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The Effects of Prior Cognitive Control Task Exposure on Responses to Emotional Tasks in Healthy Participants

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Background: Recent advances have been made in the application of cognitive training strategies as interventions for mental disorders. One novel approach, cognitive control training (CCT), uses computer-based exercises to chronically increase prefrontal cortex recruitment. Activation of prefrontal control mechanisms have specifically been identified with attenuation of emotional responses. However, it is unclear whether recruitment of prefrontal resources alone is operative in this regard, or whether prefrontal control is important only in the role of explicit emotion regulation. This study examined whether exposure to cognitive tasks before an emotional challenge attenuated the effects of the emotional challenge. **Aims:** We investigated whether a single training session could alter participants' reactivity to subsequent emotional stimuli on two computer-based tasks as well as affect ratings made during the study. We hypothesized that individuals performing the Cognitive Control (CC) task as compared to those performing the Peripheral Vision (PV) comparison task would (1) report reduced negative affect following the mood induction and the emotion task, and (2) exhibit reduced reactivity (defined by lower affective ratings) to negative stimuli during both the reactivity and recovery phases of the emotion task and (3) show a reduced bias towards threatening information. **Method:** Fifty-nine healthy participants were randomized to complete CC tasks or PV, underwent a negative mood induction, and then made valence and arousal ratings for IAPS images, and completed an assessment of attentional bias. **Results:** Results indicated that a single-session of CC did not consistently alter participants' responses to either task. However, performance on the CC tasks was correlated on subsequent ratings of emotional images. **Conclusions:** While overall these results do not support the idea that affective responding is altered by making healthy volunteers use their prefrontal cortex before the

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affective task, they are discussed in the context of study design issues and future research directions.

Keywords: Anxiety, attentional training, computer-aided psychotherapy, depression, worry.

Introduction

Emotion regulation has been strongly identified with cognitive control (Gross and John, 2002; Ochsner and Gross, 2005). Activation of prefrontal control mechanisms have specifically been linked with the attenuation of emotional responses (e.g. Ochsner et al. 2004). That said, it is unclear whether recruitment of prefrontal resources alone is operative in this regard, or whether prefrontal control is important only in the context of explicit use of emotion regulation strategies. This study examined whether exposure to a specific cognitive task (known to recruit prefrontal resources) attenuated the effects of a subsequent emotional challenge.

This study is particularly relevant for understanding response to the types of cognitive training strategies that are increasingly popular as interventions for mental disorders. For example, neurobehavioural training exercises have been used to successfully reduce the attention, memory, and executive functioning deficits exhibited by individuals with depression (Elgamal, McKinnon, Ramakrishnan, Joffe and MacQueen, 2007). Other novel computer-based training programs designed to alter cognitive biases toward negative information have been used successfully to change emotional responses to stress (Mathews and MacLeod, 2002; MacLeod and Mathews, 1988). These training programs have also been used to treat emotional disorders (Amir, Beard, Burns and Bomyea, 2009; Hazen, Vasey and Schmidt, 2009; Amir, Weber, Beard, Bomyea and Taylor, 2008). For example, Amir et al. (2009) applied an 8-session attention modification program, and found significant changes, relative to a control condition, in both attentional biases and anxiety severity among individuals with generalized anxiety disorder. Increasing prefrontal control might also contribute to other perspectives on emotion reactivity in depression, such as positive attenuation (attenuated reactivity to positive emotional stimuli) and emotion context sensitivity (attenuated reactivity to both positive and negative stimuli), which indicates that depression may produce mood-state-dependent changes in emotional reactivity (Rottenberg, Gross and Gotlib, 2005).

Recent work has specifically used cognitive training interventions to target the chronic recruitment of specific brain regions thought to be implicated in the maintenance of depressive symptoms (Siegle, Ghinassi and Thase, 2007). Specifically, depression is frequently characterized by patterns of inflexible, maladaptive, and ruminative thinking styles; these patterns themselves are thought to result from a combination of decreased attentional control, executive functioning, and increased negative affect (corresponding to decreased prefrontal cortical (PFC) activity and increased amygdala activity; Drevets, 1998; Ray et al., 2005; Holmes and Pizzagalli, 2008; Gu et al., 2008; Siegle, Steinhauer, Thase, Stenger and Carter, 2002). In a recent study, Siegle, Thompson, Carter, Steinhauer and Thase (2007) developed a neurobehavioural therapy designed to increase PFC activity and improve attentional and cognitive control among individuals with treatment-resistant major depressive disorder. This work was based on an "atrophy" model in which depressed individuals were assumed to chronically fail to recruit prefrontal control. Practising tasks requiring cognitive control over multiple weeks was hypothesized to increase their ability, likelihood, and experience with this adaptive response pattern. Study participants completed a series of computer-based tasks

designed to increase PFC recruitment in the context of increased emotional reactivity and thus, ideally, promote increased attentional and cognitive control in the face of negative affect. Improved attentional control, in turn, was hypothesized to promote improved ability to control other mood-related thinking patterns, including rumination (Siegle, Ghinassi, et al., 2007). Participants were thus selected from a severe partial-hospitalization sample, likely to be most strongly characterized by failure to recruit brain systems used in everyday functioning. These participants were randomly assigned to complete treatment as usual (TAU) in the program or six sessions of cognitive control training (CCT) over a 2-week period in addition to TAU. As hypothesized, participants who received the CCT intervention exhibited improved performance on novel executive functioning tasks that rely on PFC activity. Performance improved with each practice day consistent with a plasticity model.

The underlying assumption of such a multi-week training model is that behaviour change can result from change in organization or properties of the neural circuitry that produces the behaviour. Participants also exhibited changes in brain activity during cognitive and emotional tasks consistent with more adaptive functioning, including increased dorsolateral PFC activity and reduced sustained amygdala activity and pupil dilation, respectively (Siegle, Ghinassi, et al., 2007). A reduction in depression and rumination symptoms was also seen in the CCT group relative to participants receiving TAU. Anecdotally, participants in the CCT group reported improvements in their ability to focus on task-related activities in their daily life; however, no formal follow-up data were collected.

It is not known whether (1) these training effects operate via a long term process of cognitive remediation potentially involving extensive plasticity, or might have shorter-term effects by helping individuals to recruit prefrontal resources that largely already exist; (2) whether effects are specific to individuals with deficits characteristic of depression; and (3) the training has effects on aspects of early emotional information processing not explicitly related to voluntary control on the order of seconds to minutes. In particular, in this study we address the question of whether a single administration of cognitive exercises used in the longer-term training is associated with change in the processing of subsequently presented emotional stimuli.

A single-dose of exposure to cognitive tasks could act as an intervention, spurring short-term plasticity, or could prime activation among prefrontal mechanisms that could contribute to emotion regulation. Previous studies have found changes in brain activity following a single session of training (Browning, Holmes, Murphy, Goodwin and Harmer, 2009). Similarly, if regulatory function increases in response to prefrontal recruitment, participants exposed to affective stimuli following the cognitive challenge might be less likely to experience decreased mood. In contrast, if active intervention is more associated with longer-term repeated exposures, a single administration could serve to decrease mood. As an analogue, the type of exercises used in exposure therapy, involving prolonged exposure to a stressful stimulus, done in a single session absent a therapeutic context and clinical disorder, can actually be sensitizing. In support of this idea, the PASAT is well-known to serve as a negative mood induction (Feldner, Leen-Feldner, Zvolensky and Lejuez, 2006; Holdwick and Wingenfeld, 1999). Phasic potentiation of negative affect by a subsequent stressor could thus be expected.

To address these questions, our study examines the effects of a single dose of the cognitive training exercises used in the original CCT study**,** applied to healthy participants who did not have depression related changes in PFC functioning. Thus, the task was administered in a dose so small that it is unlikely for repeated exposure to be an operative factor in response,

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and in a population for whom depression-related PFC deficits are irrelevant. Positive results would thus suggest that the proposed mechanisms of the original CCT study, involving long-term training and remediation of depression-related deficits, are questionable. Negative results would allow for the possibility that results of the original CCT study occurred via the proposed mechanisms. Also, the original CCT study did not employ a computerized control task to ensure that observed changes in the CCT group were due to the direct effects of the CCT training on PFC activity or whether they were due to a placebo effect or the structure of working with a research member and repetitively completing any computer task.

Further, in the present study we examined whether healthy participants performing the CC task on one occasion exhibit altered responsivity to affective probes relative to those who completed a computer-based control task (peripheral vision; PV). To achieve this aim, participants were randomized to perform a CC or PV task prior to undergoing a negative mood induction (the latter was used as an affective stressor to activate possible ruminatory styles and improve the possibility of detecting differences in participants' responses to emotional stimuli). Participants then completed two tasks assessing attentional biases and emotional reactivity differences thought to maintain anxiety disorders (Mathews and MacLeod, 2002; Drevets, 1998). The first was an emotion task involving the presentation of pleasant, neutral, and unpleasant images during which participants made valence and arousal ratings. The second task was a computer-based task assessing visual attentional bias towards threatening or unpleasant words verses neutral words. Participants also rated their state affect throughout the study.

If the administered training operates by priming or mobilizing existing resources (rather than leading to more extensive plasticity through repeated training), we hypothesized that increased priming of frontal control mechanisms would be associated with decreased subjective reactivity to affective probes. This explanation would suggest that, relative to those in the PV group, individual CC participants who had high levels of performance either throughout or by the end of the working memory portion of the task would (1) report reduced negative affect following the mood induction and the emotion task, and (2) exhibit reduced reactivity (defined by lower affective ratings) to negative stimuli during both the reactivity and recovery phases of the emotion task. If prefrontal control were increased following the training task, limbic activity could be decreased in the following period, yielding decreased amygdala reactivity and thus potentiation during the mood induction. In this case we might expect participants to show less of a bias towards threatening cues in the attentional task. Exploratory analyses were conducted to evaluate the influence of the CC task on subsequent emotional responses to pleasant stimuli. It was not expected that increases in positive affect would occur, as the PASAT portion of the CC is stressful and a well-known negative-mood induction. Negative results would suggest that (1) the intervention requires sustained or repeated practice to achieve relevant effects, potentially associated with plasticity; (2) the intervention operates specifically on deficits observed in depression; or (3) the intervention's effects are specific to later voluntary processes.

Method

Participants

Fifty-nine participants (ages 18–30 years, see Table 1 for more demographic information) were recruited from community volunteers in Boston via online advertisements, and from

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Table 1. Baseline and demographic characteristics

	Mean *(SD)*		Statistic	
Variable	CC ($n = 27$)	PV ($n = 32$)[c]	*t* value	*p* value
Demographics[a]				
Age (years)	18.96 (0.90)	19.41 (2.12)	−1.07	0.29
Sex (M/F)	12/15	15/17	0.03	0.85
Race % (*n*)[d]			1.42	0.70
Caucasian	74.1 (20)	64.52 (20)		
African American	0	3.23 (1)		
Asian	18.52 (5)	25.81 (8)		
Other	7.41 (2)	6.45 (2)		
Ethnicity % (*n*)			0.47	0.49
Hispanic or Latino	7.41 (2)	12.90 (4)		
Non Hispanic or Latino	92.59 (25)	87.1 (27)		
Education (*n*)			2.67	0.10
Some college	26	29		
Completed college	0	3		
Measures[b]				
BDI-II	7.15 (3.08)	5.97 (3.91)	1.27	0.21
$PANAS_{trait}$				
Positive	33.56 (4.93)	34.47 (6.28)	−0.61	0.54
Negative	15.67 (4.52)	15.94 (4.86)	−0.22	0.83
RRS	42.52 (11.40)	39.91 (11.33)	0.88	0.38
ACS	53.07 (7.49)	51.90 (6.74)	0.63	0.53
PSWQ	45.37 (14.81)	40.97 (12.17)	1.25	0.22
AIM	145.70 (10.95)	143.94 (15.62)	0.49	0.62

Note. CC = Cognitive Control Tasks; PV = Visual Control Task; BDI-II = Beck Depression Inventory; PANAS = Positive and Negative Affectivity Scale (Trait Version); RRS = Ruminative Response Scale; ACS = Attentional Control Scale; PSWQ = Penn State Worry Questionnaire; AIM = Affective Intensity Measure. [a]Chi-square values analyses reported for all demographic variables except age ($df = 1$); [b]T-values reported for all measures and age ($df = 55$); [c]Values for race and ethnicity reflect PV ($n = 31$); [d]$df = 3$.

undergraduates enrolled in introductory psychology courses at Boston University. All met inclusion criteria (BDI-II scores < 15; Beck, Steer and Brown, 1996). Participants received either $30 (if recruited from online advertisements) or course participation credit (if recruited from Boston University's introductory psychology courses) in exchange for study participation.

Measures

Self-report questionnaires. Participants completed the BDI-II (Beck, Steer and Brown, 1996), the trait version of the Positive and Negative Affectivity Scale (PANAS; Watson, Clark and Tellegen, 1988), and the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger and Borkovec, 1990) to assess, depression severity and trait positive and negative affect, fear of anxiety-related symptoms, and worry, respectively. Participants also completed

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a battery of self-report questionnaires designed to assess aspects of affective reactivity and emotion regulation including the Affective Intensity Measure (AIM; Larsen and Diener, 1987), the Attentional Control Scale (ACS; Derryberry and Reed, 2002), and the Rumination and Response Scale (RRS; Nolen-Hoeksema, Morrow and Fredrickson, 1993). Finally, participants completed several ratings of state affect throughout the study using the state version of the PANAS (Watson et al., 1988) as well as two versions of the Visual Analog Scale (VAS) consisting of two 115-mm horizontal lines with the following bipolar dimensions: "happy/sad" and "relaxed/tense". Higher scores on theses scales indicate higher levels of sadness or tenseness.

Training tasks

Cognitive Control (CC) tasks. A modified version of the Paced Auditory Serial Addition Task (PASAT; Gronwall, 1977) and the Attention Control Intervention (Wells, 2000) were used to train participants' attentional control in accordance with procedures used by Siegle and colleagues (see Siegle, Ghinassi et al., 2007 for additional task descriptions). In the modified PASAT, participants are asked to add serially presented numbers and the speed of number presentation is adapted based on participants' performance in order to minimize frustration associated with this task. Participants began the task with a 3000 ms Interstimulus Interval (ISI). After four consecutive correct trials, the task increased in speed by 100 ms ISI. After four consecutive incorrect trials, the task decreased in speed by 100 ms ISI. Participants completed three, 5-minute blocks of this task. This task has been shown to increase dorsolateral PFC activity in healthy populations (Lazeron, Rombouts, de Sonneville, Barkhof and Scheltens, 2003). The PASAT records participants' responses and response time. In the Attention Control Intervention (Wells, 2000), individuals are asked to attend differentially to multiple auditory sources (e.g. by counting tones, discriminating the location of tones, and moving their attention between auditory sources for a prolonged period). Therefore the task trained individuals to direct attention and possibly permit them to regain voluntary control over automatic attentional processes. There are no quantifiable responses recorded during the Wells task. Each task lasted approximately 15 minutes for a total of approximately 25–30 minutes for the CC tasks.

Peripheral Vision (PV) task (C. Moore, personal communication). During this task participants view a circular array of 15 discs and are asked to move their attention, but not their eyes, clockwise around the array while auditory tones are presented. Following the presentation of a distinct target tone, the discs change colour and participants report the colour of the disc by pressing a designated button on the keyboard. This task was developed to be a non-active control condition, targeting visual and occipital areas of the brain, and therefore allows us to discriminate between the effects of completing a computer-based task from interventions that specifically target the PFC. There are no quantifiable responses recorded during the PV task. This task lasted approximately 25–30 minutes.

Mood induction

Participants watched two video clips (excerpts from *Bambi* and *The Champ)*, featuring a young character losing a parent. Clips lasted approximately 2.5 minutes each and have been used in previous studies to induce sadness without incident (Gross and Levenson, 1995;

Liverant, Brown, Barlow and Roemer, 2008; Rottenberg, Ray and Gross, 2007). This mood induction was designed to serve as an affective stressor to activate possible ruminatory styles and maximize our ability to detect differences in participants' responses during the Emotional Reactivity and Recovery Task.

Emotional Reactivity and Recovery Task (ERRT)

Participants viewed 60 images (20 pleasant, 20 neutral, and 20 unpleasant) chosen from the International Affective Picture System (IAPS; Lang, Bradley and Cuthbert, 1997). Images were selected to differ on standardized valence ratings (unpleasant $M = 2.33$, $SD = 0.64$; neutral $M = 5.24$, $SD = 0.61$; pleasant $M = 7.31$, $SD = 0.56$) but unpleasant and pleasant images were equated on arousal ratings (unpleasant $M = 6.25$, $SD = 0.79$; neutral $M = 2.80$, $SD = 0.58$; pleasant $M = 6.24$, $SD = 0.53$) which were significantly different from neutral arousal ratings (see Appendix). Each image was displayed for 9 seconds. Participants viewed the image alone for 3s before being given 3s to make a valence rating (how happy or sad they felt in response to the image), followed by 3s to make an arousal rating (how excited or relaxed they felt in response to the image). The image remained on the screen throughout the rating period; therefore these were considered the emotion "reactivity" scores. The picture was then replaced by a blank black screen for 1s, after which participants made the same valence and arousal ratings (3s/each) with no image displayed. These are considered the emotion "recovery" ratings. Participants rated images based on a digitized version of the self-assessment mannequin (Bradley and Lang, 1994), which is a non-verbal pictorial assessment that directly measures the pleasure, and arousal associated with a person's affective reaction to stimuli.

Attentional dot probe task

The dot probe paradigm (MacLeod and Mathews, 1988) is a method for assessing early pre-attentive visual attentional biases, has been used widely in the study of bias toward threat, and is sensitive to stressors (e.g. reflects an increase in bias toward threat, MacLeod, Rutherford, Campbell, Ebsworthy and Holker, 2002). Two words are presented for a short period after which one is replaced with a probe to which the participant must respond with a key stroke; attentional bias is determined by examining relative reaction time to different types of stimuli (e.g. threat cues vs. neutral cues). In this study, two words (1 neutral and 1 threat) were presented simultaneously for 500ms and then both disappeared and one was replaced with a dot. Participants were asked to identify the location of the dot as either replacing the top or bottom stimulus. Shorter response time indicated that the participant was attending to the stimulus that was replaced by the dot. The task consisted of 15 practice trials in which only neutral-neutral word pairs (e.g. leaf-tent) were presented, followed by 96 test trials consisting of 48 threat-neutral (e.g. fright-speed) and 48 neutral-neutral pairs. The inter-trial interval was 500ms. Word and probe location were counterbalanced and word pairs were presented in a random order by the computer program.

Procedure

After screening and provision of informed consent, participants completed a battery of self-report questionnaires. Participants then completed either the CC or PV tasks (task assignment was randomized across eligible study participants). Following the training tasks, participants

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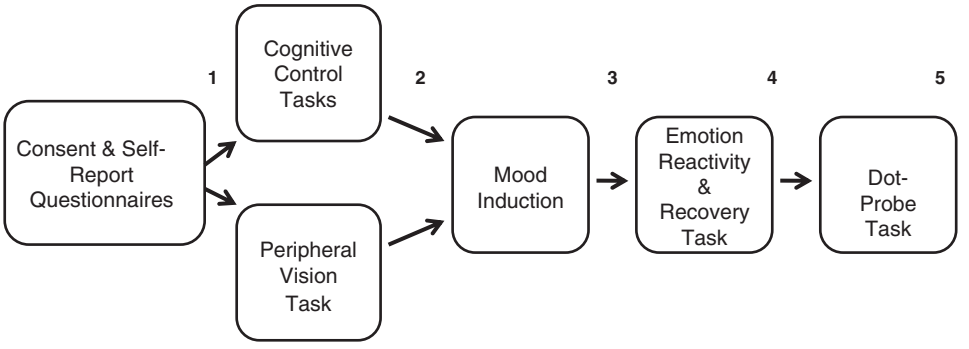

Figure 1. Schematic of study procedure. CC = cognitive training tasks; PV = peripheral vision task; ERRT = emotion reactivity and recovery task. Numbers refer to the presence of $PANAS_{state}$ and VAS assessments. 1 = pre-training; 2 = pre-mood induction; 3 = pre-ERRT; 4 = pre-dot probe, 5 = end-of-study.

underwent a sad mood induction during which they were asked to remain focused on both video clips while they were playing. The mood induction was followed by the ERRT and then a dot probe task. Participants reported on their current mood state using the PANAS and VAS scales at several time points (pre-training task, pre-mood induction, pre-ERRT, and end-of-study; see Figure 1).

Data reduction and statistical analyses

Group differences on self-report measures were evaluated using separate independent samples *t* tests or Fisher's Exact Test for categorical data. For the state affect ratings, separate difference scores were calculated by subtracting pre-training task scores from each of the subsequent $PANAS_{state}$ and VAS scores. To assess the specific effects of the mood induction, separate affect rating difference scores were calculated by subtracting $PANAS_{state}$ and VAS scores pre-mood induction task from the pre-ERRT ratings. Paired *t* tests were run separately for each of the state affect comparisons across groups. Between group comparisons of affect change were tested using independent samples *t* tests. Additional correlations were calculated with PASAT performance, the slope of PASAT performance and ERRT ratings, attentional bias on the dot-probe task, and self-report ratings of affect.

On the ERRT, trials in which participants failed to make a response or responded faster than 150ms were excluded from analysis. Participants who had greater than 50% rate of non-responsiveness on any of the four variables were excluded from analysis ($n = 34$). Pairwise comparisons were used to interpret significant main effects. Difference scores were calculated by subtracting valence and arousal ratings in response to neutral stimuli from the unpleasant and pleasant averages, separately. These difference scores were used in independent samples *t* tests to test between group differences in valence and arousal ratings during the reactivity and recovery phases. Effect sizes are reported in *d* values for *t*-tests respectively.

On the dot probe task, trials in which participants responded at a rate $+/-3$ standard deviations from their mean response time were excluded. Responses quicker than 150ms and slower than 1500ms were also excluded. If more than 10% of the trials were excluded for two

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individuals, those individuals' dot probe data were excluded from the study. Attentional bias scores were calculated by subtracting the harmonic mean reaction time to threat cues from the harmonic mean reaction time to neutral cues; thus a positive bias score reflects an attentional bias toward threat cues. Independent samples *t*-tests were used to examine between group differences in attentional bias.

Results

Demographic characteristics of the experimental groups

Groups did not differ significantly on any demographic or self-report measure using *t* tests or Fisher's Exact Tests (all $ts < 1.3$, $\chi^2 < 2.67$, $ps > .10$, see Table 1), suggesting that our randomization procedures were effective. Importantly, there were no significant differences between groups on the self-reported state affect measures prior to the training tasks ($PANAS_{negative}$: $t(56) = .22$, $p > .80$, $d = .07$; $PANAS_{positive}$: $t(56) = -.63$, $p > .50$, $d = .14$; $VAS_{happy/sad}$: $t(56) = 1.89$, $p > .05$, $d = .50$, $VAS_{relaxed/tense}$: $t(56) = 1.265$, $p > .20$, $d = .34$), indicating that participants were experiencing equivalent emotional states before the experimental manipulation.

Affect changes across tasks

For all participants, consistent with previous literature on the PASAT task, positive affect decreased after completing the cognitive tasks regardless of group (CC and PV); negative affect increased non-significantly and tension did not change on paired *t* tests ($PANAS_{negative}$ $t(57) = 1.87$, $p = .07$, $d = .25$; $PANAS_{positive}$ $t(57) = 4.30$, $p < .001$, $d = .45$; $VAS_{happy/sad}$ $t(57) = -2.16$, $p < .05$, $d = .19$; $VAS_{relaxed/tense}$ $t(57) = -0.85$, $p > .35$, $d = .10$). As expected, significant mood effects were evident across the mood induction procedure; participants showed worsened state affect scores and increased tension ($PANAS_{negative}$ $t(58) = -2.74$, $p < .05$, $d = .32$; $PANAS_{positive}$ $t(58) = 3.47$, $p < .01$, $d = .29$; $VAS_{happy/sad}$ $t(58) = -7.64$, $p < .001$; $d = .74$; $VAS_{relaxed/tense}$ $t(58) = -2.27$, $p < .05$), $d = .22$.

Differential affect changes between groups

Table 2 presents changes in mood scores across the relevant study procedures. Comparisons of state affect change between training groups indicated that there were no differences between groups before and after the cognitive training tasks as measured by independent sample *t* tests ($PANAS_{negative}$ $t(56) = 1.47$, $p > .10$, $d = .38$; $PANAS_{positive}$ $t(56) = 1.48$, $p > .10$, $d = .39$; $VAS_{happy/sad}$ $t(56) = -.15$, $p > .85$, $d = -.04$; $VAS_{relaxed/tense}$ ($t(56) = -.32$, $p > .70$, $d = -.08$).

Following the mood induction, CC participants experienced decreased positive affect compared to PV participants, $PANAS_{positive}$ ($t(57) = -3.42$, $p < .01$, $d = -.89$, as well as a trend toward a greater decrease in negative affect $PANAS_{negative}$ (t (57) $= -1.88$, $p = .07$, $d = -.49$). There were no significant differences on the $VAS_{happy/sad}$ (t (57) $= -.18$, $p > .85$, $d = -.05$) or the $VAS_{relaxed/tense}$ (t (57) $= -.12$, $p > .90$, $d = -.03$) measures across the mood induction. Additionally, PASAT performance (percent correct) did not have an affect on self-reported affect (all $F < 3.90$, all $p > .05$).

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Table 2. PANAS and VAS ratings

	Mean *(SD)*				Statistic	
Affect change scores	CC ($n = 27$)		PV ($n = 31$)		t value	p value
Across training task affect[a]						
$PANAS_{negative}$	−0.11	(3.09)	−1.16	(2.33)	1.47	0.15
$PANAS_{positive}$	−2.15	(6.58)	−4.45	(5.28)	1.48	0.15
$VAS_{happy/sad}$	3.81	(16.95)	4.37	(12.28)	−0.15	0.89
$VAS_{relaxed/tense}$	1.52	(28.64)	3.45	(16.49)	−0.32	0.75
Across mood induction affect[b]						
$PANAS_{negative}$	6.44	(6.84)	10.03	(7.69)	−1.88	0.07
$PANAS_{positive}$	−4.07	(4.64)	−0.34	(3.72)	−3.43	0.00
$VAS_{happy/sad}$	16.44	(16.75)	17.23	(17.42)	−0.18	0.86
$VAS_{relaxed/tense}$	4.81	(18.65)	5.34	(16.28)	−0.12	0.91

Note: CC = Cognitive Control Tasks; PV = Visual Control Task; ERRT = Emotional Reactivity and Recovery Task; PANAS = Positive and Negative Affectivity Scale (State Version); VAS = Visual Analogue Scale. [a]$df = 56$; [b]$df = 57$, PV ($n = 32$).

ERRT

Data from 24 participants on the emotional reactivity and recovery task (ERRT, described below) were excluded due to poor behavioural performance (e.g. greater than 50% non-response rates on any one ERRT measure). These large non-response rates likely resulted from the brief period of time available for participants to make valence and arousal ratings and the number of individuals with faulty ERRT data did not differ between experimental training groups (Fisher's Exact Test = .99).

All participants reported significant differences in valence ratings for the three categories of images (pleasant, unpleasant, and neutral; *Picture Category* F (2, 64) = 122.20, $p < .001$). Pairwise comparisons suggested that valence ratings differed predictably between each of the three valence categories (all ps $< .001$). Similarly, expected significant effects of *Picture Category* were observed for participant arousal ratings (F (2, 64) = 75.27, $p < .001$). Although pleasant and unpleasant images had been equated for arousal based on IAPS norms, participants in this study rated unpleasant images as being more arousing than pleasant images ($p < .001$), which were in turn more arousing than neutral images ($p < .001$).

No group differences emerged between the CC and PV groups for the valence and arousal ratings during the reactivity or recovery phases of the ERRT (all ts < 1.43, ps $> .15$, see Table 3). Therefore these findings did not support the hypothesis that CC alters subsequent emotional reactivity to the unpleasant images relative to PV. Additional exploratory analyses investigating whether ratings of pleasant stimuli would differ between groups also revealed no significant differences between the CC and PV groups (all ts < 1.43, ps $> .15$, see Table 3).

Analyses of PASAT performance were assessed relative to ERRT ratings. PASAT performance improved for all participants. Correlations showed significant relationships between PASAT performance (percent correct) and valence ratings of unpleasant images during both the reactivity and recovery phases (the higher the PASAT performance, the

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Table 3. ERRT valence and arousal ratings

		Mean *(SD)*		Statistic[a]	
ERRT		CC ($n = 16$)	PV ($n = 19$)	*t* value/*r value*	*p* value
Valence ratings					
Unpleasant – Neutral					
	Reactivity	2.73(0.97)	2.50(1.61)	0.49	0.63
	Recovery	2.08(1.22)	1.97(1.61)	0.23	0.82
Pleasant – Neutral					
	Reactivity	−1.35(0.71)	−0.91(1.03)	−1.42	0.16
	Recovery	−0.81(0.87)	−0.77(0.82)	−0.11	0.92
Arousal ratings					
Unpleasant – Neutral					
	Reactivity	2.94(0.99)	2.31(1.49)	1.43	0.16
	Recovery	2.16(1.28)	1.90(1.39)	0.57	0.57
Pleasant – Neutral					
	Reactivity	2.09(1.00)	1.52(1.45)	1.33	0.19
	Recovery	1.30(1.36)	1.09(0.97)	0.53	0.60
PASAT performance –					
Valence correlations					
Unpleasant					
	Reactivity	7.45(.93)	−0.59	0.006	
	Recovery	6.70(1.36)	−0.61	0.005	
Pleasant					
	Reactivity	3.17(1.07)	0.43	0.04	
	Recovery	3.57(.97)	0.41	0.05	

Note: CC = Cognitive Control Tasks; PV = Peripheral Vision Task; ERRT = Emotional Reactivity and Recovery Task; Valence ratings 1–9, higher values = more pleasant ratings; Arousal ratings 1–9, higher values = greater arousal ratings; [a]$df = 33$.

less negative the ratings of unpleasant images; $r(17) = -0.59$, $p < .01$; $r(17) = -0.61$, $p < .05$) and pleasant images (the higher the PASAT performance, the more positive the ratings of pleasant images; $r(17) = 0.43$, $p < .05$; $r(17) = 0.41$, $p < .05$, see Table 3). These correlational results are consistent with the notion that the better one does on the PASAT, the more effective the buffering effect on subsequent affective challenges.

Dot probe task

Data from two participants were excluded from the dot probe task due to poor behavioural performance (e.g. greater than 10% responses greater than +/−3 standard deviations from the individuals' mean response rate). No group differences emerged between the CCT and PVT groups on the dot probe task ($t = -.02$, $p < .95$, $d = -.01$). Additionally, PASAT performance was not correlated with bias towards threatening stimuli ($r(24) = -.28$, $p > .25$).

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Discussion

We examined whether completing tasks requiring cognitive control (CC) in a healthy population would alter emotional reactivity to and recovery from pleasant and unpleasant stimuli after a negative mood induction relative to completing a peripheral vision (PV) task. Findings suggest that participants' responses to emotional stimuli were not consistently altered by the one session cognitive task exposure. However, their performance on the CC tasks was correlated on subsequent ratings of emotional images, indicating that the better they did on CC tasks (the greater the presumed pre-frontal activation as well as mastery), the more positive the emotional images were rated. Additionally, individuals undergoing CC reported a trend toward a lower induction of negative mood following mood induction (reflecting a medium effect size), but they also reported a greater loss of positive mood. These results are consistent with previous literature using the PASAT portion of the CC tasks as a negative mood induction (Holdwick and Wingenfeld, 1999) but may show some benefit of the CC tasks as a buffer from subsequent mood induction. As such, our study results may be influenced by a "side effect" of PASAT training (negative affect) that should be differentiated from the desired effects of enhancing frontal cognitive control and buffering from subsequent mood inductions. The differences between groups in negative mood ratings were only seen in the PANAS and not the VAS scales, which may be due to the PANAS being a more broad-based measure relative to the single dimensions of the VAS ratings. Nonetheless, no significant effects were evident on our measures of mood reactivity to negative images or on our measure of attentional bias. These results were not related to demographic differences between experimental groups, differential responses to the mood induction or the failure of the ERRT stimuli to elicit the expected emotional responses. These findings join a prior study by Watson and Purdon (2008), which indicated that one session of the Attention Control task (Wells, 2000) did not alter the frequency or distress associated with intrusive thoughts among a population of undergraduates reporting high obsessive-compulsive symptoms.

These overall null results do not support the idea that affective responding is altered by making healthy volunteers use their prefrontal cortex before the affective task. This observation could stem from a number of factors. First, prior studies supporting the efficacy of cognitive and/or attentional control training interventions have tested populations seeking treatment for clinically significant psychiatric problems including major depression (Siegle, Ghinassi et al., 2007; Papageorgiou and Wells, 2000) and anxiety-related disorders (Papageorgiou and Wells, 1998; Wells, 1990; Wells, White and Carter, 1997). In contrast, the present study recruited a healthy population and excluded individuals who self-reported moderate levels of depression. Although we hypothesized that the primed use of prefrontal control could protect individuals from heightened reactivity to unpleasant stimuli in the context of an affective challenge (the mood induction), it is also possible that our healthy population has intact premorbid prefrontal recruitment and thus is not influenced by one session of cognitive task exposure. Investigations with vulnerable populations likely to have baseline deficits in attentional control may yield more promising findings. As such, further research is necessary to evaluate whether these interventions are only useful among populations with clinical levels of illness or whether they may extend to healthy controls, "at risk" populations, and those who have recovered from prior illness episodes (e.g. remitted depressed individuals).

Second, this one-session cognitive training differed markedly from the repetitive multi-day training characteristic of neurobehavioural interventions. Further investigations will be necessary to ascertain the appropriate number of sessions necessary to alter emotional and cognitive processes in both clinical and healthy populations. Browning et al. (2010) has shown that significant changes in frontal activation can follow a single session of attentional training on the dot probe task, with testing within that same attentional domain. The success of single session training may rely on the exclusive focus on changing attentional strategy in the dot probe task as compared to the focus on modifying recruitment of cognitive control resources more broadly with the CC training. As shown in other studies, cross-task generalization may require much more extensive training (Owen et al., 2010). A longitudinal study design may also provide additional information above that of the cross sectional design used in the present study. Additional outcome measures associated with working memory as well as sustained attention may provide results more favourable than those seen on the dot probe task.

Third, our study involved a computerized task (ERRT) that measured many of our emotional reactivity dependent variables. Due to the time sensitivity of this task (participants had to make ratings within 3 seconds), 40% of participants' data on the ERRT had to be excluded because they had less than 50% response rate on any of the four dependent variables (emotional response/reactivity on valence/arousal). This is a significant limitation of the present study. Future adaptations of the ERRT could address this constraint.

Fourth, our study used a computer task as an active comparison condition. An active comparison condition (placebo computer task) was not used in the clinical study by Siegle, Ghinassi et al. (2007) and will be important in further clinical evaluations to minimize placebo effects and allow a more straightforward examination of the effects of the CCT training relative to other interventions. This study supports the feasibility of using a PV task as a relevant comparison condition.

It is not clear whether attention control interventions alter emotional responsivity in general or maladaptive responses to unpleasant stimuli in particular. The present study attempted to investigate this by including pleasant stimuli in the ERRT, and this may be a particularly promising route for investigations of depression that are characterized by hyporesponsivity to pleasant stimuli (Pizzagalli, Iosifescu, Hallett, Ratner and Fava, 2009). Does improved attentional control result in the inhibition of all emotional reactivity, resulting in decreased ratings of pleasant and unpleasant stimuli, or does improved attentional control allow participants to "release" attention from unpleasant stimuli and selectively linger on neutral or pleasant stimuli? It may be worthwhile testing whether the use of CCT during naturally occurring periods of affective challenge (e.g. when undergraduates are studying for final exams), results in a more promising outcome than when conducted during more affectively neutral situations following an affect induction.

The present study adds to an important developing literature on the nature and efficacy of the role of prefrontal control in affective reactivity and, more tangentially, to understanding necessary preconditions for neurobehavioural therapies. Specifically, this study suggests that several important methodological variables may affect the extent to which exposure to prefrontal control tasks is associated with changes in affective function including: the participant population, number of training sessions, the sensitivity of measures of affective change, and the comparison interventions.

References

Amir, N., Beard, C., Burns, M. and Bomyea, J. (2009). Attention modification program in individuals with generalized anxiety disorder, *Journal of Abnormal Psychology, 118*, 28–33.

Amir, N., Weber, G., Beard, C., Bomyea, J. and Taylor, C. T. (2008) The effect of a single-session attention modification program on response to a public-speaking challenge in socially anxious individuals, *Journal of Abnormal Psychology, 117*, 860–868.

Beck, A. T., Steer, R. A. and Brown, G. K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio, TX: Psychological Corporation.

Bradley, M. M. and Lang, P. J. (1994). Measuring emotion: the self-assessment mannequin and the semantic differential. *Journal of Behavioral Therapy and Experimental Psychiatry, 25*, 49–59.

Browning, M., Holmes, E. A., Murphy, S. E., Goodwin, G. M. and Harmer, C. J. (2010). Lateral prefrontal cortex mediates the cognitive modification of attentional bias. *Biological Psychiatry, 67*, 919–925.

Derryberry, D. and Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology, 111*, 225–236.

Drevets, W. C. (1998). Functional neuroimaging studies of depression: the anatomy of melancholia. *Annual Review of Medicine, 49*, 341– 361.

Elgamal, S., McKinnon, M., Ramakrishnan, K., Joffe, R.T. and MacQueen, G. (2007). Successful computer-assisted cognitive remediation therapy in patients with unipolar depression: a proof of principle study. *Psychological Medicine, 37*, 1229–1238.

Feldner, M. T., Leen-Feldner, E. W., Zvolensky, M. J. and Lejuez, C. W. (2006). Examining the association between rumination, negative affectivity, and negative affect induced by a paced auditory serial addition task. *Journal of Behavior Therapy and Experimental Psychiatry, 37*, 171–187.

Gronwall, D. M. A. (1977). Paced Auditory Serial-Addition Task: a measure of recovery from concussion. *Perceptual and Motor Skills, 44*, 367–373.

Gross, J. J. and Levenson, R. W. (1995). Emotion elicitation using films. *Cognition and Emotion, 9*, 87–108.

Gross, J. J. and John, O. P. (2002). Wise emotion regulation. In L.F. Barrett and P. Salovey (Eds.), *The Wisdom in Feeling: psychological processes in emotional intelligence, motions and social behavior* (pp. 297–319). New York: Guilford Press.

Gu, B. M., Park, J., Kang, D., Lee, S. J., Yoo, S. Y., Jo, H. J., Choi, C., Lee, J. and Kwon, J. S. (2008). Neural correlates of cognitive inflexibility during task-switching in obsessive-compulsive disorder. *Brain: A Journal of Neurology, 131*, 155–164.

Hazen, R. A., Vasey, M. W. and Schmidt, N. B. (2009). Attention retraining: a randomized clinical trial for pathological worry. *Journal of Psychiatric Research, 43*, 627–633.

Hofmann, S. G., Pollack, M. H. and Otto, M. W. (2006). Augmentation treatment of psychotherapy for anxiety disorders with D-cycloserine. *CNS Drug Review, 12*, 208–217.

Holdwick, D. J. Jr. and Wigenfeld, S. A. (1999). The subject experience of PASAT testing: does the PASAT induce negative mood? *Archives of Clinical Neuropsychology, 143*, 273–284.

Holmes, A. J. and Pizzagalli, D. A. (2008). Response conflict and frontocingulate dysfunction in unmedicated participants with major depression. *Neuropsychologia, 46*, 2904–2913.

Lang, P. J., Bradley, M. M. and Cuthbert, B. (1997). *International Affective Picture System*. Gainesville, Fl: NIMH Center for the Study of Emotion and Attention.

Larsen, R. J. and Diener, E. (1987). Affect intensity as an individual difference characteristic: a review. *Journal of Research in Personality, 21*, 1–39.

Lazeron, R. H., Rombouts, S. A., de Sonneville, L., Barkhof, F. and Scheltens, P. (2003). A paced visual serial addition task for fMRI. *Journal of Neurological Sciences, 213*, 29–34.

Liverant, G. I., Brown, T. A., Barlow, D. H. and Roemer, L. (2008). Emotion regulation in unipolar depression: the effects of acceptance and suppression of subjective emotional experience on the

intensity and duration of sadness and negative affect. *Behavior Research and Therapy, 46*, 1201–1209.

MacLeod, C. and Mathews, A. (1988). Anxiety and the allocation of attention to threat. *Quarterly Journal of Experimental Psychology, 40*, 653–670.

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G. and Holker, L. (2002). Selective attention and emotional vulnerability: assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology, 111*, 107–123.

Mathews, A. and MacLeod, C. (2002). Induced processing biases have causal effects on anxiety. *Cognition and Emotion, 16*, 331–354.

Meyer, T. J., Miller, M. L., Metzger, R. L. and Borkovec, T. D. (1990). Development and validation of the Penn State Worry Questionnaire. *Behavior Research and Therapy, 28*, 487–495.

Nolen-Hoeksema, S., Morrow, J. and Fredrickson, B. L. (1993). Response styles and the duration of episodes of depressed mood. *Journal of Abnormal Psychology, 102*, 20–28.

Ochsner, K. N. and Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Science, 9*, 242–249.

Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D. and Gross, J. J. (2004). For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. *NeuroImage*, *23*, 483–499.

Owen, A. M., Hampshire, A., Grahn, J. A., Stenton, R., Dajani, S., Burns, A. S., Howard, R. J. and Ballard, C. G. (2010). Putting brain training to the test. *Nature, 465*, 775–778.

Papageorgiou, C. and Wells, A. (1998). Effects of attention training on hypochondriasis: a brief case series. *Psychological Medicine, 28*, 193–200.

Papageorgiou, C. and Wells, A. (2000). Treatment of recurrent major depression with attention training. *Cognitive Therapy and Behavioral Practice, 7*, 407–413.

Pizzagalli, D. A., Iosifescu, D., Hallett, L. A., Ratner, K. G. and Fava, M. (2009). Reduced hedonic capacity in major depressive disorder: evidence from a probabilistic reward task. *Journal of Psychiatric Research, 43*, 76–78.

Ray, R. D., Oschsner, K. N., Cooper, J. C., Robertson, E. R., Gabrieli, J. D. E. and Gross, J. J. (2005). Individual differences in trait rumination and the neural systems supporting cognitive reappraisal. *Cognitive, Affective and Behavioral Neuroscience, 5*, 156–168.

Rottenberg, J., Gross, J. J. and Gotlib, I. H. (2005). Emotion context insensitivity in major depressive disorder. *Journal of Abnormal Psychology, 114*, 627–639.

Rottenberg, J., Ray, R. D. and Gross, J. J. (2007). Emotion elicitation using films. In J. A. Coan and J. B. J. Allen (Eds.), *Handbook of Emotion Elicitation and Assessment* (pp. 9–28). New York: Oxford University Press.

Siegle, G. J., Steinhauer, S. R., Thase, M. E., Stenger, V. A. and Carter, C. S. (2002). Can't shake that feeling: event-related fMRI assessment of sustained amygdala activity in response to emotional information in depressed individuals. *Biological Psychiatry, 51*, 693–707.

Siegle, G. J., Thompson, W., Carter, C. S., Steinhauer, S. R. and Thase, M. E. (2007). Increased amygdala and decreased dorsolateral prefrontal BOLD response in unipolar depression: related and independent features. *Biological Psychiatry, 61*, 198–209.

Siegle, G. J., Ghinassi, F. and Thase, M. E. (2007). Neurobehavioral therapies in the 21st century: summary of an emerging field and an extended example of cognitive control training for depression. *Cognitive Therapy and Research, 31*, 235–262.

Watson, D., Clark, L. A. and Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology, 54*, 1063–1070.

Watson, C. and Purdon, C. (2008). Attention training in the reduction and reappraisal of intrusive thoughts. *Behavioral and Cognitive Psychotherapy, 36*, 61–70.

Wells, A. (1990). Panic disorder in association with relaxation-induced anxiety: an attentional training approach to treatment. *Behavior Therapy, 21*, 273–280.

Wells, A. (2000). *Emotional Disorders and Metacognition Innovative Cognitive Therapy*. New York: Wiley.

Wells, A., White, J. and Carter, K. (1997). Attention training: effects on anxiety and beliefs in panic and social phobia. *Psychological Assessment, 9*, 227–284.

Appendix. International Affective Picture System (IAPS) images used in ERRT

Unpleasant images	IAPS #	Neutral images	IAPS #	Pleasant images	IAPS #
Pit bull	1300	Fan	7020	Ice cream	7270
Open grave	3005.1	Basket	7010	Money	8501
Mutilation	3225	Spoon	7004	Water slide	8496
Infant	3350	Tissue	7950	Sailboat	8170
KKK rally	9810	Shoes	7031	Liftoff	5450
Attack	3530	Butterfly	1602	Jaguar	1650
Tornado	5973	Birds	1419	Turkey	7230
Aimed gun	6230	Fish	7484	Puppies	1710
Snake	1120	Cow	1670	Lion	1720
Attack	6510	Man	2570	Skier	8190
Attack	6550	Girl	2320	Rafters	8400
Car accident	9902	Men	2397	Skydivers	8185
Roach on pizza	7380	Neut woman	2038	Astronaut	5470
Cemetery	9000	Woman	2620	Roller coaster	8490
Garbage	9340	Tourist	2850	Bungee	8179
Sliced hand	9405	Twins	2890	Hiker	5629
Soldier	9410	Factory worker	2393	Ice climber	8191
Duck in oil	9560	Elderly man	2480	Sky surfer	8186
Man on fire	9635.1	Teenager	2870	Gymnast	8470
Fire	9921	Neut girl	2440	Rafting	8370