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Does a high working memory capacity attenuate the negative impact of trait anxiety on attentional control? Evidence from the antisaccade task

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According to attentional control theory, high trait anxious individuals experience reduced attentional control as compared to low trait anxious individuals due to the imbalance between goal-directed and stimulus-driven attentional systems. One consequence is that high trait anxious individuals have difficulty resisting distraction, as compared to low trait anxious individuals. A separate line of research on individual differences in working memory capacity (WMC) has shown that individuals with higher WMC have better attentional control and thus are better able to resist distraction. The present study investigated the hypothesis that high WMC compensates for high trait anxiety in a task that evaluates the ability to resist distraction, the antisaccade task. Participants completed the State-Trait Anxiety Inventory to measure trait anxiety and the Operation Span and Reading Span tasks to measure WMC. As hypothesised, individuals who were high trait anxious exhibited increased attentional control on the antisaccade task when they had high WMC. Theoretical implications and directions for future research are discussed.

Keywords: Antisaccade task; Attentional control; Trait anxiety; Working memory capacity.

Anxiety is an aversive emotional state that occurs in situations of real or perceived threat. It is characterised by a sense of apprehension and worry that is typically concerned with potentially negative future outcomes (Otto, Calkins, & Hearon, 2010). Anxiety can be differentiated into state and trait anxiety. Trait anxiety is considered a personality dimension characterised by a stable and chronic propensity to experience moderate to high levels of anxiety, whereas state anxiety is a more acute and transient emotional experience of anxiety (Speilberger, 2010). State anxiety is typically triggered by an interaction between trait anxiety and situational stress, as high trait anxious individuals are more likely to experience a situation as threatening or anxiety provoking, and therefore are more likely to experience a state of anxiety than low trait anxious individuals (Eysenck & Calvo, 1992).

Researchers have long recognised the associations between attention and attentional processes and state and trait anxiety (e.g., Beck & Clark, 1997; Easterbrook, 1959). One theoretical framework that accounts for these associations is attentional

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control theory (Eysenck, Derakshan, Santos, & Calvo, 2007). This theory proposes that when individuals experience a situation as threatening and feel anxious, they widen the focus of their attention, so that detection of potential threat is facilitated. An additional claim is that anxiety reduces the influence of top-down goal-directed attention (guided by current goals), and as a result there is an increase in the influence of stimulus-driven attention (driven by salient sensory stimuli), thereby disrupting the balance between these two attentional systems. High trait anxious individuals are therefore predicted to experience less attentional control as compared to low trait anxious individuals because attention is more likely to be captured by irrelevant stimuli. One of the resulting impairments experienced by high trait anxious individuals is difficulty resisting distraction. Further, due to their reduced attentional control, high trait anxious individuals require more cognitive resources to attain comparable performance to low trait anxious individuals in tasks that require attentional control. That is, according to attentional control theory, high trait anxious individuals can attain a similar level of effectiveness (accuracy) as low trait anxious individuals, but their increased effort to attain the same level of accuracy affects their efficiency (speed of responding) in tasks that require resisting distraction (Eysenck et al., 2007).

The antisaccade task as a measure of attentional control

Researchers have employed a variety of paradigms to measure the ability to resist distraction in trait anxiety (see Eysenck et al., 2007, for a review). A well-established paradigm to measure the ability to override reflexive orienting to distracting stimuli is the antisaccade task (Hallett, 1978). This task requires participants to make a saccade (i.e., a fast eye movement) away from (an antisaccade) a visually salient peripheral cue that flickers at high frequency. Performance on the antisaccade task is typically compared to performance on the prosaccade task, in which the participant is required to make a saccade toward the peripheral cue. In some studies, the participant is also required to identify a target presented at the location of the cue or the location opposite the cue after they have made a saccade (e.g., Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009; Kane, Bleckley, Conway, & Engle, 2001), which is referred to as the target identification task. The prosaccade task is thought to reflect the prepotent or reflexive response to a salient peripheral cue (Hutton & Ettinger, 2006), whereas the antisaccade task evaluates the ability to suppress a reflexive saccade toward a salient peripheral cue (a distracting stimulus) and generate a voluntary saccade toward a static cue in the opposite location. The ability to resist distraction is indexed by both correct saccade latencies and errors on the antisaccade task, such that individuals who are slower and more error prone have more difficulty resisting the distracting stimulus and making a saccade in the correct direction. According to attentional control theory, high trait anxious individuals should perform more poorly on the antisaccade task than low trait anxious individuals because performance in this task requires attentional control and high trait anxiety impairs attentional control. For the prosaccade task no differences between high and low trait anxious individuals are predicted because the task involves the dominant, more reflexive response, and therefore requires minimal attentional control.

Derakshan et al. (2009) used the antisaccade task to test these contrasting predictions for antisaccade and prosaccade performance. They created groups of high and low trait anxious participants using scores on the State-Trait Anxiety Inventory (STAI; Speilberger, Gorsuch, & Lushene, 1970). As predicted, high trait anxious participants had significantly slower eye movement latencies on the antisaccade task (mean difference = 27 ms) than low trait anxious participants, whereas for the prosaccade task the high and low trait anxious groups did not differ (mean difference = 6 ms). Derakshan et al. found no corresponding difference between the trait anxious groups for latencies on the target identification task. In addition, Derakshan et al. did not find a group difference in the percentage of antisaccade errors. According to attentional control theory, high trait anxious individuals exert more effort and thus are slower to achieve the same performance (accuracy) as low trait anxious participants, which would explain why there would be a group difference in antisaccade latency, but not in antisaccade accuracy.

These results have been replicated in other studies that have examined anxiety and distraction with a focus on inhibitory functioning, using variations of the antisaccade task (e.g., Ansari & Derakshan, 2010, 2011a, 2011b). Ansari and Derakshan (2011a) found that as compared to low trait anxious participants, high trait anxious participants exhibited lower event-related potential (ERP) activity at frontocentral and central recording sites just prior to the onset of the to-be-inhibited target. In a second experiment using the antisaccade task with interleaved prosaccade and antisaccade trials Ansari and Derakshan (2011a) reported higher activity at frontal cortical sites in high trait anxious participants when given preparatory time prior to target onset, which suggests increased allocation of cognitive resources to prepare for inhibitory action. Taken together, these findings suggest that high trait anxious individuals exhibit impairments in inhibitory functioning (as demonstrated by lower cortical activity prior to inhibition of the target) and recruit more resources to engage in an inhibitory action (as demonstrated by higher activation when preparing for the inhibitory action). These results are in line with predictions made by attentional control theory.

Working memory capacity (WMC) and attentional control

WMC is a temporary form of storage that allows for the cognitive manipulation of information and thus determines what information is available for conscious use (Conway et al., 2005). WMC has been shown to affect attentional control in general (see Barrett, Tugade, & Engle, 2004, for a review) and susceptibility to distraction in particular (e.g., Kane et al., 2001; Unsworth, Schrock, & Engle, 2004). Researchers have used the antisaccade task to assess the influence of WMC on the ability to resist distraction (Kane et al., 2001; Unsworth et al., 2004). Kane et al. (2001) compared individuals with high and low WMC, as indexed by the Operation Span task (OSPAN; Turner & Engle, 1989), in two experiments that used the antisaccade task. They found that participants with high WMC performed faster on the antisaccade task and the target identification task than participants with low WMC. Participants with high WMC also made fewer errors on both the antisaccade and the target identification task than participants with low WMC. No group differences were found with the prosaccade task. Unsworth et al. (2004) replicated these results in a study that also examined saccade latencies and errors on the antisaccade and prosaccade tasks. These two studies indicate that individuals with high WMC are better able to resist distracting information than individuals with low WMC, as indexed by better performance on the antisaccade task.

Two studies have examined the interaction between WMC and anxiety on cognitive performance, although not with the antisaccade task. Johnson and Gronlund (2009) had participants perform a demanding short-term memory task that overloaded the phonological loop (Baddeley & Hitch, 1974); participants were instructed to attend to a secondary auditory tone discrimination task only if they had "spare effort." Johnson and Gronlund found that trait anxiety and WMC interacted to predict performance effectiveness (errors) on the discrimination task, such that the negative effects of anxiety were reduced for participants with high WMC. However, they did not find an interaction between WMC and trait anxiety for latencies with either task. These findings suggest that when demands on working memory are high, anxiety impairs accuracy, but this impairment is reduced in those who have high WMC.

On the other hand, a study investigating the interaction between WMC and performance pressure (i.e., monetary incentives and paired peer pressure) on math performance reached the opposite conclusion. Beilock and Carr (2005) found that participants with high WMC were most impaired by high-pressure situations (i.e., when in a state of anxiety). Specifically, on challenging math problems, the performance of participants with high WMC decreased under performance pressure (i.e., they made more errors), whereas the performance of participants with low WMC was not affected by performance pressure. It is not clear if the different conclusions reached in these studies is due to state versus trait anxiety (Johnson & Gronlund, 2009, were examining trait anxiety, whereas Beilock and Carr manipulated state anxiety), the different tasks used (see Ramirez, Gunderson, Levine, & Beilock, 2013, for an explanation based on different strategies used by high and low WMC individuals depending on task demands), or to the combined effect of these differences. What is clear is that more research is required to understand the impact of WMC and anxiety on attentional control. Indeed, we agree with Eysenck et al. (2007) that individual differences in WMC may be of "direct relevance to an understanding of anxiety and susceptibility to distraction".

The present study

The present study examined the hypothesis that WMC and trait anxiety interact in their influence on attentional control. Individual differences in cognitive functioning could account for an individual's susceptibility to anxiety-related deficits in distraction, and thus this is an important area of investigation to further our understanding of anxiety and the associated impairments in attentional control. The antisaccade task was used because of its documented ability to measure individual differences in the ability to resist distraction, and because it has been used in studies that have investigated both trait anxiety and attentional control, and, separately, WMC and attentional control. No previous study has combined these separate lines of inquiry and used the antisaccade task to test the hypothesis that WMC moderates the negative impact of anxiety on attentional control.

As noted, attentional control theory assumes that anxiety decreases attentional control, and therefore high trait anxious individuals are predicted to be more easily distracted than low trait anxious individuals. Attentional control theory further predicts that latency is compromised more than accuracy (errors) on tasks that require attentional control, and therefore high trait anxious individuals are expected to have longer latencies than low trait anxious individuals on the antisaccade task, but not the prosaccade task. With respect to antisaccade errors, the prediction is less clear because there is no straightforward way to determine whether antisaccade latencies have been affected more than errors (as is predicted by attentional control theory). Further, Derakshan et al. (2009) found no effect of trait anxiety on antisaccade errors, whereas Kane et al. (2001) and Unsworth et al. (2004) found that high WMC was associated with fewer errors on the antisaccade task. For these reasons we made no predictions for the pattern of antisaccade errors. Based on previous research that demonstrated an association between WMC and performance on the antisaccade task, it was predicted that high WMC would attenuate the negative influence of anxiety on antisaccade performance, whereas prosaccade performance would not be affected. That is, high trait anxious individuals would not experience as much impairment in antisaccade performance when they have high WMC, as compared to high trait anxious participants who have low WMC, given the documented association between high WMC and superior antisaccade performance (Kane et al., 2001; Unsworth et al., 2004).

METHOD

Participants

The participants were 174 University of Calgary undergraduate students between the ages of 18 and 50 ($M = 22$). Inclusion criteria were normal or corrected-to-normal vision and English as a first language. The majority of participants were female (79%). Participants received bonus course credit for their participation. The study was approved by the institutional research ethics board.

State-Trait Anxiety Inventory

Participants completed the STAI for adults (Speilberger et al., 1970). The STAI is a self-report measure that assesses both trait and state anxiety. The trait anxiety scale (A-Trait) measures the general propensity to experience a range of situations as threatening. The state anxiety scale (A-State) measures the level of anxiety experienced at a particular moment in time. Overall scores range from 20 to 80 on both scales, with higher scores indicating greater levels of anxiety. Both measures have high levels of internal reliability (>.89; Barnes, Harp, & Jung, 2002). Although both the trait and state version of the STAI were administered, the present study focuses on trait anxiety.

Working memory span tasks

Two measures of WMC were administered: modified versions of both the OSPAN (Turner & Engle, 1989) and the Reading Span task (RSPAN; Daneman & Carpenter, 1980). The OSPAN task requires participants to solve a series of math operations while they attempt to remember a set of unrelated words. Participants are shown a math problem and a to-be-recalled word (e.g., "Is (9/3) − 2 = 1? DOG"). The participant is asked to read the math problem aloud and say aloud whether the equation is correct or not ("yes" or "no"); then the participant reads the word aloud ("dog"). After the word is read aloud the experimenter toggles the next math problem and to-be-recalled word (e.g., "Is (8 × 4) + 2 = 34? HOLE"). This procedure is repeated until a prompt appears in the display that asks the participant to recall the words in the order in which they were presented (i.e., "dog," "hole").

The RSPAN task is similar to the OSPAN task. Participants are presented with a coherent or a nonsensical sentence and a to-be-recalled letter (e.g., "We were 50 lawns out at sea before we lost sight of land? M"). Half of the sentences are nonsensical, with the nonsensical word (e.g., "lawns") appearing equally as often in the beginning, middle, or end of the sentence. Similar to the OSPAN task, the participant reads the sentence aloud, verifies whether the sentence makes sense (a "yes" or "no" response), and then reads the letter aloud. A set of trials is defined by a number of trials (between two and five) that is followed by a recall cue, in which the participant is asked to recall the letters in the order that they were presented within the set.

For both tasks, the WMC score is the sum of recalled words (OSPAN) or letters (RSPAN) for all sets in which the entire set is recalled in the correct serial order. An accuracy of at least 85% on the processing ("yes"/"no") component of the task ("yes"/"no") is required to ensure that participants are performing the task as intended (see Conway et al., 2005). Participants who do not meet the 85% criterion are excluded from all analyses.

The OSPAN and RSPAN tasks have adequate reliability. Estimates of internal consistency range from .70 to .90 (Conway et al., 2005). The OSPAN task has demonstrated good test–retest reliability (.70 to .80; Conway et al., 2005), whereas the test–retest reliability of the RSPAN task is lower (.40 to .65; MacDonald, Almor, Henderson, Kempler, & Anderson, 2001). The OSPAN and RSPAN tasks have been shown to correlate well with one another (between .40 and .60; Conway et al., 2005) and both tasks predict performance on a large number of higher order cognitive tasks (see Ilkowska & Engle, 2010).

Prosaccade and antisaccade tasks

Each trial began with the presentation of a fixation marker in the centre of a computer display and two white square cues positioned horizontally 11° of visual angle to the left and right of the fixation marker (see Figure 1). The fixation marker and the cues were displayed for a randomly determined interval of between 600 and 2,200 ms (in 200-ms increments). Then, one of the two cues flickered for 400 ms. The eye tracker was programmed such that a trial started only if a participant's eyes were fixating the fixation marker. For the prosaccade task, participants were instructed to make an eye movement toward the flickering cue; for the antisaccade task participants were instructed to make an eye movement away from the flickering cue to the cue location on the other side of the fixation marker. For both tasks participants were instructed to make their eye movements as quickly and as accurately as possible. Immediately following the offset of the flickering cue a target (a ↑ or ↓) appeared at one of the two cue locations: at the location of the flickering cue in the prosaccade task and at the location opposite the flickering cue in the antisaccade task. A double-headed arrow (↕) appeared in the non-target location to prevent the participant from using an empty space to determine where the target was presented. Participants were asked to identify, by key press, as quickly and as accurately as possible, whether the target pointed up (↑) or a down (↓). The target was presented until a response was made, and target identification latencies were measured to the nearest millisecond. The purpose of the target identification task was to motivate participants to perform well on the prosaccade and antisaccade tasks, and for this reason the target identification data are a good index of participants' performance on these tasks.

Equipment and procedure

Participants' eye movements were monitored using an EyeLink 1000 eye-tracking device (SR Research Ltd). The device consists of a desk-mounted camera and infrared illuminator that tracks the pupil and corneal reflections of one eye at a rate of once per millisecond (1000 Hz). Chin and forehead rests were used to position the head approximately 65 cm away from the computer display. Participants completed a total of 352 antisaccade and prosaccade trials, consisting of 4 sets of 80 trials, which alternated sets of prosaccade and antisaccade trials, each preceded by 8 practice trials. Trials were blocked such that only one task type occurred per trial set (e.g., 80 antisaccade trials, followed by 80 prosaccade trials or vice versa) and these were counterbalanced across subjects. Within each 80-trial set the flickering cue was equally likely to appear to the right or left of fixation. For each task, the target arrow pointing up (↑) was presented equally as often as target arrow pointing down (↓).

Following the antisaccade and prosaccade tasks, the STAI was administered on a separate

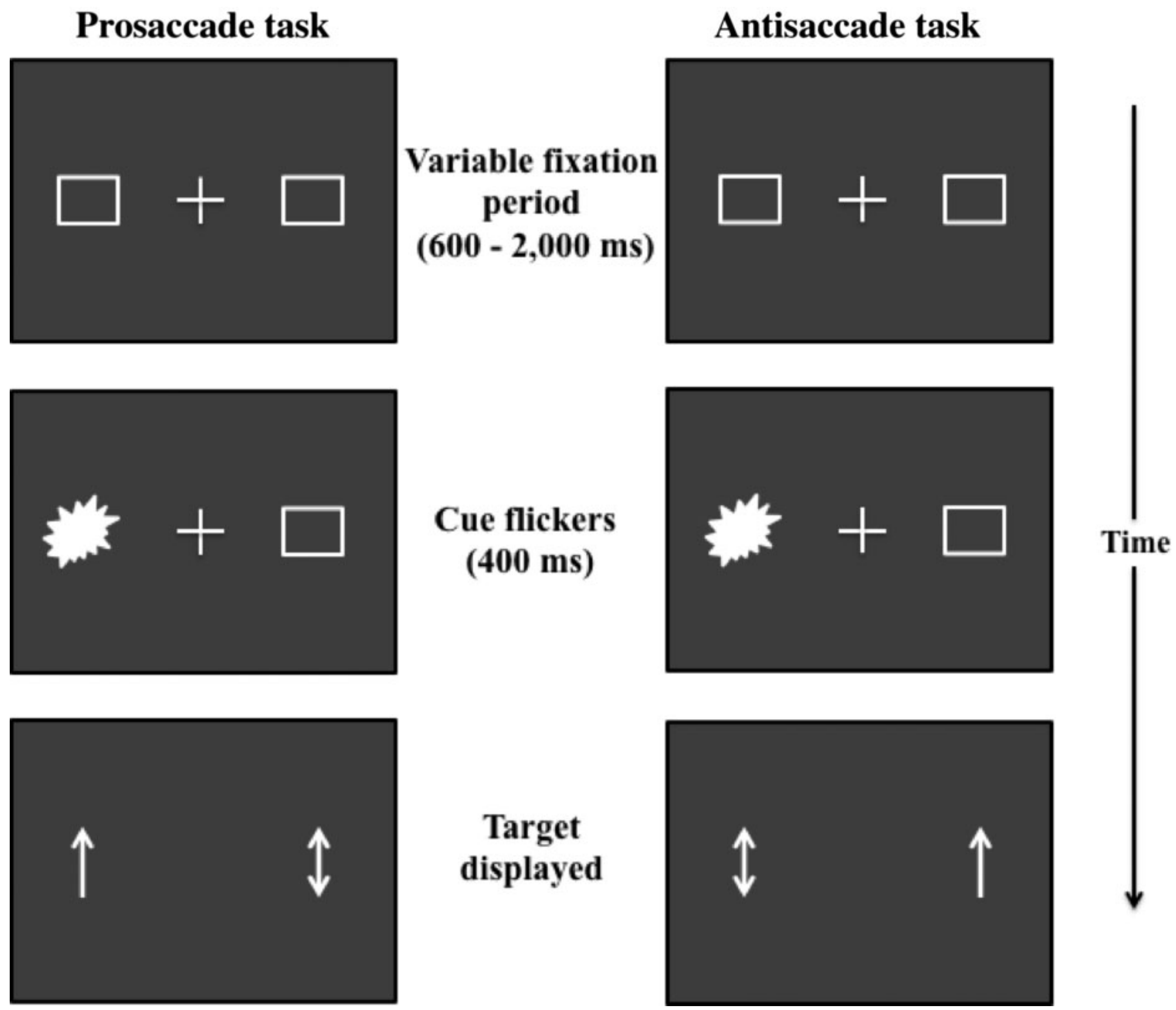

Figure 1. Antisaccade and prosaccade tasks.

computer, after which the participant completed the OSPAN and RSPAN tasks (counterbalanced for order across subjects). The OSPAN and RSPAN trials were presented in sets of two, three, four and five; the trials in each set were presented in a random order. A total of 42 trials were presented (three sets of two, three, four and five trials in each set). The different set sizes were presented randomly to each participant, so that the number of words to be recalled was not known prior to the recall prompt.

Data preparation

Working memory. Four participants were missing RSPAN data due to computer malfunctions. The data from nine participants were excluded because they did not meet the 85% accuracy criterion employed by other investigators to score the OPSPAN and RSPAN tasks (e.g., Kane et al., 2001; Unsworth et al., 2004). All-or-nothing load scoring was employed for the OSPAN and RSPAN tasks (see Conway et al., 2005). This procedure is commonly employed in studies examining individual differences in working memory (e.g., Kane et al., 2001; Unsworth et al., 2004; see Conway et al., 2005, for a detailed description of this scoring method). Total scores ranged from 0 to 42.

Eye-movement data. A fixation was defined as an eye-movement that remained stationary for 100 ms and was not followed or preceded by a blink. For each trial the first saccade (which ended in a fixation) after the onset of the flickering cue was examined. The trial was classified as correct if the first saccade was in the appropriate direction (toward the flickering cue in the case of prosaccade trials and toward the cue location opposite the flickering cue in the case of antisaccade trials). Trials were classified as incorrect if the eye movement was in the inappropriate direction or an eye movement was made outside the two cue areas. Trials were classified as missing if no eye movement was made throughout the trial.

Data from seven participants were excluded due to persistent eye-tracking failures. The eye-movement data were inspected for missing data, and another seven participants were excluded because they did not make an eye movement on more than 40% of trials. For the remaining participants, trials with no eye movements made up 6% of trials. Missing trials were excluded from all analyses. Trials with correct eye movements (antisaccade or prosaccade) were subjected to a non-recursive outlier identification procedure (Van Selst & Jolicoeur, 1994). For each participant, trials with saccade latencies 2.5 *SD* away from greater than or less than the mean of all trials in each condition (task: antisaccade vs. prosaccade; block: 1 vs. 2) were excluded. Outliers represented 1.7% of all trials. To reduce the influence of unusual and extreme values on the analyses, participants were classified as outliers if their mean latencies or percent errors for each task were greater than or less than 3 *SD* from the sample means (eight participants were excluded: two as outliers for latencies and six as outliers for errors). (A more conservative 3 *SD* was used for subject outliers because more data are lost through exclusion of subject outliers than trial outliers.)

Target identification data. Target identification latencies were analyzed for correct saccade trials only (i.e., trials in which a saccade was made in the correct direction). As before, outliers for each participant were removed by excluding trials with latencies 2.5 *SD* greater than or less than the mean of all trials in each condition. Outliers represented 2.1% of total target identification trials, and there was no difference in the number of trials excluded for high or low trait anxious participants. Participants were classified as outliers if their latency or percent errors on the target identification task were less than or greater than 3 *SD* from the sample mean (for either the prosaccade or the antisaccade target trial). In total, 16 participants were removed as outliers because of saccade or target identification performance. Thirty-eight percent of subject outliers had low trait anxiety scores, 6% had high trait anxiety scores and the remainder fell between these extremes.

RESULTS

Correlations between trait anxiety and the working memory measures are discussed later. For group analyses, high and low trait anxiety groups were created using a quartile split on the STAI-T anxiety scores. An analysis of variance (ANOVA) was used to analyze group differences on the antisaccade and prosaccade tasks. To capitalise on the continuous nature of the OSPAN and RSPAN measures of WMC, multiple regression analyses were used to test for an interaction between WMC and trait anxiety.

Correlations for the entire sample

Trait anxiety was not significantly correlated with OSPAN or RSPAN scores ($r = -.08$, $df = 132$ and $r = -.03$, $df = 128$; respectively). As expected, the OSPAN and RSPAN scores were positively correlated ($r = .43$, $p < .001$, $df = 128$), and this correlation was consistent with the correlations of between .40 and .60 reported by Conway et al. (2005).

Group analyses of trait anxiety

Like Derakshan et al. (2009), high and low trait anxious groups were created to examine the association between trait anxiety (measured by the STAI) and attentional control (measured by the antisaccade task). As noted, the high and low trait anxiety groups were created using a quartile split of trait anxiety scores of the entire sample ($N = 134$). This resulted in 35 individuals in the high trait anxiety group (mean STAI-T = 54.20, $SD = 4.00$) and 35 individuals in the low trait anxiety group (STAI-T = 30.80, $SD = 3.69$). Note that the mean STAI-T scores of the high and low trait anxiety groups were very similar to the mean STAI-T scores of Derakshan et al.'s high and low trait anxiety groups ($M = 49.50$, $SD = 5.05$ and $M = 30.30$, $SD = 2.88$; respectively). Table 1 lists the descriptive statistics for the high and low trait anxious groups.

TABLE 1
Participant characteristics for high and low trait anxious groups

	Low trait anxious group	*High trait anxious group*
N	35	35
Age	21 (3.3)$_a$	22 (2.4)$_a$
STAI-T	30.8 (3.7)$_a$	54.2 (4.0)$_b$
STAI-S	24.6 (4.5)$_a$	47.7 (10.6)$_b$
OSPAN	15.9 (8.6)$_a$	13.5 (5.4)$_b$
RSPAN	18.8 (8.3)$_a$	18.3 (6.7)$_a$

Standard deviations in parentheses.
Means in the same row with the same subscript are not significantly different at $p < .05$.
STAI-T, State-Trait Anxiety Inventory–Trait version; STAI-S, State-Trait Anxiety Inventory–State version; OSPAN, Operation Span task; RSPAN, Reading Span task.

Trait anxiety and attentional control

To examine the effect of trait anxiety on attentional control, mixed-model factorial ANOVAs were used to analyze saccade latencies and saccade errors. Preliminary analyses tested for interactions between task order (antisaccade task first vs. prosaccade task first) and the other factors of interest (Anxiety Group and Task), given that Kane et al. (2004) reported such interactions. There were no interactions in these preliminary analyses (all Fs < 1), and so the analyses reported below were conducted without consideration of task order.

It was predicted that trait anxiety would interact with task for saccade latencies. No predictions were made for the effect of trait anxiety on saccade errors because there is no straightforward way to determine whether antisaccade latencies have been affected more than errors, as would be predicted by attentional control theory. Further, Derakshan et al. (2009) found no effect of trait anxiety on antisaccade errors, whereas Kane et al. (2001) and Unsworth et al. (2004) found that high WMC was associated with fewer errors on the antisaccade task.

Trait anxiety and saccade latencies. The main analysis was a mixed-model ANOVA with Anxiety Group (high vs. low) and Task (prosaccade vs. antisaccade) as factors and saccade latencies as the dependent variable. The prosaccade and antisaccade latencies are listed in Table 2. As expected, there was a main effect of Task, $F(1, 68) = 220.06, p < .001, MSE = 222402.86$, partial $\eta^2 = .76$, with longer latencies for the antisaccade task (436 ms) than the prosaccade task (356 ms). There was no effect of Anxiety Group, $F(1, 68) = 1.20, p > .20, MSE = 6637.83$, partial $\eta^2 = .02$, as the high and low trait anxiety groups had similar overall latencies (403 and 389 ms, respectively). Most important was the significant interaction between Anxiety Group and Task, $F(1, 68) = 6.00, p < .05, MSE = 6058.86$, partial $\eta^2 = .08$. The high and low trait anxiety groups had virtually identical prosaccade latencies (356 and 355 ms, respectively), whereas the high trait anxiety group had slower antisaccade latencies than the low trait anxiety group (449 vs. 422 ms). This is the same interaction that Derakshan et al. (2009) observed in their data.

The interaction was followed up by comparing the two groups on their antisaccade latencies, controlling for prosaccade latencies. To control for prosaccade latencies, prosaccade latencies were used as a covariate in an analysis of covariance (ANCOVA) that compared the antisaccade latencies of the two groups. By controlling for prosaccade latencies, the two groups were equated on the speed with which they were able to make a saccade, likely a key consideration given that longer prosaccade latencies were associated with longer antisaccade latencies ($r = .68, p < .01, df = 132$). This analysis therefore ruled out the possibility that the high trait anxious individuals were slower on the antisaccade task merely because their overall saccade latencies were slower. It also provided a more sensitive test for a group difference by reducing the within-group error variance. As expected, the effect of the prosaccade latency covariate was significant, $F(1, 67) = 63.45, p < .001, MSE = 122857.14$, partial $\eta^2 = .49$. The ANCOVA also revealed a significant main effect of group, $F(1, 67) = 6.32, p < .05$,

TABLE 2
Saccade and target identification data for high and low trait anxious groups

	Task	*Low trait anxious group Mean (SD)*	*High trait anxious group Mean (SD)*
Saccade latencies	Anti	422 (60)	449 (61)
	Pro	355 (56)	356 (50)
Saccade errors	Anti	10.8 (10.7)	9.5 (8.4)
	Pro	3.4 (3.8)	2.7 (3.8)
Target identification latencies	Anti	557 (99)	572 (111)
	Pro	491 (90)	495 (103)
Target identification errors	Anti	4.1 (2.6)	4.2 (3.5)
	Pro	2.6 (2.1)	2.7 (2.5)

Errors, percent errors; *SD*, standard deviation.

MSE = 12230.98, partial η^2 = .09. High trait anxious individuals were significantly slower on the antisaccade task (adjusted *M* = 450 ms) than low trait anxious individuals (adjusted *M* = 423 ms). This outcome confirmed that high trait anxiety was associated with slower antisaccade latencies even when individual differences in the speed of saccade generation were taken into account.[1]

Trait anxiety and saccade errors. A mixed-model ANOVA with the percentage of saccade errors as the dependent variable revealed a main effect of Task, $F(1, 68) = 56.08$, $p < .001$, $MSE = 1760.98$, partial $\eta^2 = .45$, no main effect of Anxiety Group ($F < 1$), and no Anxiety Group × Task interaction ($F < 1$).

Summary of Anxiety Group × Task analyses. To summarise, these group analyses nicely replicate the findings of Derakshan et al. (2009). Our analyses of the saccade latencies produced the same Anxiety Group × Task interaction that Derakshan et al. reported, with the high trait anxious participants having slower antisaccade latencies than the low trait anxious participants, whereas for prosaccade latencies there was no group difference. In addition, like Derakshan et al. (2009), there was no Anxiety Group × Task interaction for saccade errors. These findings are consistent with the idea that anxiety leads to increased use of cognitive resources and affects latency (but not errors) on tasks that require attentional control (Eysenck et al., 2007).

Trait anxiety, WMC, and attentional control

To test the prediction that high WMC attenuates the negative impact of high trait anxiety on attentional control, multiple linear regression was used to analyze the antisaccade latencies. Trait anxiety group (dummy coded), working memory measures (either OSPAN or RSPAN score) and the Anxiety Group × WMC interaction term were used as predictors. The interaction was the key effect in these analyses, as an interaction between trait anxiety and WMC for antisaccade performance would be expected if higher WMC has a protective effect for high trait anxious individuals. Hierarchical regression was used so that prosaccade latencies could be entered as a covariate, given that they were highly correlated with antisaccade latencies ($r = .68$, $p < .001$, $df = 132$). As recommended by Aiken and West (1991), the moderator variables (OSPAN and RPSAN scores) and the interaction term were centred for the purpose of the analysis.

OSPAN and antisaccade latencies. Prosaccade latency was entered as a covariate in the first step of the regression. In the second step, Anxiety Group, OSPAN scores and the Anxiety Group × OSPAN interaction term were entered simultaneously. Prosaccade latency was a significant covariate, $F(1, 68) = 59.07$, $p < .001$ ($B = .80$, $\beta = .68$, $p < .001$).With Anxiety Group, OSPAN scores, and the interaction term entered, the prediction model was statistically significant, $F(4, 64) = 17.44$, $p < .001$, $R^2 = .72$, adjusted $R^2 = .49$. The Anxiety Group predictor was significant ($B = 25.51$, $\beta = .21$, $p < .05$), such that high trait anxiety was associated with longer antisaccade latencies. The Anxiety Group × OSPAN interaction was not significant ($B = -1.49$, $\beta = -.09$, $p > .20$). Thus, OSPAN scores did not moderate antisaccade latencies for either trait anxious group, contrary to the prediction that high WMC would attenuate the negative influence of anxiety on antisaccade performance.

RSPAN and antisaccade latencies. RSPAN data for 3 of the 70 participants were missing due to computer malfunctions. Prosaccade latency was a significant covariate, $F(1, 65) = 79.18$, $p < .001$, $R^2 = .74$, adjusted $R^2 = .54$ ($B = .91$, $\beta = .74$, $p < .001$). With Anxiety Group, RSPAN scores, and the interaction term entered on the second step, the prediction model was statistically significant, $F(4, 62) = 24.69$, $p < .001$, $R^2 = .78$, adjusted $R^2 = .59$. Most important, the Anxiety Group × RSPAN interaction was significant ($B = -3.24$, $\beta = -.25$, $p < .05$). As can be seen in Figure 2, the interaction reflected the fact that the difference between the high and low trait anxiety groups for antisaccade latencies was modulated by WMC—for lower

[1] The target identification component of the task was not expected to be affected by attentional control abilities, but for completeness we report the analyses of the target identification latencies and errors. A mixed-model ANOVA with target identification latencies as the dependent variable produced a main effect of Task, $F(1, 68) = 85.55$, $p < .001$, $MSE = 179322.22$, partial $\eta^2 = .56$, no effect of Anxiety Group ($F < 1$), and no Anxiety Group × Task interaction ($F < 1$). The identical analysis of the percentage of target identification errors also produced a main effect of Task, $F(1, 68) = 28.57$, $p < .001$, $MSE = 77.14$, partial $\eta^2 = .30$, no effect of Anxiety Group ($F < 1$), and no Anxiety Group × Task interaction ($F < 1$).

RSPAN scores, the high trait anxious participants had longer antisaccade latencies than the low trait anxious participants, whereas for higher RSPAN scores the difference between high and low trait anxious participants was substantially reduced. Thus, high WMC (as measured by the RSPAN task) decreased the negative impact of high trait anxiety in a task that requires attentional control.[2] The discrepancy between the OSPAN and RSPAN regression analyses is considered in the Discussion.

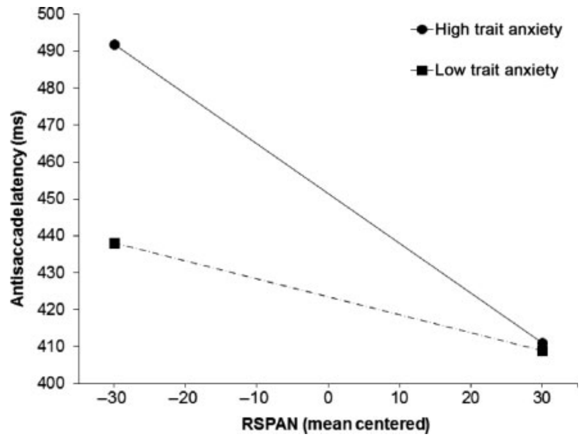

Figure 2. Regression lines for high and low trait anxiety groups, showing the RSPAN × Trait Anxiety interaction for antisaccade latencies. A value of zero (0) for mean-centred RSPAN reflects the average RSPAN value.

DISCUSSION

The purpose of the this study was to investigate the hypothesis that high WMC attenuates the negative impact of trait anxiety on attentional control. This was accomplished by examining the impact of WMC on the ability to resist distraction, as measured by the antisaccade task, in high and low trait anxious individuals. According to attentional control theory (Eysenck et al., 2007), WMC is expected to be an important modulator of the negative effects of anxiety on distractibility. This was the first study to directly test this possibility.

Like Derakshan et al. (2009), we found that high trait anxious individuals were slower on the antisaccade task (a task that requires attentional control) than low trait anxious individuals, whereas there was no group difference for the prosaccade task (a task that does not place demands on attentional control). The group difference for antisaccade latencies was preserved when prosaccade latencies were controlled for in the analysis to account for individual differences in the speed of saccade generation. This finding supports attentional control theory's prediction that anxiety impairs latency on tasks that require attentional control. Also consistent with the results of Derakshan et al. (2009) was the absence of an effect of trait anxiety on antisaccade accuracy (as assessed by the antisaccade error data). The fact that anxiety impaired antisaccade latency but not antisaccade accuracy is an important result for attentional control theory, because the theory predicts that accuracy is affected only when there is a significant demand (such as a load) on attentional control/WMC. Thus, it is possible that the antisaccade task is not sufficiently demanding to produce negative effects on accuracy in high trait anxious individuals. This is a possibility that should be explored in future research.

With respect to the hypothesis that high WMC attenuates the negative impact of trait anxiety on attentional control, the regression analyses revealed that for high trait anxious individuals, higher WMC, as measured by the RSPAN task, increased their ability to resist distraction. More specifically, the analyses showed that high trait anxious individuals with lower RSPAN scores were slower on the antisaccade task than low trait anxious individuals with lower RSPAN scores, whereas the performance of high trait anxious individuals with higher RSPAN scores was similar to that of low trait anxious individuals with higher RSPAN scores. These results indicate that for individuals with high levels of trait anxiety, higher WMC makes it easier to resist distraction and thereby confers a "protective" benefit.

In contrast to the results with RSPAN scores, we did not find an analogous interaction between trait anxiety and WMC when WMC was measured with OSPAN scores. This outcome is, of course, rather surprising, given that both the RSPAN and the OSPAN tasks purport to measure WMC. As previously noted, however, in our sample the

[2] We created a composite measure of WMC (using the mean of the standardised OSPAN and RSPAN scores) and used this predictor in the same regression analysis of antisaccade latencies. Using this composite measure, the Anxiety Group × RSPAN/OSPAN interaction was marginally significant ($B = -27.98$, $\beta = -.190$, $p = .05$). The nature of the interaction was identical to the one observed in the RSPAN regression analysis (the difference between the groups' antisaccade latencies decreased as scores on the RSPAN/OSPAN composite measure increased). This outcome suggests that this interaction is present for both measures of WMC, but that it is weaker for the OSPAN measure.

correlation between the RSPAN and OSPAN measures was quite modest (r = .43). A close examination of the OSPAN regression data did reveal that high trait anxious participants with higher OSPAN scores had faster antisaccade latencies than high trait anxious participants with lower OSPAN scores, although, as noted, this difference was not statistically significant. It may be that the statistical power to detect this interaction was reduced due to a restriction of range in the high trait anxious group. Indeed, OSPAN scores were significantly lower in the high trait anxious group than in the low trait anxious group, unlike the RSPAN scores (Table 1). We suspect that the mathematical operations in the OSPAN task may be anxiety provoking in high trait anxious individuals, leading to an underestimation of their WMC. For this reason, the RSPAN task may be a better measure of WMC in an anxious population. This is an important consideration for future research.

An interesting question for future research is whether higher WMC attenuates the negative impact of anxiety when a cognitive load is present. Recently, Berggren, Richards, Taylor, and Derakshan (2013) found that a cognitive load negatively impacts the performance of high trait anxious individuals on the antisaccade task. Given our finding that higher WMC attenuates the negative impact of trait anxiety on antisaccade performance, incorporating a cognitive load manipulation into the antisaccade paradigm would allow one to further explore the relationships between trait anxiety, WMC, and attentional control.

Recent research has shown that WMC is associated with the ability to suppress neutral stimuli (e.g., a white bear) and personally relevant obsessional thoughts (Brewin & Beaton, 2002; Brewin & Smart, 2005). Brewin et al. found that higher WMC was related to more effective thought suppression in non-clinical samples. Another recent study demonstrated an association between self-reported attentional control and perseverative worry in a sample of individuals with generalised anxiety disorder (Armstrong, Zald, & Olatunji, 2011). Given the previous research that suggests associations between WMC/attentional control and symptoms of anxiety, a potentially important theoretical implication derived from our findings is that individuals who are high trait anxious and have lower WMC may be more susceptible to symptoms of anxiety that are associated with poor attentional control (i.e., intrusive thoughts, worry). Indeed, Brewin and Beaton (2002) raised the possibility that WMC may account for some of the variance in treatment response. For example, in the case of anxious individuals, lower WMC may reduce the ability to suppress competing cognitions while new appraisals and coping strategies are considered. Cognitive training to increase WMC may therefore be a beneficial supplement in the clinical treatment of anxiety (e.g., Klingberg, 2010; although see Shipstead, Redick, & Engle, 2012).

One limitation of the present study concerns the possible influence of state anxiety on antisaccade performance (also a limitation of related studies; e.g., Derakshan et al., 2009). As expected, trait and state anxiety were highly correlated in our sample (r = .78 in the entire sample, and r = .86 when considering the high and low trait anxious participants only). Not surprisingly then, there was a significant difference between the trait anxiety groups on state anxiety scores, with the high trait anxious individuals having significantly higher state anxiety scores. It was not possible with the present design to delineate the unique effects of state and trait anxiety on attentional control. However, current research suggests that trait anxiety exerts its effects on executive control (top-down processing), whereas state anxiety affects alerting and orienting networks of attention (bottom-up processing). For example, Pacheco-Unguetti, Acosta, Callejas, and Lupianez (2010) used the Attention Network Test (Fan, McCandliss, Sommer, Raz, & Posner, 2002) to assess three networks of attention: alerting, orienting, and executive control, at various levels of trait and state anxiety. High trait anxiety was associated with difficulty in the executive control network (as measured by the Attention Network Test), whereas high state anxiety was associated with over-functioning alerting and orienting networks. In addition, neuroimaging research (e.g., Bishop, 2008) has shown that higher trait anxiety is associated with decreased use of prefrontal resources, known to be important in cognitive control mechanisms. All of these findings are consistent with the interpretation that it is trait anxiety that negatively impacts attentional control. Nevertheless, one direction for future research is to experimentally manipulate state anxiety in high and low trait anxious participants to determine which type of anxiety affects attentional control as indexed by antisaccade performance.

To conclude, there were two main findings in the present study. First, our results confirmed those of Derakshan et al. (2009); namely, that high trait anxiety negatively affects antisaccade latencies, but not antisaccade accuracy. This outcome lends support to one of the key predictions of attentional control theory (Eysenck et al., 2007). Second, our results demonstrate that high WMC (as measured by the RSPAN task) has a protective effect for high trait anxious individuals on their ability to resist distraction, a crucial requirement for maintaining attentional control. It will be important to extend this finding to other tasks that require attentional control and to a clinical sample. A key question for future research is whether the interaction between anxiety and WMC has implications for the severity of certain anxiety symptoms.

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