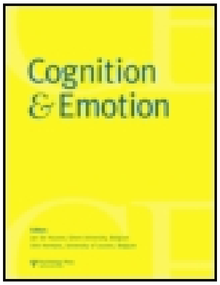

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Emotion, working memory task demands and individual differences predict behavior, cognitive effort and negative affect

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We examined whether positive and negative affect motivates verbal and spatial working memory processes, respectively, which have implications for the expenditure of mental effort. We argue that when emotion promotes cognitive tendencies that are goal incompatible with task demands, greater cognitive effort is required to perform well. We sought to investigate whether this increase in cognitive effort impairs behavioural control over a broad domain of self-control tasks. Moreover, we predicted that individuals with higher behavioural inhibition system (BIS) sensitivities would report more negative affect within the goal incompatible conditions because such individuals report higher negative affect during cognitive challenge. Positive or negative affective states were induced followed by completing a verbal or spatial 2-back working memory task. All participants then completed one of three self-control tasks. Overall, we observed that conditions of emotion and working memory incompatibility (positive/spatial and negative/verbal) performed worse on the self-control tasks, and within the incompatible conditions individuals with higher BIS sensitivities reported more negative affect at the end of the study. The combination of findings suggests that emotion and working memory compatibility reduces cognitive effort and impairs behavioural control.

Keywords: Emotion; Cognitive control; BIS; Negative affect.

Early theories of emotion and cognition have suggested that emotions motivate specific goals and cognitions to guide behaviour (e.g., Lang, 1995; Simon, 1967). One intriguing idea is that emotions motivating specific behaviours may have implications for the expenditure of metabolic resources. Specifically, Friston (2010) proposed that the ability to predict the cognitive needs of a situation, defined as minimising surprise or prediction error, reduces the expenditure of metabolic resources. Moreover, brain areas that work together to minimise surprise are often functionally integrated. Recent research has

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suggested that specific emotions and working memory task demands may be functionally integrated (e.g., Gray, 2004; Pessoa, 2008; Storbeck, 2012), and that specific emotions may motivate specific kinds of working memory processes (Storbeck, 2012). The goal of this article was to explore whether the integration of specific emotional states and working memory task demands reduces metabolic expenditure, which we term cognitive effort.

It has been suggested that emotion and working memory are integrated (Gray, 2004). Gray and colleagues found that induced positive affective states (i.e., happiness) improved verbal working memory performance, whereas induced negative affective states (i.e., sadness) improved spatial working memory performance (Gray, 2001; Gray, Braver, & Raichle, 2002). Critically, functional imaging has revealed that the same conditions that improved working memory performance were also associated with less activation in the dorsolateral prefrontal cortex (DLPFC), which suggests reduced mental effort (Gray et al., 2002).

Emotion and working memory appear to be integrated, but does such integration reduce cognitive effort when completing the working memory task? To help answer this question, Storbeck (2012) developed the emotion-cognition depletion paradigm. The emotion-cognition depletion paradigm was modelled from Baumeister's ego-depletion paradigm, in which performance on a self-control task is dependent upon the amount of cognitive effort exerted on a prior cognitive task. Performance on the self-control task is better when preceded by an easy task than preceded by a hard task (Hagger, Wood, Stiff, & Chatzisarantis, 2010; Inzlicht & Schmeichel, 2012; Muraven & Baumeister, 2000). Likewise, Storbeck reasoned that when emotion motivates a cognitive process that is goal compatible with the demands of the working memory task (e.g., positive/verbal and negative/spatial), cognitive effort would be reduced because the emotional states successfully predicted the cognitive needs for the task. However, when emotion motivates a cognitive process that is goal incompatible with the demands of the working memory task (e.g., positive/spatial and negative/verbal), cognitive effort would be increased due to goal competition. Storbeck predicted that the reduced cognitive effort expended because of emotion and working memory compatibility would yield superior performance on a subsequent self-control task compared to that of emotion and working memory incompatibility. His prediction was supported when either a Stroop task (Stroop, 1935) or an implicit association task (IAT; Nosek, Greenwald, & Banaji, 2007) was completed following the working memory task. Specifically, individuals in the emotion and working memory compatible, compared to incompatible, conditions yielded a smaller Stroop interference score (Experiment 1) and had a reduced implicit black bias on a race IAT (Experiment 2).

One assumption of resource models is that there is a single, general pool of psychological resources from which any form of cognitive control can deplete resources (Hagger et al., 2010; Kahneman, 1973; Vergauwe, Barrouillet, & Camos, 2010). When this pool of resources is depleted, performance on cognitive control tasks becomes impaired. In Storbeck's (2012) experiment, the two tasks used to assess the depletion of psychological resources were reliant on interference resolution (Stroop, 1935; MacLeod, 1991) and set-shifting (IAT; Klauer, Schmitz, Teige-Mocigemba, & Voss, 2010). Across a domain of cognitive control processes, this sample was quite limited. We are interested in examining whether or not the effects generalise to a broader array of cognitive control processes, including cognitive flexibility (Experiment 1), attentional control (Experiment 2) and inhibition (Experiment 3). Moreover, we selected these tasks because they related to psychological phenomena of creativity (Experiment 1), dual-task performance (Experiment 2) and the ability to control implicit racial biases (Experiment 3).

Dispositional motivation, cognitive conflict and negative affect

The primary goal of this paper was to examine whether emotion and working memory task demand interactions influence cognitive effort by examining performance on a self-control task. However, a complementary way of assessing cognitive effort may be through individual differences associated with trait motivation. Individual differences in trait motivation predict affective experiences and cognitive effort when cognitive control is required (e.g., Amodio, Master, Yee, & Taylor, 2008; Carver & White, 1994; Gray et al., 2005; Harmon-Jones & Allen, 1997). One conceptualisation for trait differences in motivation is the behavioural activation and inhibition systems (BAS and BIS, respectively; Carver & White, 1994; Corr & McNaughton, 2012; Gray & McNaughton, 2000).

BIS is conceptualised as an attentional system that is sensitive to cues of punishment, non-reward and novelty. It also serves to interrupt or inhibit behaviour in order to further process threat-related cues (Corr & McNaughton, 2012; Gray & McNaughton, 2000). BIS has been associated with increased levels of stress and negative affect and decreased regulatory control. Correlational studies have observed that, during emotional challenges, higher levels of BIS sensitivity are associated with higher levels of negative emotionality (e.g., Carver & White, 1994; Gross, Sutton, & Ketelaar, 1998; Harmon-Jones & Allen, 1997), increased levels of anxiety (Dennis, 2007), cortisol reactivity (Kagan & Snidman, 1991) and negative affect (e.g., Fowles, 1988; Gable, Reis, & Elliot, 2000). As for cognitive challenges, individuals high in BIS have also predicted impaired regulatory abilities, increased negative affect and higher levels of stress reactivity (Eisenberger, Lieberman, & Satpute, 2005; Mathews & Mackintosh, 1998; Wood, Mathews, & Dalgleish, 2001). Moreover, BIS has also been correlated with neural markers of cognitive conflict (e.g., N2, ERN, Ne) measured with event-related potentials (ERPs). Specifically, individuals higher in BIS yielded larger amplitudes for ERP components associated with cognitive conflict (Amodio et al., 2008; Boksem, Tops, Wester, Meijman, & Lorist, 2006; Gray et al., 2005).

BAS is conceptualised as a motivational system that is sensitive to signals of reward, non-punishment and escape from punishment. People high in BAS have been associated with increased capacity for managing competing cognitive goals (Gray et al., 2005). Moreover, individuals with higher BAS sensitivity report more Positive Affect (Gable et al., 2000).

In the current studies, we explored whether emotion and working memory interactions interact with trait motivations in predicting negative affect. Individual differences in BIS predict stress and negative reactivity when cognitively challenged. Both working memory and self-control tasks are cognitively challenging. However, in our conceptualisation of how emotion and working memory interact, participants would experience greater cognitive challenge when emotion motivates inappropriate, compared to appropriate, cognitive processes given working memory task demands. Therefore, we expected that the emotion and working memory interactions would moderate the relationship between BIS and negative affect. Specifically, individuals high in BIS would experience greater levels of negative affect in conditions of emotion and working memory incompatibility. Conversely, conditions of emotion and working memory compatibility would reduce cognitive effort, thereby minimising negative affect within these individuals.

Design and predictions

The basic design for all experiments was a 2 × 2 between-subjects design manipulating emotion (positive, negative) and working memory task demand (verbal, spatial). Participants were randomly assigned to one of the four conditions. The working memory task served two purposes: (1) to activate verbal and spatial working memory processes, which rely on dissociated areas in the prefrontal cortex (e.g., D'Esposito et al., 1998; Fletcher & Hanson, 2001) and (2) to deplete self-control resources (Baddeley & Logie, 1999; Vergauwe et al., 2010). The combination of the induced emotional state and working memory task demands created conditions of compatibility (positive/verbal or negative/spatial) or incompatibility (positive/spatial or negative/verbal). The mood check was then administered, followed by the self-control task. For Experiments 1–3, we assessed whether emotion and working memory compatibility influences cognitive effort during the working memory task. Cognitive effort was measured by performance on one of the self-control tasks that assessed cognitive flexibility (Experiment 1; Nijstad, De Dreu, Rietzschel, & Baas, 2010), attentional control (Experiment 2; Klee & Garfinkel, 1983) and inhibition (Experiment 3; Payne, 2005). Then, participants completed the Brief Mood Introspection Scale (BMIS; Mayer & Gaschke, 1988) which served as the main measure of negative affect, followed by the BIS/BAS questionnaire (Carver & White, 1994).

Aim 1: Do emotion and working memory task demands interact to influence cognitive effort? The main prediction was that the compatibility of emotion and working memory task demands has implications for cognitive effort. To assess cognitive effort during the working memory task, we measured success on the self-control task, with greater success implying less expended effort during the working memory task. For the first three experiments, we predicted that the emotion and working memory compatible conditions would: (1) persist longer on the task and produce more ways to use a brick on the brick creativity task (Experiment 1), (2) perform more accurate trials on the continuous performance task (the secondary task, Experiment 2) and (3) be more successful at inhibiting their implicit stereotypes of African-Americans during a weapons task (i.e., lower automatic anti-black sensitivity score, Experiment 3).

Aim 2: Do individual differences for BIS predict negative affect when emotion and working task demands are incompatible? For predictions concerning negative affect following the self-control task, across all four experiments, we predicted that individuals high in BIS would experience higher levels of negative affect on the BMIS, and that this positive correlation would only occur in the incompatible conditions. In addition, because the relationship between BIS and negative affect was not tested in the IAT from Storbeck (2012), we examined this relationship in Experiment 4. Finally, in Experiment 5, we combined the findings of the first four experiments in order to test whether emotion and working memory interactions moderate the relationship between BIS and negative affect. We expected that BIS would predict negative affect in the incompatible conditions, but not in the compatible condition, thus, demonstrating moderation. We do not have predictions for BAS rather any significant findings with BAS should be deemed exploratory.[1]

BRICK TASK (EXPERIMENT 1)

The brick creativity task involves both cognitive flexibility (switching among categories for using a brick—weapon, building, art) and task persistence when generating novel uses for a brick (Friedman & Forster, 2001; Nijstad et al., 2010). The depletion of self-control resources results in reduced cognitive flexibility and less persistence on a task (Muraven & Baumeister, 2000; Kruglanski, 1990). We predicted that the emotion and working memory compatible, compared to incompatible, conditions would generate more uses for a brick and persist longer on the task. Second, we also predicted that people high in BIS within the incompatible conditions would report higher levels of negative affect.

Method

Because of the similarity in experimental design across the four experiments, the first experiment will include the methodology for all four experiments. Participant information and the description of the self-control task will be presented within each experiment. Sample size was determined by estimates from Storbeck (2012; ~27 participants per condition). Participants who scored below 60% on the working memory task or below chance performance on the self-control tasks were removed from the analyses.

[1] The BAS sub-components were also analysed. However, there were no consistent relationships. Thus, we have excluded the subcomponent analyses from the paper and only reported the global BAS score.

Participants

One hundred and three (67 female) undergraduate students from Queens College participated to fulfil a course requirement (age: M = 18.57, SD = 0.94).

Stimuli and apparatus

Mood induction. A positive (happy) or a negative (sad) mood state was induced with a five-minute clip from *Jerry Seinfeld: Stand up in New York* or with a five-minute clip from *The Champ*, respectively (Storbeck, 2012; Storbeck & Clore, 2011).

Working memory task. A verbal or a spatial 2-back working memory task was used to activate verbal and spatial working memory processes, respectively (D'Esposito et al., 1998; Fletcher & Hanson, 2001). On each trial, a single letter was presented in one of six spatial locations. Each trial began with a single letter shown for 1 second, followed by the response screen which showed the response options. Participants responded when the response screen was present, and the next letter was shown after a response was made. Participants were instructed to determine whether the letter (spatial location) presented was the same ("A" key) or different ("L" key) from the letter (spatial location) presented two trials back. There were 80 trials in total; the stimuli consisted of consonant, uppercase letters presented in black font on a white screen. Twenty per cent of the trials required a response of *SAME*.

Mood check. A mood check assessed the efficacy of the mood induction. Participants were instructed to indicate how happy they felt while viewing the movie using a 6-point scale ("6" = very happy to "1" = very unhappy).

Brick creativity task. For the brick creativity task, participants were instructed to come up with as many uses for a brick as possible (Friedman & Forster, 2001). Participants were instructed to generate uses for a brick until they could no longer generate new uses. Following the instructions, a screen with a centred response window appeared, participants were instructed to type their response (e.g., weapon) and then press "enter"; after pressing enter, a blank response window appeared. Under the response box, the following message appeared: "If you can no longer generate new responses, you can press the 'ESC' key to continue with the study". Thus, the participants could terminate at their own discretion; however, after seven minutes all participants were forced to continue onto the next phase of the experiment. On average, the participants took about two minutes (SD = 1.25) to complete the task.

Post-task mood assessment—negative affect. The post-task mood check consisted of a series of affective adjectives (BMIS; Mayer & Gaschke, 1988). Participants were asked "to rate how well each adjective or phrase describes your present mood." The 12 adjectives were selected to represent feelings related to *Positive Activation* (lively, active, peppy), *Positive Low Activation* (careful, content, calm), *Negative Activation* (fed up, jittery, nervous) and *Negative Low Activation* (drowsy, gloomy, tired). The three items were averaged together to create a mean score for each factor.

BIS/BAS Questionnaire. To assess BAS and BIS, the Carver and White (1994) BIS/BAS 24-item questionnaire was administered with 13 items assessing BAS and 7 items assessing BIS. The respective items were averaged together to create a global BAS and BIS score with higher scores indicating higher levels of each.

Procedure. A cover story was used to disguise the intent of the emotion induction. Participants were told that we were piloting this movie for a future study, and they would be asked some questions about it at the end of the study. Moreover, they were told it was occurring in between the practice and the experimental trials of the working memory task to prevent stimuli interference between the practice and experimental trials. Participants were randomly assigned to complete either the verbal or spatial working memory task and received 20 practice trials for the assigned task. We had participants practice the working memory trials before the mood induction to ensure that the mood induction would be temporally close to the experimental trials of the working memory task. They were then randomly assigned to an emotion condition and viewed either the positive or the negative movie. Participants then completed the experimental trials for the working memory task followed by the mood check, the self-control task, the post-task mood assessment, the BIS/BAS questionnaire and demographic questionnaires.

Results

The same type of analyses was conducted for Experiments 1–3, and the details of the analyses will be discussed in the current experiment. Table 1 contains descriptive statistics for the dependent measures for all experiments, and Table 2 contains correlational values for all experiments.

Mood manipulation check

To examine the efficacy of the emotion manipulation, a 2 × 2 [Emotion (positive, negative) × Task (verbal, spatial)] factorial analysis of variance (ANOVA) was run on self-reported happiness. The positive conditions rated themselves as happier than the negative conditions, $F(1, 99) = 339.31$, $p < .01$, $\eta^2 = .77$. Task, $F < 1$, and the interaction, $F = 1$, were both non-significant.

Working memory task

A 2 × 2 [Emotion (positive, negative) × Task (verbal, spatial)] factorial ANOVA was conducted on working memory accuracy. Participants in the verbal conditions performed better on the working memory task compared to the spatial conditions, $F(1, 99) = 5.39$, $p = .02$, $\eta^2 = .05$. The Emotion main effect, $F = 1$, and the interaction, $F(1, 99) = 2.31$, $p = .13$, $\eta^2 = .023$, were both non-significant.

Brick task

Two 2 × 2 [Emotion (positive, negative) × Task (verbal, spatial)] factorial analyses of covariance (ANCOVA's) were run, one for each dependent variable (DV), and working memory accuracy served as the covariate because of the task differences in working memory performance.

For task persistence, as predicted, the Emotion × Task interaction was significant, $F(1, 98) = 13.87$, $p < .01$, $\eta^2 = .12$. Participants in the compatible conditions ($M = 150.00$, $SD = 94.48$) persisted longer on the task than those in the incompatible conditions ($M = 87.45$, $SD = 51.17$). Critically, when comparing the individual compatible conditions to the individual incompatible conditions, all effects were significant, ps $< .02$. Emotion, Task and the covariate were all non-significant, Fs < 1. See Figure 1 for a display of the means.

For the number of ideas generated, we predicted and found a marginally significant Emotion × Task interaction, $F(1, 98) = 2.90$, $p = .08$, $\eta^2 = .030$. Mean comparisons revealed that the happy/verbal condition outperformed the happy/spatial condition, $p = .03$, and the negative/spatial was marginally better than the happy/spatial, $p = .06$ (all other comparisons were non-significant, ps $> .15$). Emotion and Task main effects were not significant (Fs < 1), and the effect of the covariate was marginally significant, $F(1, 98) = 3.11$, $p = .08$, $\eta^2 = .03$. See Figure 2 for a display of the means.

Post-task mood assessment—negative affect

Although the BMIS consists of four factors, correlational analyses were run to ensure that Positive Activation and Positive Low Activation assessed individual components of Positive Affect, and likewise, Negative Activation and Negative Low Activation assessed individual components of negative affect. Across all four studies, Positive Activation was significantly correlated with Positive Low Activation (all rs $> .38$, ps $< .02$ for all studies), and Negative Activation was significantly correlated with Negative Low Activation (all rs $> .26$, ps $< .02$ for all studies). Therefore, we averaged together Positive Activation and Positive Low Activation for a composite Positive Affect score, and the same was done with the negative factors to create a composite Negative Affect score. Correlations involving the original

Table 1. *Descriptive statistics for the mood manipulation check and other variables in Experiments 1–4*

	Descriptive statistics			
Conditions	*Positive/verbal*	*Positive/spatial*	*Negative/verbal*	*Negative/spatial*
Experiment 1—Brick creativity task				
Number of participants	27	24	27	25
Mood manipulation check	5.01 (1.01)	4.92 (1.00)	1.67 (0.78)	1.84 (0.75)
Working memory accuracy	0.95 (0.04)	0.88 (0.14)	0.94 (0.06)	0.93 (0.11)
Average creativity score	2.68 (0.71)	2.27 (0.67)	2.38 (0.64)	2.39 (0.50)
Positive affect	3.67 (0.73)	4.00 (0.50)	3.20 (0.87)	3.29 (0.50)
Negative affect	3.13 (0.68)	3.19 (0.68)	3.84 (0.95)	3.37 (0.61)
BAS	3.22 (0.30)	3.21 (0.27)	3.15 (0.42)	3.08 (0.29)
BIS	3.05 (0.44)	3.09 (0.46)	3.21 (0.56)	3.12 (0.36)
Experiment 2—Divided attention task				
Number of participants	26	28	27	27
Mood manipulation check	4.62 (1.60)	4.90 (0.97)	1.78 (0.70)	1.81 (0.83)
Working memory accuracy	0.87 (0.14)	0.82 (0.15)	0.85 (0.11)	0.85 (0.14)
Mean recall for presented words	49.50 (13.59)	48.89 (14.63)	51.48 (9.22)	48.00 (7.40)
Mean recall for critical lures	2.90 (1.81)	2.96 (2.03)	3.22 (1.65)	3.48 (1.67)
Mean number of errors	6.04 (4.84)	8.18 (6.56)	7.74 (4.27)	6.00 (3.80)
Positive affect	3.54 (0.92)	3.45 (0.80)	3.49 (0.83)	3.48 (0.91)
Negative affect	3.51 (0.97)	3.51 (0.62)	3.17 (0.81)	3.14 (0.93)
BAS	3.22 (0.49)	3.17 (0.32)	3.11 (0.52)	3.18 (0.32)
BIS	2.96 (0.45)	3.01 (0.49)	3.07 (0.47)	2.96 (0.43)
Experiment 3—Weapons task				
Number of participants	20	21	20	21
Mood manipulation check	4.45 (1.32)	4.81 (1.25)	1.65 (1.22)	1.67 (0.73)
Working memory accuracy	0.89 (0.09)	0.81 (0.07)	0.84 (0.12)	0.81 (0.07)
Relative preference ratings	3.15 (1.23)	3.19 (1.25)	3.35 (0.99)	3.00 (1.22)
A-A warmth ratings	5.85 (2.32)	5.38 (1.75)	6.10 (2.38)	5.52 (1.57)
E-A warmth ratings	6.10 (2.05)	6.43 (1.91)	6.85 (2.23)	6.24 (2.07)
Control white	0.30 (0.38)	0.39 (0.37)	0.28 (0.31)	0.32 (0.41)
Control black	0.34 (0.36)	0.38 (0.34)	0.27 (0.32)	0.34 (0.43)
Automatic black	0.54 (0.16)	0.59 (0.13)	0.59 (0.14)	0.53 (0.16)
Positive affect	3.66 (1.00)	3.78 (0.86)	3.83 (0.72)	3.43 (0.98)
Negative affect	3.28 (0.76)	2.96 (0.64)	3.38 (0.84)	3.22 (0.99)
BAS	3.16 (0.48)	3.15 (0.54)	3.12 (0.42)	3.06 (0.34)
BIS	2.86 (0.59)	3.02 (0.39)	3.24 (0.44)	2.93 (0.56)
Experiment 4—IAT				
Number of participants	21	23	21	24
Mood manipulation check	4.86 (1.15)	4.83 (0.89)	1.86 (0.65)	1.92 (0.88)
Positive affect	4.04 (0.81)	3.86 (0.89)	3.98 (0.69)	3.91 (0.79)
Negative affect	3.02 (0.76)	2.91 (0.87)	3.26 (0.71)	3.18 (0.75)
BAS	3.23 (0.35)	3.04 (0.35)	3.17 (0.49)	3.04 (0.49)
BIS	2.76 (0.57)	3.07 (0.60)	3.12 (0.51)	3.12 (0.55)

Note: Standard deviations are in parentheses.
A-A, African-American; E-A, European-American; BAS, behavioural activity system.

four affective factors and BIS/BAS can be found in the Supplemental Table.

Separate 2 × 2 [Emotion (positive, negative) × Task (verbal, spatial)] ANOVAs were performed on Positive and Negative Affect. Significant main effects were observed for Emotion for both Positive Affect, $F(1, 99) = 19.08$, $p < .01$, $\eta^2 = .16$, and Negative Affect, $F(1, 99) = 9.28$, $p < .01$, $\eta^2 = .09$. The positive, compared to negative, mood conditions reported higher levels of Positive

Table 2. *BIS partial correlations for Experiment 1–4*

	Condition			
	Compatible		*Incompatible*	
Affective ratings	*BAS*	*BIS*	*BAS*	*BIS*
Experiment 1—Brick task				
Positive affect	−0.13	−0.20	0.04	−0.19
Negative affect	0.15	0.26^	−0.22	0.47**
Experiment 2—Divided attention				
Positive affect	0.05	−0.04	−0.01	−0.26^
Negative affect	−0.04	0.07	−0.04	0.47**
Experiment 3—weapons				
Positive affect	0.14	−0.04	0.03	−0.15
Negative affect	0.01	0.04	−0.06	0.31^
Experiment 4—IAT				
Positive affect	0.36*	−0.25	0.13	−0.35*
Negative affect	−0.39**	0.29^	−0.16	0.30*

Note: ^p < .10; *p < .05; **p < .01. The variables that were controlled for included the main DV associated with each self-control task (i.e., Experiment 1 = total number of items generated; Experiment 2 = total number of items recalled; Experiment 3 = the controlled component for African-Americans; Experiment 4 = the IAT *d*-score) and the self-reported level of happiness resulting from the mood check.

Affect and lower levels of Negative Affect. For Task, there were no main effects for Positive Affect, $F(1, 99) = 2.50$, $p = .12$, $\eta^2 = .03$, nor for Negative Affect, $F(1, 99) = 1.92$, $p = .17$, $\eta^2 = .02$. As for the interaction, there was no interaction for Positive

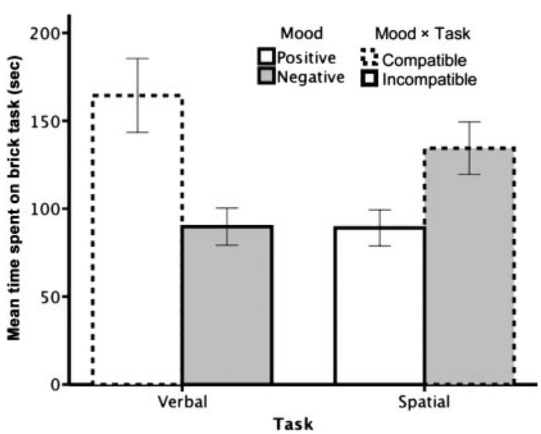

Figure 1. *Mean time spent generating items on the brick creativity task (Experiment 1). Bars represent one standard error of the mean.*

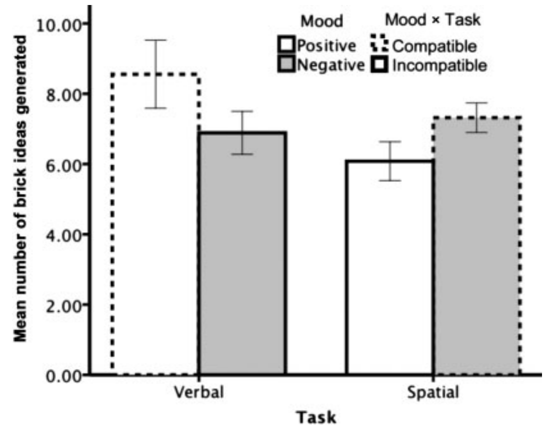

Figure 2. *Mean number of items generated during the brick creativity task (Experiment 1). Bars represent one standard error of the mean.*

Affect, $F < 1$; however, there was a marginal interaction for Negative Affect, $F(1, 99) = 3.17$, $p = .08$, $\eta^2 = .03$. The negative/verbal condition reported higher levels of Negative Affect compared to the other conditions (all ps < .05). No other conditions were different from each other (all ps > .10).

BIS/BAS Questionnaire

Separate 2 × 2 [Emotion (positive, negative) × Task (verbal, spatial)] ANOVAs were performed on BAS and BIS. For both BAS and BIS, all effects were non-significant (ps > .12).

Correlations

For all correlations, we assessed BAS and BIS scores and the critical DV of Positive Affect and Negative Affect. Partial correlations were used to control for the mood check rating and the critical DV from the self-control task to ensure that the mood induction and performance on the self-control task were not driving changes in mood after the self-control task. Moreover, because of low participant numbers within each cell, which can reduce reliability of the correlations, we collapsed across the two compatible conditions and the two incompatible conditions. (See Supplement

Materials for correlations within each cell of the 2 × 2 design for Experiments 1–4.)

For simple correlations, BIS was positively correlated with Negative Affect, $r = .36$, $p < .01$, and marginally, negatively correlated with Positive Affect, $r = -.18$, $p = .07$. There were no relationships between BAS and Positive Affect, $r = .01$, $p = .99$, and Negative Affect, $r = -.07$, $p = .50$. For incompatible conditions, as predicted, individuals high in BIS were more likely to report higher levels of Negative Affect, $r = .41$, $p < .01$. Though not predicted, we found a marginal correlation within the compatible condition, such that individuals high in BIS were also more likely to report higher levels of Negative Affect, $r = .26$, $p = .06$.

For the partial correlations, we controlled for mood induction ratings and the total number of ideas generated. For the incompatible condition, as predicted, higher levels of BIS were associated with higher levels of Negative Affect, $r = .47$, $p < .01$. For the compatible condition, we did observe a marginal correlation between BIS and Negative Affect, $r = .26$, $p = .07$. No other correlations were found to be significant.

Discussion

We found tentative support for both Aims 1 and 2, such that conditions of emotion and working memory incompatibility performed worse on the self-control task and individuals higher in BIS reported higher levels of Negative Affect. Specifically, the incompatible conditions quit faster on the brick creativity task. As for brick generation, we observed that the incompatible happy/spatial condition performed the least well compared to the two compatible conditions. It is notable that the positive/spatial condition performed the worse given that Positive Affect often increases creativity (e.g., Ashby, Isen, & Turken, 1999; Isen, 1999). As for the correlations with BIS and BAS, we found, as predicted, that within the incompatible condition, individuals high in BIS reported higher levels of Negative Affect. However, there was a marginal effect within the compatible condition such that individuals high in BIS also reported higher levels of Negative Affect. No relationships were observed with BAS and Positive/Negative Affect and BIS and positive affect. We also observed main effects for Positive and Negative affect, such that those induced into a positive, compared to a negative, mood reported higher levels of positive affect and lower levels of Negative Affect. We believe these effects may have resulted from lingering effects from the mood induction given the short duration of the brick task.

DIVIDED ATTENTION (EXPERIMENT 2)

Attentional control within a dual-task paradigm is another domain that involves the use of self-control resources. The ability to maintain two goals or multiple tasks involves cognitive control, and performance depends on the availability of resources (Muraven & Baumeister, 2000). The current experiment required participants to remember 15 words that were related to a non-presented critical lure (i.e., false memory task; Roediger & McDermott, 1995) while engaged in a continuous performance task (Klee & Garfinkel, 1983). We predicted that the incompatible conditions would perform worse on the secondary task (continuous performance task) because resources will be depleted by the primary goal (remembering the words) leaving fewer resources to control behaviour on the continuous performance task. We also predicted that because of the increased cognitive effort experienced within the incompatible conditions it would lead to a reliance on gist processing resulting in more false memories (Brainerd & Reyna, 2002). As for BIS, we predicted that within the incompatible condition individuals high in BIS would report higher levels of Negative Affect.

Method

Participants

One hundred and eight participants (71 females) from Queens College—CUNY participated for course credit (age: $M = 20.10$, $SD = 3.40$).

Stimuli and apparatus

Dual task. A Deese–Roediger–Mcdermott (DRM) false memory task (primary task; Roediger & McDermott, 1995) and a four-box continuous response task (secondary task; Klee & Garfinkel, 1983) were used. For the false memory task, seven lists with 15 words each were selected. The four-box continuous task stimuli consisted of four, 4′′ (h) × 2′′ (w) rectangles arranged linearly across the screen (with two boxes on the left side of the screen and two boxes on the right).

The task began with the presentation of a single DRM list. Words were serially presented for 2 seconds each. The continuous task was started after the last word. At the start of a trial, a single asterisk appeared randomly in one of the boxes. Participants had to press a key that corresponded to the box in which the asterisk was located. The continuous performance task ended after 60 seconds, and the recall test was given, which self-terminated after 60 seconds. This was repeated until all seven DRM lists were presented. Each block (learn + asterisk task + recall) took approximately 160 seconds, and the entire task took about 20 minutes to complete.

Results

Manipulation check

The positive conditions reported higher levels of happiness compared to the negative conditions, $F(1, 104) = 201.57$, $p < .01$, $\eta^2 = .66$. Effects for Task and the interaction, Fs < 1, were non-significant.

Working memory task

There were no effects of Emotion, $F < 1$, Task, $F = 1$, and the interaction, $F < 1$, for working memory performance.

Divided attention task

Recall task. Three DVs were associated with the recall task: recall of presented items, recall of critical lures and errors (not including critical lures). For presented items and critical lures, no significant differences were observed, all Fs < 1. Though not predicted, we observed a significant interaction for errors, $F(1, 104) = 4.15$, $p = .04$, $\eta^2 = .04$. The compatible, compared to incompatible, conditions made fewer recall errors. The main effects were not significant, Fs < 1.

Four-box continuous performance

We computed the total number of *accurate* trials completed over all seven blocks. As predicted, the compatible, compared to incompatible, conditions completed more trials accurately, as revealed by the significant interaction, $F(1, 104) = 7.77$, $p < .01$, $\eta^2 = .07$. When comparing the individual effects, all the compatible conditions were different from the incompatible conditions, ps < .05 (no other effects were significant). The main effects of Mood, $F < 1$, and Task, $F(1, 104) = 2.00$, $p = .16$, $\eta^2 = .02$, were both non-significant. Figure 3 presents the continuous performance task means.

Post-task mood assessment

There was a single effect observed. For the mood main effect, people in the positive condition reported higher levels of Negative Affect, $F(1, 104) = 4.90$, $p = .03$, $\eta^2 = .05$. All other effects were not significant, $F < 1$.

BIS/BAS Questionnaire

The BAS and BIS scores were similar across all conditions, all Fs < 1.

Correlations

For simple correlations, we observed that individuals higher in BIS reported higher levels of Negative Affect, $r = .25$, $p = .01$, and those individuals also reported lower levels of Positive Affect, $r = -.16$, $p = .09$, at a marginal level. No effects of BAS were observed. For in the incompatible conditions, individuals high in BIS were more likely to report higher levels of Negative Affect, $r = .44$, $p < .01$, and lower levels of Positive Affect, $r = -.25$, $p = .07$, at a marginal level. For the compatible conditions, no significant correlations were observed.

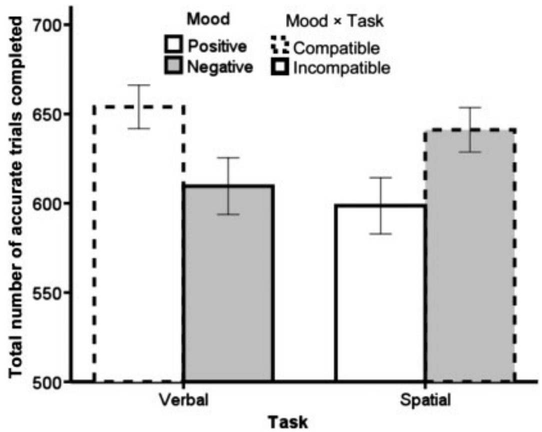

Figure 3. *Total number of accurate trials completed for all seven continuous performance blocks (Experiment 2). Bars represent one standard error of the mean.*

As for the partial correlations, we controlled for the mood induction ratings and the total number of items recalled. For the incompatible condition, as predicted, people higher in BIS reported higher levels of Negative Affect, $r = .47$, $p < .01$, and they reported lower levels of Positive Affect, $r = -.26$, $p = .07$, at a marginal level. All other correlations were non-significant for both the incompatible and compatible conditions.

Discussion

The findings from the divided attention task suggested that the incompatible conditions were less effective than the compatible conditions in managing attentional resources necessary to perform well on both tasks. In particular, the incompatible conditions expectedly performed worse on the continuous performance task, and they made more recall errors for the memory task. Although making more recall errors was not predicted, it was still consistent with our hypothesis. As expected, people high in BIS reported higher levels of Negative Affect following the self-control task, but only when they were in the incompatible condition. Again, both Aims 1 and 2 were supported, suggesting that when emotion and working memory task demands are goal incompatible more cognitive effort is expended during the working memory task.

WEAPONS TASK (EXPERIMENT 3)

To assess inhibition as the self-control domain, we used the weapon identification task by Payne (2001) to examine whether emotion and cognition interactions influence the control of implicit racial biases. The weapon identification task requires inhibitory control (Bartholow, 2010; Payne, 2001), and when psychological resources are depleted expression of stereotype-consistent attitudes emerge (Payne, 2005). We adopted both a response window (Payne, 2001) and the process dissociation procedure (Jacoby, 1991) to identify implicit biases. The automatic anti-black component of the process dissociation is thought to reflect automatic stereotype biases (Payne, 2005), and individuals low in psychological resources reveal higher automatic anti-black scores. Therefore, we predicted that the incompatible, compared to compatible, conditions would have a larger automatic anti-black score. As for BIS, we predicted, within the incompatible conditions, that people high in BIS would be associated with higher Negative Affect.

Method

Participants

Eighty-two (52 female) undergraduate students from Queens College participated to fulfil a course requirement (age: $M = 22.34$, $SD = 7.74$).

Stimuli and apparatus

Explicit racial attitude preference. Explicit racial attitudes were assessed using a relative attitude single-item question on a 1 (strongly prefer African-Americans) to 7 scale (strongly prefer European-Americans) (Nosek et al., 2007). The questionnaire was completed after the BIS/BAS questionnaire.

Weapon identification task. The goal is to discriminate the target pictures as either tools or weapons prior to the response deadline. For each trial, a prime (a African-American or European-American face) was presented for 200 ms, and then replaced by a target picture (a tool or a gun); after 200 ms, the target was replaced by a visual mask that remained for 500 ms. Participants were instructed to indicate whether a gun ("I" key) or a tool ("E" key) was presented prior to the response deadline. If no response was entered before the response deadline, a series of red X's appeared. Forty-eight practice trials were completed with only targets (no primes), followed by 192 experimental trials in which all trials presented both primes and targets. The weapons task (practice and experimental trials) took about 10 minutes to complete.

Results

Manipulation check

The positive mood conditions reported significantly greater feelings of happiness than the negative mood conditions, $F(1, 81) = 136.45$, $p < .01$, $\eta^2 = .64$. All other effects were not significant, Fs < 1.

Working memory task

The verbal task resulted in better performance compared to the spatial task, $F(1, 81) = 9.26$, $p < .01$, $\eta^2 = .11$. The Emotion main effect, $F(1, 81) = 1.69$, $p = .20$, $\eta^2 = .02$, and the interaction, $F(1, 81) = 1.78$, $p = .19$, $\eta^2 = .02$, were not significant.

Explicit racial attitude preference

A 2 (Emotion) × 2 (Task) factorial ANOVA was run. There were no differences in explicit attitudes, all Fs < 1.

Weapons task

Sensitivity. The weapons task has two trial types: 1. Congruent trials: primes and targets are stereotype consistent (black and gun, white and tool), and 2. Incongruent trials: primes and targets are stereotype inconsistent (black and tool, white and gun). Accuracy on these conditions was used to calculate controlled and biased responding (Payne, 2001). Controlled components assessed errors made on congruent trials with white primes (control white) or black primes (control black). Biased responding accounts for errors made on congruent and incongruent trials, which reflects a bias to pair black faces with guns (automatic anti-black) or to pair white faces with guns (automatic anti-white).

A multivariate 2 (Emotion) × 2 (Task) factorial multivariate analysis of covariance (MANCOVA) on control (black and white) and automatic (black and white) with working memory accuracy as the covariate was run.[2] The interaction was significant, $F(4, 74) = 3.60$, $p = .01$, $\eta^2 = .16$. Separate one-way ANCOVAs were run for each DV. As predicted, the compatible, compared to incompatible, conditions had a lower automatic anti-black bias, $F(1, 81) = 12.31$, $p < .01$, $\eta^2 = .14$. As for the group comparisons, the negative/spatial condition performed better than both incompatible conditions, ps < .05, and the happy/verbal performed marginally better than the happy/spatial, $p = .09$. All other effects for the anti-black bias were non-significant, Fs < 1.

As for the remaining components, there were no differences for the automatic anti-white component, ps > .15. The control black measure resulted in a significant effect of working memory accuracy, $F(1, 81) = 5.32$, $p = .02$, $\eta^2 = .07$ (remaining effects were not significant, ps > .17). The control white measure resulted in a significant effect of working memory accuracy, $F(1, 81) = 6.26$, $p = .02$, $\eta^2 = .08$

[2] We assessed whether ethnicity, including in-group/out-group effects, influenced performance on the weapons task (Experiment 3) and the IAT (Experiment 4). We failed to find any influence of ethnicity and in-group/out-group effects on the automatic and controlled components (weapons task) or for any of the correlational analyses for both the weapons task and the IAT. However, some cells had a small number of participants for a given ethnicity, and therefore, these results should be interpreted with caution.

(remaining effects were not significant, ps > .12). See Figure 4 for the means of the automatic anti-black bias scores.

Reaction time and accuracy. There were no differences for reaction time and accuracy, ps > .17, and working memory accuracy served as a covariate.

Post-task mood assessment

All conditions reported similar affective ratings, ps < .19.

BIS/BAS ratings

For BIS, we observed a significant interaction, $F(1, 81) = 4.41$, $p = .04$, $\eta^2 = .05$. The negative/verbal condition had the highest BIS score, whereas the positive/verbal condition had the lowest score, ps < .05. The other effects were not significant, ps > .22. No differences in BAS were observed, Fs < 1.

Correlations

For simple correlations, we observed no significant relationships among BAS and BIS with Positive and Negative Affect. For the compatible conditions, no significant relationships were observed. However, as expected, we observed that individuals in the incompatible conditions who were high in BIS were more likely to report higher levels of Negative Affect, $r = .38$, $p = .02$. All other effects failed to be significant.

As for the partial correlations, we controlled for the automatic anti-black component and self-reported happiness. For the incompatible condition, individuals higher in BIS reported higher levels of Negative Affect, $r = .30$, $p = .06$ (marginally significant). All other effects were not significant for BIS and BAS.

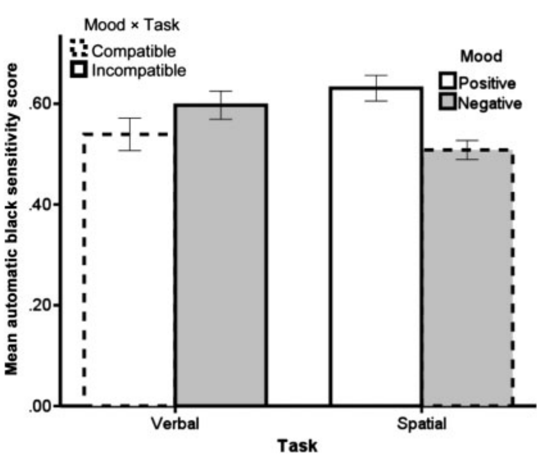

Figure 4. *Automatic Black Sensitivity Score for the weapons identification task (Experiment 3). Bars represent one standard error of the mean.*

Discussion

Consistent with the hypothesis, the compatible, compared to incompatible, conditions demonstrated fewer implicit biases towards African-Americans, suggesting that incompatible conditions were worse at inhibiting the activated stereotype. However, the difference between the positive/verbal and negative/verbal conditions failed to reach a level of significance. In general, these findings support previous research, which observed that automatic anti-black biases increase when psychological resources are taxed (Payne, 2005). As for BIS, we observed group differences in BIS, which suggests that the manipulation and/or the cognitive tasks may have influenced how participants responded on the BIS/BAS questionnaire. This may help to explain why for the simple correlations BIS was strongly related to Negative Affect, but when we controlled for self-reported mood and weapons task performance, the effect became marginally significant. Overall, the findings provide further support that goal compatibility among emotion and working memory task demands reduces cognitive effort impairing performance on the self-control task and resulting in higher levels of negative reported by individuals high in BIS.

IMPLICIT ASSOCIATION TEST (EXPERIMENT 4)

In Storbeck's (2012) study, two experiments were run; however, only the IAT experiment

(Experiment 2) included the BIS/BAS questionnaire. The BIS/BAS data were not discussed in that publication. Therefore, we tested predictions specific to Aim 2: individuals high in BIS would report higher levels of Negative Affect within the incompatible conditions. Because the behavioural data have been reported in Storbeck's (2012) study, we are only presenting statistics related to the post-task mood assessment, BIS/BAS questionnaire and relevant correlations.

Method

Participants

Eighty-nine[3] (56 female) undergraduate students from Queens College participated to fulfil a course requirement (age: M = 21.03, SD = 5.71).

Stimuli and apparatus

Implicit association test. The task was described in Storbeck's (2012) study. Participants completed a standard seven-block black/white race IAT (Nosek et al., 2007). Five of the blocks consisted of 20 trials, whereas the two critical blocks consisted of 40 trials, for a total of 180 trials. The IAT took about 10 minutes to complete.

Results

Mood check

The results of the mood check were significant and are reported in Storbeck's (2012) study.

Post-task mood assessment

No significant effects were observed among the various conditions and the reporting of mood, Fs < 1 (except for the Emotion main effect for Negative Affect; $F(1, 85) = 2.36$, $p = .13$, $\eta^2 = .03$).

BIS/BAS Questionnaire

For BAS, there was a marginal effect for Task, $F(1, 85) = 3.08$, $p = .08$, $\eta^2 = .04$. The verbal working memory conditions had a higher mean BAS score compared to the spatial conditions. The Emotion main effect and interaction were both non-significant, Fs < 1. For BIS, the negative conditions had marginally higher BIS scores than the positive conditions, $F(1, 85) = 2.90$, $p = .09$, $\eta^2 = .03$. The Task main effect, $F < 1$, and the interaction, $F(1, 85) = 1.63$, $p = .21$, $\eta^2 = .02$, were both non-significant.

Correlations

For the simple correlations, individuals high in BAS were more likely to report higher levels of Positive Affect, $r = .24$, $p = .02$, and lower levels of Negative Affect, $r = -.24$, $p = .02$. As for BIS, individuals high in BIS were more likely to report lower levels of Positive Affect, $r = -.30$, $p < .01$, and higher levels of Negative Affect, $r = .31$, $p < .01$. Specific to the compatible conditions, individuals high in BAS were more likely to report higher levels of Positive Affect, $r = .35$, $p = .01$, and they were more likely to report lower levels of Negative Affect, $r = -.39$, $p < .01$. For BIS within the compatible conditions, individuals high on BIS were more likely to report lower levels of Negative Affect, $r = .31$, $p = .04$. As for the incompatible conditions, we observed that individuals higher in BIS were more likely to report higher levels of Negative Affect, $r = .32$, $p = .03$, and lower levels of Positive Affect, $r = -.36$, $p = .02$.

As for the partial correlations, the IAT d-score and the self-reported happiness served as control variables. For the incompatible condition, people high in BIS were more likely to report higher levels of Negative Affect, $r = .31$, $p = .04$, confirming our prediction, and lower levels of Positive Affect, $r = -.35$; $p = .02$. No relationships were observed between BAS and Positive and

[3] In Storbeck (2012) control conditions were included. However, for the purpose of this paper and analyses, we removed the control conditions.

Negative Affect. For the compatible condition, people high in BIS reported higher levels of Negative Affect, $r = .29$, $p = .06$, at a marginal effect. Moreover, individuals high in BAS were more likely to report higher levels of Positive Affect, $r = .33$, $p = .03$, and lower levels of Negative Affect, $r = -.39$, $p = .01$.

Discussion

We found support for predictions concerning BIS. Individuals in the incompatible conditions who were high in BIS reported higher levels of Negative Affect, and they also reported lower levels of positive affect. However, for individuals high in BAS, we found the opposite, as they were less likely to report feelings of Negative Affect. As for the compatible conditions, we observed that individuals high in BIS experienced less positive affect and at a marginal effect higher levels of Negative Affect. As for BAS, those individuals high in BAS experienced the least amount of Negative Affect and the greatest amount of positive affect. Thus, support for Aim 2 was tentatively supported. In particular, full support was found with in the incompatible conditions; however, contrary to our prediction, individuals high in BIS and who were in the compatible condition also reported higher levels of Negative Affect.

EXPERIMENT 5

We combined the four experiments to run a moderation analysis and determine whether emotion and working memory interactions moderate individual differences in BIS predicting Negative Affect. We hypothesised that BIS would predict Negative Affect under conditions of incompatibility (with people high in BIS reporting higher levels of Negative Affect), but not under conditions of compatibility.

Procedure

The four experiments presented earlier were included in the meta-analysis. Within each experiment, BIS scores and Conditions (compatible, incompatible) were standardised and centred at the mean. The moderator variable of ZBIS × ZCondition was created by multiplying *z*-scores of BIS and Condition. The moderation analysis included ZBIS, ZCondition and the moderation variable as independent predictors and Negative Affect as the DV.

Results

The moderation analysis was significant, $F(3, 379) = 12.08$, $p < .01$. The main effect for Condition was not significant, $p = .99$. A main effect for BIS was observed, $p < .01$. People higher on BIS reported higher levels of Negative Affect. The interaction demonstrating moderation was also significant, $p < .01$. As predicted, people high in BIS and who were in the incompatible conditions reported higher levels of Negative Affect. However, BIS did not predict Negative Affect in the compatible conditions. See Table 3 for regression statistics and Figure 5 for a display of the moderation effect.

GENERAL DISCUSSION

Theoretically, we examined how emotion and cognitive control interactions influenced the management of psychological resources and performance on various self-control tasks. The predictions were based on the belief that specific emotions are integrated with specific cognitive control processes, and this integration can minimise cognitive effort and increase behavioural control. Integration, we believe, results when affective states promote goal-oriented behaviour, which includes specific cognitive orientations (Lang, 1995; Simon, 1967). For the current research, we were concerned with primarily testing the goal compatibility model, and therefore, we selected emotion and working memory due to their functional integration (e.g., Gray, 2001; Gray et al., 2002).

Overall, we found evidence to support that goal compatibility between emotion and specific cognitive processes can minimise cognitive effort. First, when emotion and working memory task demands were goal compatible, performance on

Table 3. *BIS correlations for Experiment 5 (meta-analysis)*

	Affective adjective ratings			
Condition	*B*	*SE*	*β*	*p*
BIS	0.22	0.04	0.26	<.01
Condition	0.001	0.04	−0.03	.99
ZBIS × ZCondition	0.09	0.04	0.14	.03

Note: The predicted variable was Negative Affect, with the independent variables being BIS score, Condition (compatible vs. incompatible), and the moderating variable created by taking the ZBIS score and multiplying it to the ZCondition score.

the self-control tasks was better than when emotion and task demands were goal incompatible. This effect was consistent across various domains of self-control that included task persistence and minimal support cognitive flexibility (Experiment 1), attentional control (Experiment 2) and inhibition of stereotype activation (Experiment 3), which extends the domains examined in Storbeck's (2012) study of interference resolution (Experiment 1; Stroop Task) and set-shifting (Experiment 2; IAT). Second, individual differences in BIS predicted Negative Affect following the completion of the self-control task. The effect

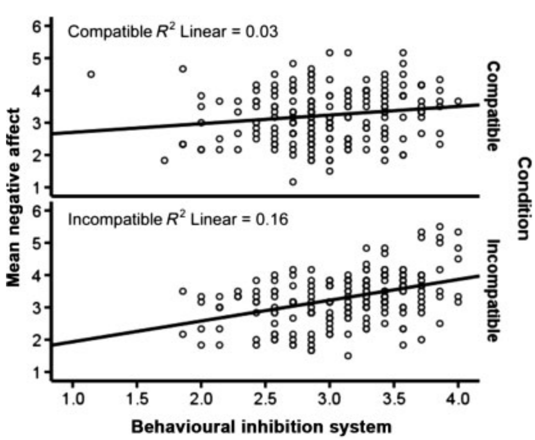

Figure 5. *The scatter-plot presents how Condition moderates the influence BIS has on self-reported negative affect in Experiment 5. The top panel presents the influence BIS has on negative affect for people in the compatible condition, whereas the bottom panel presents the influence BIS has on negative affect for people in the incompatible condition.*

was strongest in the incompatible emotion and working memory conditions. This was true across the various self-control domains. For the compatible conditions, BIS did not predict Negative Affect; however, in the IAT (Experiment 4) experiment, we observed a marginal effect for BIS and the experience of Negative Affect. Lastly, a meta-analysis of the current experiments found that emotion and working memory interactions moderated the relationship between BIS and Negative Affect. Incompatible conditions led individuals high in BIS to experience more Negative Affect, whereas compatible conditions, we believe, reduced cognitive effort resulting in lessened Negative Affect. Overall, we found support that emotion and specific cognitive control functions can be integrated to reduce cognitive effort and increase behavioural control.

The disadvantage of emotions motivating behaviour was observed when current task demands required a different cognitive process than the one promoted by the affective state. Under these conditions, we suggest that emotion automatically activated cognitive processes that were task-incompatible resulting in increased demands on cognitive control. Specifically, we suggest that cognitive control was required to regulate competition between the two incompatible goals. Regulation of cognitive or emotional goals is often demanding and limits resources for use on other self-control-demanding tasks. Whether a domain-general or domain-specific pool of resources exists for cognitive control resources has been debated for some time (Baddeley & Logie, 1999; Vergauwe et al., 2010). Our results suggest that emotion and working memory interactions deplete a common pool of resources influencing cognitive control processes of cognitive flexibility, attentional control and inhibition, which extends our prior research that examined interference resolution and set-shifting (Storbeck, 2012).

Goal compatibility and incompatibility of emotion and working memory task demands also interacted with trait differences in motivation. BIS is conceptualised as a motivational system that is sensitive to cues of punishment, non-reward and novelty, and it serves to interrupt or inhibit behaviour (Gray & McNaughton, 2000). In particular, BIS has been associated with deficiencies in regulatory control for both emotional and cognitively challenging situations (Dennis, 2007; Fowles, 1988; Gross et al., 1998; Harmon-Jones & Allen, 1997; Kagan & Snidman, 1991). In the current research, we suggest that participants in the incompatible conditions had to manage competing goals, which served to increase task difficulty. The increase in task difficulty may have increased the experience of Negative Affect. Therefore, our results add to the growing literature in suggesting that individuals high in BIS have a difficult time managing competing goals between emotion and task demands.

EMOTION SPECIFICITY AND COMPETING EMOTIONAL STIMULI

Questions still remain with respect to how emotion and cognition interact to influence cognitive resources and behaviour. Although we are lacking a specific model for when emotion and cognitive processes are compatible, we do propose a simplified heuristic. We believe that positive affect promotes a goal for social relations and exploration (e.g., Ashby et al., 1999; Beckes & Coan, 2011; Clore et al., 2001; Fredrickson, 2001), which may activate cognitive processes related to language (e.g., semantic memory, episodic memory retrieval, verbal working memory, etc.), planning and cognitive flexibility. On the other hand, Negative Affect promotes a goal for detecting threat and (cognitive) errors (e.g., Corr & McNaughton, 2012; Clore et al., 2001; Vuilleumier, 2005), which may activate cognitive processes related to perceptual/spatial analysis (e.g., spatial perception, spatial working memory, inhibition, etc.). Therefore, if the task goal is to successfully hold spatial relations in memory, a negative affective state would motivate a cognitively compatible goal (i.e., spatial working memory), whereas a positive affective state would motivate a cognitively incompatible goal (i.e., verbal working memory). Thus, cognitive effort would be decreased with a negative state, but increased with a positive state.

Other research has examined how emotion influences various executive functions, and the results appear consistent with our proposed heuristic for emotions promoting specific behaviour goals and cognitive tendencies. When states of positive affect (happiness) are induced there is enhanced performance for executive functions that include planning, cognitive flexibility, task-switching and verbal working memory (Bolte, Goschke, & Kuhl, 2003; Gray, 2001; De Dreu, Baas, & Nijstad, 2008; Dreisbach & Goschke, 2004; Kuhl & Kazen, 1999; Locke & Braver, 2008; Padmala & Pessoa, 2011; Phillips, Bull, Adams, & Fraser, 2002; Savine, Beck, Edwards, Chiew, & Braver, 2010). There is also strong evidence that BAS and reward motivation can facilitate verbal working memory efficiency (Gray et al., 2005; Watanabe, 1996) and increase the ability to maintain goal-sets (Locke & Braver, 2008). Negative Affect (sadness) often fails to enhance cognitive control processes; however, there is evidence that it does improve inhibitory control (Goldstein et al., 2007), spatial working memory (Gray, 2001) and attentional control (Rowe, Hirsh, & Anderson, 2007). Similarly, BIS has been associated with inhibitory and attentional control (Corr & McNaughton, 2012; Dennis, 2007). Therefore, it is possible that both state and trait motivations are part of a larger, dual system network involving various cognitive control mechanisms. Moreover, the similar effects observed between state and trait motivations may suggest that motivation maybe the critical component of the emotional state driving the effects.

There are several questions that remain outstanding and require further research. First, the components of emotions and moods need to be functionally defined in order to make more accurate predictions concerning the activation of specific cognitive processes. The two most common distinctions of emotions are based on categorical or dimensional approaches. Both approaches can render clear predictions for the activation of cognitive tendencies (i.e., via behavioural goals). Namely, for categorical approaches, specific emotions should promote a specific set of cognitive processes based on the motivational tendencies each emotional state invokes (see Moors, Ellsworth, Scherer, & Frijda, 2013, for a review). For instance, an emotion like anxiety may predict the activation of spatial or verbal working memory depending on whether anxiety is associated with a threat or rumination, respectively (Heller, Nitschke, Etinne, & Miller, 1997; Shackman et al., 2006; Vytal, Cornwell, Letkiewicz, Arkin, & Grillon, 2013). Thus, each emotion should have clearly defined motivational tendencies based on cognitive appraisals, resulting in goal compatibility when the cognitive task has cognitive processing goals in common with those of the emotional state.

As for dimensional approaches, a motivational approach may also serve as a likely model. Namely, emotions consist of motivational orientations to either approach or withdraw from stimuli and it is believed to interact with cognitive control in order to influence behaviour (Bradley, Codispoti, Cuthbert, & Lang, 2001; Corr & McNaughton, 2012; Custers & Aarts, 2010; Frijda, 1988; Harmon-Jones, Gable, & Peterson, 2010; Simon, 1967). Therefore, predictions can be based on whether or not an emotion state invokes approach or withdraw tendencies. However, recent research may suggest a caveat where predictions must also incorporate the intensity of motivation to approach or withdraw. For instance, Gable and Harmon-Jones (2008) demonstrated that approach states low in motivation facilitate broadening of attention, but approach states high in motivation narrow attention irrespective of the motivational orientation (see also Locke & Braver, 2008; Savine et al., 2010).

Finally, different predictions may be required for when the emotional induction or emotional stimuli distract or compete with task goals (Dolcos, Iordan, & Dolcos, 2011; Eysenck & Calvo, 1992; Iordan, Dolcos, & Dolcos, 2013; Pessoa, 2009; Robinson, Vytal, Cornwell, & Grillon, 2013; Shackman, Maxwell, McMenamin, Greischar, & Davidson, 2011; Vytal et al., 2013). For instance, a recent study examined how induced anxiety influenced both verbal and spatial working memory tasks under low and high demands (Vytal et al., 2013). They found that for verbal working memory, anxiety impaired performance under low load conditions (1- and 2-back working memory task), but not under high load conditions (3-back). However, for spatial working memory, regardless of the load, anxiety consistently impaired performance (see Lavric, Rippon, & Gray, 2003; Shackman et al., 2006; Vytal et al., 2012, for similar findings). Under such conditions, competition results in the maintenance or proactive control of two active goals (one associated with emotional control and the other with non-emotional control), which serve to limit the availability of resources to sustain cognitive control (Berggren, Richards, Taylor, & Derakshan, 2013; Braver, 2012; Clarke & Johnstone, 2013; Dolcos & McCarthy, 2006; Shackman et al., 2006, 2011; Pessoa, 2009). Moreover, emotions like anxiety or fear may also motivate lower level processes in order to bias processing towards anxiety-related targets, which increase the psychology demand to resolve competing anxiety- and task-related goals (e.g., Dolcos & McCarthy, 2006; Shackman et al., 2006; Vuilleumier, 2005; Vytal et al., 2012, 2013). Therefore, we suggest that when emotion and task demands require a similar subset of cognitive processes for their respective goals (i.e., attending to the threat and completing the spatial working memory task), goal competition increases resulting in greater cognitive effort and subsequently worse behavioural control.

FUTURE DIRECTIONS

There are several questions that remain concerning aspects of working memory performance. We failed to find differences in working memory performance due to the induced emotional states. One reason may have been that the working memory task was easy enough to allow for compensatory processing to maintain performance. But, the use of compensatory processes would have been psychological demanding, which may be the reason for worse performance by the incompatible conditions on the self-control tasks. Studies that have observed emotion directly influencing working memory performance have used a 3-back task (e.g., Gray, 2001), which is harder than a 2-back task that was used in the current study. Therefore, we suggest that a systematic manipulation of working memory difficulty is required to address issues related to compensatory processing (see Vytal et al., 2013). Another issue was the performance differences between the verbal and spatial working memory tasks observed in Experiments 1 and 3 (see Shackman et al., 2006 and Strauss, 2001, for the implications when tasks are not psychometrically matched). The fact that the tasks were not psychometrically matched may suggest that the effects on the self-control tasks were driven more by the demands of the working memory task than the interaction between task and emotion. Thus, caution should be used when interpreting the interaction effects. Though, for Experiment 2 in which performance was similar between the two working memory tasks, the results conceptually replicated the other experiments where the working tasks were not psychometrically matched. Moreover, within each working memory task, we consistently observed differences in self-control performance caused by the mood induction. Specifically, across the experiments, we observed with the post hoc analyses that the positive/verbal condition outperformed the negative/verbal condition, and likewise, the negative/spatial condition outperformed the positive/spatial condition.

Two other concerns should be noted. First, the BIS/BAS questionnaire is intended to measure trait effects, but it is possible that state effects may have influenced responding. Participants were asked to complete the questionnaire following the manipulation and the cognitive tasks, which may have led some participants to use their current feelings when answering the questions. For instance, in Experiment 3, we observed that people in the compatible (positive/verbal) condition had a lower BIS score than the incompatible (negative/verbal) condition, which suggests that the experience of cognitive challenge may have influenced how they responded on the questionnaire. Second, the study lacked a control condition. Our prior research found that the incompatible conditions performed worse than the control conditions (Storbeck, 2012). In the current study, we limited our hypotheses to compatible and incompatible conditions making our effects relative rather than absolute. As a result, we cannot claim that emotion and working memory interactions increased or decreased cognitive effort compared to a neutral condition.

CONCLUSION

Overall, these findings support the view advanced over 50 years ago by Simon (1967): that an important function of emotion is to change the cognitive and behavioural agenda. But, we proposed that when emotion correctly predicted the cognitive needs of the situation, cognitive effort would be minimised. As expected, when emotion motivated cognitive tendencies that were goal compatible with the demands of the working memory task cognitive effort was minimised, which resulted in increased behavioural control. Moreover, these benefits interacted with BIS sensitivities, such that emotion and working memory task demands that were goal-compatible guarded against negative reactivity often observed during a cognitively challenging task. In sum, when emotions tune cognition to be compatible with situational demands, performance is enhanced, psychological resource expenditure is minimised and negative reactivity is reduced for individuals sensitive to regulatory challenges.

Supplementary material

Supplementary material (Tables 1–4) is available via the "Supplementary" tab on the article's online page (10.1080/02699931.2014.904222).

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