al., 2011), including slightly elevated average valence and arousal ratings for both the negative and neutral image sets. These differences were a consequence of minimizing all possible confounding variables, including image content, the spatial disposition of central features, and visual properties such as colour and brightness. Because almost all extremely-negative IAPS images depict human bodies or faces, this matching process required the inclusion of many body- and face-images in the neutral condition, which likely introduced a confounding effect of image salience, such that during brief presentations, both the negative and neutral images were highly arousing. It is argued, however, that matching negative and neutral images, particularly with respect to content, is imperative in order to draw any conclusions about the effects of emotional versus non-emotional distraction.

Further, as previously discussed, many facial images in the neutral condition may have been perceived with some degree of positive or negative valence. Thus, a second limitation in the current study is its omission of subjective participant ratings for the negative and neutral images. Due to the nature of the experimental paradigm, participants could not rate the images beforehand, as prior exposure may have influenced valence effects in the emotional flanker task. Similarly, after completing the flanker task and the incidental learning paradigm, all negative and neutral images had been presented a total of 13 times, possibly attenuating their perceived valence and arousal. An additional study should obtain subjective valence and arousal ratings from an independent sample of undergraduate students, presenting all negative and neutral images for 100ms durations. Such ratings would supplement normed IAPS ratings and determine whether the neutral distractors can truly be considered “non-emotional”.

The current sample also contained significant individual variability in flanker task performance. Across participants, all performance measures (congruency effect, valence effect, conflict adaptation effects, and the three-way valence-adaptation interaction) ranged from large negative effects to large positive effects. Excluding the basic congruency effect, all mean scores were smaller than anticipated, ranging from 3 to 13ms. The non-significant findings for an effect of distractor valence on various flanker performance measures may therefore be partly explained by the extreme variability in flanker task performance and small mean effects. Additionally, the extreme length of the flanker task and frequent repetition of all distractor images may have facilitated practice effects and enhanced general performance over the course of the task, attenuating any differences between the impact of negative and neutral distractors. In future replications, a shorter task duration should be sufficient and may reveal stronger effects.

Interestingly, despite significant individual variability in flanker task performance, there were no significant correlations with other individual difference variables, including emotion regulation ability and baseline executive functioning. Emotion regulation ability was assessed using the Emotion Regulation Questionnaire, which is a very brief self-report measure assessing only two emotion regulation strategies (reappraisal and suppression). Additionally, the Positive and Negative Affect Schedule, completed before and after the flanker task, provided a measure of participants' change in positive and negative affect as a coarse proxy for task-related emotion regulation. Future studies should explore the role of emotion regulation more thoroughly by utilizing objective and comprehensive measurements, including psychophysiological measures of arousal and observational measures of behaviour and facial expression, which may reveal interesting individual differences in moment-by-moment emotional reactivity (i.e., responses to negatively-valenced distractors) and emotion regulation (i.e., management or inhibition of emotional responses). Additionally, non-significant correlations between flanker performance and baseline executive functioning measures may indicate that the HTML tasks did not accurately assess executive function, or assessed cognitive processes distinctly different from those engaged by the flanker task. Future studies should include validated measures of baseline cognitive control differences.

Future investigations should also explore the interference of emotionally-salient distractors in the context of across-task conflict adaption effects. According to theoretical frameworks of conflict adaptation, the presence of *across*-task conflict adaptation depends on the extent to which two consecutive tasks require some common cognitive process (e.g., Botvinick et al., 2001; Egner, 2008; Freitas & Clark, 2015). If a specific process is required in the current trial, having engaged that same process in the previous trial should facilitate faster response times (Freitas & Clark, 2015). This is easily observed in classic within-task conflict adaptation, as discussed throughout the current study: consecutive incongruent trials engage the same conflict-monitoring or attentional-narrowing processes, leading to faster response times on the latter trial. To investigate across-task conflict adaptation, future studies should vary the dependent task of the paradigm, such that two consecutive trials *do not* always include the same stimuli, follow the same attention-guiding rules, or engage the same cognitive processes (e.g., flanker trial followed by Stroop trial followed by Simon trial, etc.). This would allow for more detailed investigations of which specific processes are interrupted by emotionally-salient distractors (and which are not). Further clarification of the conditions under which emotion hinders cognition may also facilitate future investigations of how the mechanism varies across individuals and changes over the course of development.

4.4 Conclusions

The current study adds to a growing body of literature investigating the impact of emotionally-salient distractors on cognitive control. Results suggest that *both* neutral and negatively-valenced images have a hindering effect; when matched for content, such that both negative and neutral images contain primarily people and faces, there is no effect of distractor valence on subsequent cognitive task performance. Further, null effects persist in all conditions of prior and current congruency; valence effects do not differ as a function of the complexity of the previous or following task. Contrary to mechanistic ideas presented in the literature, these findings suggest that cognitive resources, such as attention, are allocated to both neutral and negatively-valenced distractor images, and that the cognitive demand of complex (i.e., incongruent) flanker trials does not diminish the effect of the subsequent distractor. In contrast, distractor effects *are* impacted by individual differences in emotion regulation, such that greater use of reappraisal is associated with better management of negatively-valenced distractors. Future studies should address the limitations of the current study and determine whether the utilization of non-content-matched images results in successful replication of a valence effect. Further investigations should also explore additional individual differences and employ across-task conflict adaptation paradigms to develop a more nuanced understanding of the interaction between emotional distraction and cognition.

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Appendix A: Supplementary Material

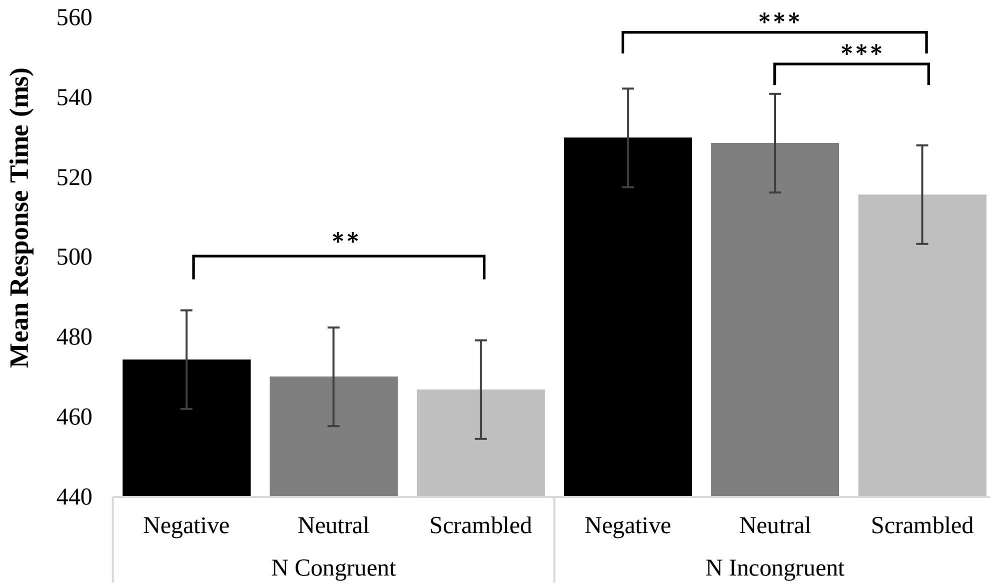

Figure 1. The significant interaction between preceding distractor type and current trial congruency when including scrambled distractors. Averaging across both congruent and incongruent conditions, RTs remained significantly faster for scrambled trials (M = 491.26) relative to both negative (M = 502.11, p < .001) and neutral trials (M = 499.29, p < .001). Note: *p < .05; **p < .01; ***p < .001.

Table 1.

Mean response time effects (ms) and associated ranges and standard deviations for individual difference measures of flanker task performance.

Measure	**Actual Range**	***M***	***SD***
Congruency Effect[a]	-8.31 – 104.32	53.81	21.839
Valence Effect[b]	-33.15 – 33.93	3.39	14.902
Conflict Adaptation Effect[c]	-66.37 – 69.82	12.59	23.848
Negative Conflict Adaptation Effect[d]	-53.40 – 83.42	7.76	33.604
Neutral Conflict Adaptation Effect[d]	-113.52 – 90.22	11.60	40.379
Three-Way Conflict Adaptation Effect[e]	-109.61 – 124.09	3.84	47.268

[a] Incongruent – Congruent
[b] Negative Distractor – Neutral Distractor
[c] (ConIncon – ConCon) – (InconIncon – InconCon) across all trials
[d] Conflict adaptation effect across trials interleaved by negative and neutral distractors, respectively
[e] Negative Conflict Adaptation Effect – Neutral Conflict Adaptation Effect

Table 2.

Summary of the four flanker image conditions, counter-balancing the assignment between the four image subsets and the four sequential flanker conditions (C=Congruent, I=Incongruent).

Condition	**CC Trials**	**CI Trials**	**IC Trials**	**II Trials**
1	A	B	C	D
2	D	A	B	C
3	C	D	A	B
4	B	C	D	A

Note: Each image set contained 5 of the 20 negative images and 5 of the 20 neutral images.

Table 3.

Between-subjects comparison of percent accuracy outcome variables in the incidental learning paradigm across the four flanker image conditions.

Outcome Variable	***F***	***p***
Total (All Images)	1.588	.206
Real	1.200	.321
Foil	0.725	.543
Negative	2.414	.080
Neutral	0.829	.485
Prior Congruent Flanker	1.372	.264
Prior Incongruent Flanker	0.995	.404

Table 4.

Cross-correlations between accuracies on the incidental learning paradigm (ILP; total accuracy, negative images, neutral images, prior-congruent images, prior-incongruent images) and all individual difference measures of interest, including scores on the ERQ (reappraisal, suppression), PANAS (change in positive affect), and BIS/BAS Scales (inhibition, drive, fun-seeking, reward responsivity), and performance on the executive functioning tasks (Digit Span, Spatial Search, Verbal Reasoning).

	ERQ Reapp	ERQ Supp	PANAS Positive Change	BIS Inhib	BAS Drive	BAS FunSeek	BAS RewResp	Digit Span	Spat Srch	Verb Reas	ILP Total	ILP Neg	ILP Neu	ILP Con	ILP Incon
Reapp															
Supp	.08														
PANAS	-.25~	.12													
Inhibition	.06	-.04	.05												
Drive	-.23	.25~	.10	.16											
FunSeek	-.14	.38**	.17	.19	.54**										
RewResp	-.21	.36*	.37*	.37**	.62**	.72**									
Digit Span	-.03	-.07	-.02	-.01	.04	.15	.24								
Spat Srch	.00	-.06	-.05	-.08	-.03	-.34*	-.27~	.06							
Vrb Reas	-.20	-.36*	-.23	.03	-.24	-.35*	-.32*	-.03	.15						
ILP Total	-.17	-.09	.18	-.01	-.06	-.14	-.19	-.19	.35*	.10					
ILP Neg	-.18	.01	.21	.01	-.06	-.19	-.18	-.18	.31*	.12	.93**				
ILP Neu	-.14	-.19	.12	-.02	-.06	-.07	-.17	-.18	.35*	.06	.93**	.74**			
ILP Con	-.12	-.17	.17	.08	-.07	-.12	-.16	-.18	.30*	.10	.66**	.86**	.90**		
ILP Incon	-.20	-.01	.17	-.09	-.04	-.15	-.19	-.18	.37*	.09	.60**	.90**	.84**	.77**	

Note: ~$p < .10$; *$p < .05$; **$p < .01$.

Table 5.

Cross-correlations between accuracies on the incidental learning paradigm (ILP; total accuracy, negative images, neutral images, prior-congruent images, prior-incongruent images) and response times on the flanker task (FT; valence effect, congruency effect, sequential congruency effect, negative-image sequential congruency effect, neutral-image sequential congruency effect, three-way interaction effect).

	ILP Total	ILP Neg	ILP Neu	ILP Con	ILP Incon	FT ValEff	FT ConEff	FT SeqEff	FT NegSeq	FT NeuSeq	FT 3way
ILP Total											
ILP Neg	.93**										
ILP Neu	.93**	.74**									
ILP Con	.66**	.86**	.90**								
ILP Incon	.60**	.90**	.84**	.77**							
FT Val	.19	.21	.15	.03	-.04						
FT Con	.01	.04	-.02	-.07	-.22	-.10					
FT Seq	.08	.12	.04	.00	-.08	.28~	.54**				
FT NegSeq	.14	.12	.13	.15	-.03	.36*	.29*	.60**			
FT NeuSeq	.05	.09	.01	-.02	-.08	-.04	.34*	.59**	.19		
FT 3way	-.05	-.01	-.09	-.12	-.05	-.29*	.08	.08	-.55**	.72*	

Appendix B: Individual Difference Questionnaires

Emotion Regulation Questionnaire (ERQ)

Instructions
We would like to ask some questions about your emotional life, in particular, how you control (that is, regulate and manage) your emotions. The questions below involve two distinct aspects of your emotional life. One is your **emotional experience,** or what you feel like inside. The other is your **emotional expression,** or how you show your emotions in the way you talk, gesture, or behave. Although some of the following questions may seem similar to one another, they differ in important ways. For each item, please answer using the following scale:

1---------------2---------------3---------------4---------------5---------------6---------------7
strongly disagree | **neutral** | **strongly agree**

1. When I want to feel more positive emotion (such as joy or amusement) I change what I'm thinking about.

2. I keep my emotions to myself.

3. When I want to feel less negative emotion (such as sadness or anger) I change what I'm thinking about.

4. When I am feeling positive emotions, I am careful not to express them.

5. When I am faced with a stressful situation, I make myself think about it in a way that helps me stay calm.

6. I control my emotions by not expressing them.

7. When I want to feel more positive emotion, I change the way I'm thinking about the situation.

8. I control my emotions by changing the way I think about the situation I'm in.

9. When I am feeling negative emotions, I make sure not to express them.

10. When I want to feel less negative emotion, I change the way I'm thinking about the situation.

Positive and Negative Affect Schedule

Instructions
This questionnaire consists of a number of words that describe different feelings and emotions. Read each item and then select the appropriate answer using the scale below that word. Indicate to what extent you feel this way RIGHT NOW, at the present moment.

Please answer using the following scale.

1	2	3	4	5
very slightly or not at all	**a little**	**moderately**	**quite a bit**	**extremely**

______ interested	______ irritable
______ distressed	______ alert
______ excited	______ ashamed
______ upset	______ inspired
______ strong	______ nervous
______ guilty	______ determined
______ scared	______ attentive
______ hostile	______ jittery
______ enthusiastic	______ active
______ proud	______ afraid

Behavioural Inhibition and Approach System Scales

Instructions
Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item says. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

1 ----------------------------- 2 ----------------------------- 3 ----------------------------- 4
very true for me somewhat true for me somewhat false for me very false for me

1. A person's family is the most important thing in life.
2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.
3. I go out of my way to get things I want.
4. When I'm doing well at something, I love to keep at it.
5. I'm always willing to try something new if I think it will be fun.
6. How I dress is important to me.
7. When I get something I want, I feel excited and energized.
8. Criticism or scolding hurts me quite a bit.
9. When I want something I usually go all-out to get it.
10. I often do things for no reason other than that they might be fun.

11. It's hard for me to find the time to do things such as get a haircut.
12. If I see a chance to get something I want I move on it right away.
13. I feel pretty worried or upset when I think or know somebody is angry at me.
14. When I see an opportunity for something I like I get excited right away.
15. I often act on the spur of the moment.
16. If I think something unpleasant is going to happen I usually get pretty "worked up".
17. I often wonder why people act the way they do.
18. When good things happen to me, it affects me strongly.
19. I feel worried when I think I have done poorly at something important.
20. I crave excitement and new sensations.

21. When I go after something I use a "no holds barred" approach.
22. I have very few fears compared to my friends.
23. It would excite me to win a contest.
24. I worry about making mistakes.

Appendix C: Ethics Approval

Western Research

Research Ethics

Western University Non-Medical Research Ethics Board

NMREB Delegated Initial Approval Notice

Principal Investigator: Prof. J Bruce Morton
Department & Institution: Social Science\Psychology,Western University

NMREB File Number: 109417
Study Title: Executive Functioning and Distractor Interference

NMREB Initial Approval Date: September 27, 2017
NMREB Expiry Date: June 30, 2018

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Revised Western University Protocol		2017/09/21
Instruments	Questionnaires	2017/05/24
Other	Community Resources	2017/05/24
Other	Study images	2017/09/21
Recruitment Items	Email recruitment script	2017/09/21
Recruitment Items	Facebook recruitment post	2017/09/21
Recruitment Items	SONA ad	2017/09/21
Letter of Information & Consent	Summer participants	2017/05/24
Revised Letter of Information & Consent	SONA participants	2017/09/21

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the above named study, as of the NMREB Initial Approval Date noted above.

NMREB approval for this study remains valid until the NMREB Expiry Date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

[redacted]

Ethics Officer, on behalf of Dr. Randal Graham, NMREB Chair or delegated board member

EO: Erika Basile __ Grace Kelly__ Katelyn Harris__ Nicola Morphet __ Karen Gopaul __ Patricia Sargeant __ Kelly Patterson ✓

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2016-Present, M.Sc.

Honours and Awards:

Natural Sciences and Engineering Research Council (NSERC) Doctoral Scholarship
Western University
2018-2021

Graduate Student Teaching Award
Western University
2017

NSERC Undergraduate Student Research Award
Queen's University
2015

Volunteer of the Year
Queen's University
2014-2015

Degree with Distinction
Queen's University
2012-2016

Dean's Honour List for Academic Excellence
Queen's University
2012-2016

Academic Excellence Admissions Scholarship
Queen's University
2012

Related Work Experience:

Sessional Instructor
Western University
Child Development (PSYC 2040)
2017

Research Assistant
Western University
Neurocognitive Development Lab, Dr. J. Bruce Morton
2018

Teaching Assistant
Western University
Introduction to Developmental Psychology (PSYC 2410)
Exceptional Children: Developmental Disorders (PSYC 2043)
2016-2017

Research Assistant
Queen's University
Adolescent Dynamics Lab, Dr. Tom Hollenstein
Autism Spectrum Disorder Studies Lab, Dr. Elizabeth Kelley
2013-2016

Publications:

Goldsmith, S. F., & Morton, J. B. (2017). Time to disengage from the bilingual advantage hypothesis. *Cognition.* https://doi.org/10.1016/j.cognition.2017.09.011.

Goldsmith, S. F., & Kelley, E. (2017). Associations between emotion regulation and social impairment in children and adolescents with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s10803-018-3483-3.

Presentations:

Goldsmith, S. F., & Kelley, E. (2018). Associations between emotion regulation and social impairment in children and adolescents with Autism Spectrum Disorder. Poster presented at Development 2018 Conference, St. Catharine's, Canada.

Goldsmith, S. F., & Kelley, E. (2016). Emotion regulation in children and adolescents with Autism Spectrum Disorder. Poster presented at the Ontario Psychology Undergraduate Thesis Conference, Waterloo, Canada.