State Anxiety Impairs Attentional Control When Other Sources of Control are Minimal

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Abstract

Research suggests anxiety impairs attentional control; however, this effect has been unreliable. We argue that anxiety's impairment of attentional control is subtle, and can be obscured by other non-emotional sources of control. We demonstrate this by examining *conflict adaptation*, an enhancement in attentional control following a trial with high conflict between distracter and target stimuli. Participants completed a Stroop task featuring incongruent (e.g. RED in green font; high conflict) and control (e.g. +++ in green font; low conflict) trials. More state anxious participants showed greater Stroop interference following control trials, but interference was uniformly low following incongruent trials. This suggests state anxiety can impair attention, but other sources of top-down control – such as conflict adaptation – can easily overcome this impairment. This is consistent with recent theories of anxious cognition, and shows that anxiety researchers must attend to the dynamics and sources of attentional control.

Keywords: Anxiety; attentional control; Stroop; conflict-adaptation; reactive control

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It has long been suggested that anxiety impacts negatively upon cognitive performance, and particularly upon attention and cognitive control (see Eysenck, Derakshan, Santos, & Calvo, 2007, for a review). While most anxiety research has focused on anxious individuals' performance in the presence of potential threats, it is perhaps more important to understand anxious individuals' performance in 'cold', non-affective contexts: a general deficit in cognitive control will affect performance whether or not threats are present. Attentional control theory (Eysenck et al., 2007) suggests that anxiety disrupts top-down endogenous control of attention, by impeding the inhibition and shifting functions of the central executive. Evidence for this comes from studies suggesting anxiety impairs performance on inhibition tasks (Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009) and task-switching (Derakshan, Smyth, & Eysenck, 2009). However, this impairment can be moderated by individual differences, for example different clinical groups may show different patterns of impairment (Dorahy, McCusker, Loewenstein, Colbert, & Mulholland, 2006).

Probably the most favoured method for assessing attentional control is the Stroop task (Stroop, 1935). In this task, participants must quickly identify the font colour of words, while ignoring the word meaning. *Stroop interference* refers to slower responses to *incongruent* trials (e.g. the word RED presented in green font) compared to *congruent* (GREEN in green font) or *control* (+++ in green font) trials. Stroop interference therefore provides an index of selective attention, the ability to pay attention to one aspect of a stimulus while ignoring another. Specifically, it provides an index of inhibition, the ability to inhibit processing of and responding to salient but task-irrelevant stimuli (Miyake et al., 2000). Previous findings on Stroop interference and anxiety have been inconsistent. Basten, Stelzel and Fiebach (2011) and Hopko, Hunt and Armento (2005) found that trait anxiety (the predisposition to experience anxiety; Spielberger, Gorsuch, & Lushene, 1970) correlated positively with Stroop interference; however, Alansari (2004) and Warren and colleagues (2013) reported null results. Similarly, some studies found that state anxiety (a currently-present anxious mood) and stress reduced Stroop interference (Booth & Sharma, 2009), where others found null effects (Kofman, Meiran, Greenberg, Balas, & Cohen, 2006).

Further complicating this picture, there is some evidence that state and trait anxiety might have different effects on cognitive performance. For example, Pacheco-Unguetti, Acosta, Callejas, and Lupiáñez (2010) found that state anxiety was associated with attentional orienting towards salient stimuli, whereas trait anxiety was more associated with a general weakness in top-down attentional control. This specific association between trait anxiety and poor attentional control is not predicted by attentional control theory, which assumes that trait anxiety is simply a predisposition towards experiencing state anxiety (Eysenck et al., 2007; Spielberger et al., 1970), implying that the two types of anxiety should have similar effects on performance. However, this distinction between trait and state anxiety effects has not been thoroughly studied in the context of the Stroop task.

We reasoned that state and/or trait anxiety might generally affect inhibitory attentional control in the presence of neutral stimuli, but its effects might be subtle. Eysenck et al. (2007) argued that anxious people may sometimes work harder to maintain adequate performance on tasks. They may perform as effectively, but less efficiently, than less anxious people: where high anxious people have the motivation and opportunity to exert extra control when needed, high and low anxious people’s performance may be indistinguishable (Hayes, MacLeod, & Hammond, 2009). Analogously, we suspected that anxiety’s effects on attentional control might be most apparent where other top-down influences on control are minimal (see Booth & Sharma, 2009).

To test this idea, we examined anxiety's relationship with an effect variously called the *conflict adaptation effect*, the congruency sequence effect, or the Gratton effect. This refers to the fact that, in an interference task like the Stroop, interference on trials following an incongruent trial is reduced relative to interference on trials following a congruent trial. Although low-level learning and stimulus-repetition effects contribute to this reduction in interference (Notebaert, Gevers, Verbruggen, & Liefooghe, 2006), with experimental or statistical control (Notebaert et al., 2006; Notebaert & Verguts, 2007) it is possible to isolate the conflict adaptation component. This component represents top-down modulation of attentional selectivity, in response to recently-experienced conflict between word and colour. Since top-down attentional control is boosted following an incongruent trial, we predicted that anxiety's effects on attentional control might be less apparent on trials following an incongruent trial, and more apparent on trials following a control trial.

A similar approach has been employed by Osinsky and colleagues (Osinsky, Alexander, Gebhardt, & Hennig, 2010; Osinsky, Gebhardt, Alexander, & Hennig, 2012) to examine dynamic attentional control in trait anxiety. They found ERP evidence that high anxious participants increased attentional control following stimulus conflict more than did low anxious participants; however, they did not directly examine distracter interference following incongruent versus congruent trials, and they also did not assess state anxiety's influence on conflict adaptation.

We therefore looked for influences of both state and trait anxiety on Stroop and conflict adaptation effects, predicting that conflict adaptation might moderate anxiety's impairment of inhibitory attentional control as measured in our Stroop task. Based on Osinsky et al.'s (2010; 2012) findings, we hypothesised that anxiety would more clearly predict greater interference following low-conflict control trials, when conflict adaptation is minimal; based on the literature, it was unclear whether state anxiety, trait anxiety, or both would relate to interference and conflict adaptation. Participants completed a normal Stroop task, and conflict adaptation was assessed post hoc. Although conflict adaptation is usually assessed by comparing incongruent to congruent trials, Booth and Sharma (2009) have found that the presence of congruent trials can interact with stress and anxiety's effects on Stroop interference, so we elected to compare only non-linguistic control trials (e.g. '+++++') to incongruent trials. We found a normal-sized conflict adaptation effect with this method (see Results). An anonymous reviewer suggested that using control trials confounds the study, as anxiety may differentially affect the processing of words and nonwords, independently of any effect it has on interference. We think this is unlikely: if anxious individuals process words more slowly (they tend to read less efficiently; see Eysenck et al., 2007, for relevant studies), this should reduce interference from words in a speeded response task, which is contrary to our predictions and our results. We also assessed worry, since this variable has been implicated in anxiety's effects on performance (Eysenck et al., 2007), and depression: depression and anxiety are closely correlated, so we wanted to be able to discount potential influences of depression on our variables of interest. Finally, we assessed social desirability concerns as a control variable. This is a common approach in anxiety and cognition research, since defensive responding – i.e., participants underreporting their anxiety level – weakens analyses. It is possible that social desirability might be related to particular aspects of anxiety which should not be controlled, such as social anxiety; however, in this study controlling social desirability changed only the effect sizes rather than the overall pattern of results.

Method

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

Participants

One-hundred and seven students (*M* age = 20.51, *SD* = 2.61, 94 females) participated voluntarily or for course credit. This sample provides more than .80 power to detect a medium-sized correlation of .30. All were native Turkish speakers. Participants were not selected for anxiety, and exhibited normal psychopathological characteristics for student samples (see Table 1). In addition to these, eight more participants were tested but failed to achieve a 90% accuracy rate on the Stroop task, so their data were excluded from analyses.

Design

The study used a correlational design. The predictors were state and trait anxiety, worry and depression, and social desirability concerns were assessed as a control variable. The criterion variables were overall Stroop interference, Stroop interference on trials following incongruent trials, and Stroop interference on trials following control trials.

Materials and Procedure

The study was conducted using E-Prime and a PC with a 40 cm CRT monitor. Participants responded using a standard Microsoft USB keyboard. Participants were tested individually. After giving consent, participants completed our questionnaires on the computer.

Participants first completed the State-Trait Anxiety Inventory (Spielberger et al., 1970). This consists of two, 20-item scales, the state scale assessing how participants 'feel right now' and the trait scale assessing how they feel 'generally, in [their] life'. Participants respond on a four-point scale. The state scale was reliable, Cronbach's α = .88, with scores falling within the expected range for undergraduates (Spielberger et al., 1970), as was the trait scale, α = .84.

Participants next completed the Penn State Worry Questionnaire (Meyer, Miller, Metzger, & Borkovec, 1990). They answered 16 items such as 'My worries overwhelm me' on a 5-point scale, anchored by 1 = ‘Not at all typical of me’ and 5 = ‘Very typical of me’. The scale was reliable, α = .88.

They then completed the Beck Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). They rated the frequency with which they experienced 21 depressive symptoms such as sadness and self-dislike, on a 0-3 scale. The scale was reliable, α = .85.

Participants next completed the Marlowe-Crowne social desirability scale (Crowne & Marlowe, 1964). This consists of 33 items, each presenting a socially desirable but unlikely behaviour, to which participants respond ‘Yes [I do this]’ or ‘No [I do not do this]’. The scale was moderately reliable, α = .56; after removing items 18, 21, 24, and 29 this was raised to .62. The reliability of this scale is often artificially low, since it uses a dichotomous response scale. Allocating a score of 2 to Yes responses and 1 to No responses, the mean score was 48.89, *SD* = 4.33. This score has been adjusted upwards (mean item score × 33), so it is comparable to scores based on the full 33-item scale.

Finally, participants completed the Stroop task. They first completed 96 practice trials: fine-grained inter-trial response time (RT) measures require fast responses, so in our laboratory we ensure participants over-learn the response keys so they can respond quickly without looking down at them. Twelve animal names were presented in 32-point Courier New capitals against a black background. Words were presented in red, blue, yellow or green font with equal probability. Participants were asked to indicate the font colour with a key-press, as quickly and accurately as possible. There was a 500 ms response-stimulus interval. After a break, participants then completed 240 experimental trials. Fifty percent of trials were incongruent, and 50% were control trials. Incongruent trials consisted of the word KIZIL (crimson), MAVİ (blue), SARI (yellow) or YEŞİL (green) presented in one of the non-matching colours. Control trials were the same except that all letters were replaced with the plus sign, e.g. KIZIL became +++++. Each word appeared in the three non-matching colours with equal probability. Trials were presented in a random order. In conflict adaptation experiments, trial order is sometimes controlled to avoid too many repeating words or colours. We did not do this as task composition may moderate state anxiety's effect on Stroop interference (Booth & Sharma, 2009); furthermore allowing the number of repeating words and colours to fluctuate randomly should add random noise to the data, weakening rather than biasing the results, so our approach is conservative.

Results

Data Preparation

The first trial of the experiment and trials with incorrect responses (5.1%) were excluded from analyses. Remaining control and incongruent trial RTs were subjected to a condition- and participant-specific non-recursive moving criterion outlier-removal procedure, following van Selst and Jolicoeur (1994). In this technique, as the number of observations rises, the outlier criterion climbs towards 2.5 standard deviations from the mean; 2.67% of trials were discarded. Overall Stroop interference was calculated as the difference between the mean incongruent RT and the mean control RT. Stroop interference in accuracy was calculated as the difference between the control accuracy rate and incongruent accuracy rate. Conflict adaptation was assessed by calculating the Stroop interference scores for trials following an incongruent trial and trials following a control trial separately. To isolate true conflict adaptation from more bottom-up stimulus repetition effects, only complete alternations (trials on which neither the distracter word nor the target colour matched that of the previous trial; 64.22% of available trials) were included in these scores, following Notebaert et al. (2006; including all trials did not affect the results). Outlier criteria were recalculated for each score (here 5.5% of trials were discarded). An overall conflict adaptation score was also calculated as the difference between Stroop interference following a control trial and Stroop interference following an incongruent trial. Mean scores for all psychopathological and performance measures are presented in Table 1.

Hypothesis Tests

We tested for correlations between the psychopathological measures and our Stroop-based indices of cognitive control (see Table 1). Since social desirability was found to correlate significantly with both state anxiety, r (105) = -.28, 95% CI [-.45, -.10], p = .003, and trait anxiety, r (105) = -.41, 95% CI [-.56, -.24], p < .001, we partialled social desirability out from our correlation analyses. We find this is often necessary in our laboratory, as students can be unwilling or unable to report anxious feelings; however, these results were not greatly affected if social desirability was not controlled (see Table 1). Overall Stroop interference in RTs did not correlate with either state, r (104) = .04, 95% CI [-.16, .23], p = .71, nor trait anxiety, r (104) = .03, 95% CI [-.17, .21], p = .76.

Conflict adaptation effects did not correlate with trait anxiety, r (104) = .04, 95% CI [-.15, .23], p = .66, but did show a medium-size, positive correlation with state anxiety, r (104) = .31, 95% CI [.12, .47], p = .001, so that more state-anxious participants showed larger conflict adaptation effects (this analysis was not affected by outliers, Cook's distances < 0.12). This was due to the fact that state anxiety correlated positively with Stroop interference on trials following a control trial, r (104) = .26, 95% CI [.07, .43], p = .01, but did not correlate with Stroop interference on trials following an incongruent trial, r (104) = -.12, 95% CI [-.30, .08], p = .23. From Figure 1, it can be seen that higher state anxiety was associated with increased Stroop interference after control trials, but Stroop interference was more uniformly low following incongruent trials.

State and trait anxiety were highly correlated in these data, which is typical; there was also a marginal correlation between conflict adaptation and worry, r (104) = .19, 95% CI [.00, 37], p = .05. To examine whether it was uniquely state anxiety which was related to conflict adaptation, state and trait anxiety were entered into a linear regression model with conflict adaptation as the criterion, and social desirability as a control variable. The coefficient for state anxiety was significant, standardised $\beta = .41$, $SE = .11$, $p = .001$, but the coefficient for trait anxiety was not significant, $\beta = -.17$, $SE = .12$, $p = .15$. This confirmed that state anxiety uniquely predicted conflict adaptation, independent of trait anxiety. Adding worry to the model did not improve model fit, R^2 change = .02, $F = 2.58$, $p = .11$, suggesting that worry's relationship with conflict adaptation ($\beta = .20$, $SE = .12$) is largely an artefact of worry's relationship with state anxiety. Depression was not related to any Stroop-related variable, all $|r|$s < .13, *p*s > .20.

We also used moderated regression to test for interactions between state and trait anxiety on conflict adaptation, controlling for social desirability. Including the interaction term in the model did not improve model fit, R^2 change = .005, $F = .57$, $p = .45$, indicating no significant interaction.

To confirm the above results, Stroop and conflict adaptation effects were re-estimated for each participant using the technique of Notebaert and Verguts (2007). First, each participant's individual data were subjected to separate multiple regressions, predicting response time on each trial from six dummy variables coding for Stroop interference, repetitions of word and colour, complete versus partial repetitions, and trials where the colour matched the word from the previous trial or vice versa. The residuals from these analyses were then subjected to a second multiple regression, with two dummy variables representing the congruency of the previous trial, and conflict adaptation. The unstandardised regression coefficient *B* for each dummy variable represents the effect that variable had on that particular participant's response times, controlling for all the other trial-level and inter-trial effects. Other than the high statistical control, the advantage of this technique is that analyses are based on all available data, not just on the subset of complete alternation trials.

Participants' *B* estimates for all the dummy variables above were then correlated with the emotion scales, controlling for social desirability as in the primary analyses above. State anxiety was related to the conflict adaptation effect, r (104) = .25, 95% CI [.06, .42], p = .01; it was not related to Stroop interference or any other repetition effect, all $|r|$s < .15, ps > .15. Trait anxiety, worry and depression were not related to any Stroop-based variable, all $|r|$s < .17, ps > .08. These results replicate the primary analyses above and also show that state anxiety's relationship with conflict adaptation is not an artefact of switching from word-based incongruent to nonword-based control trials, other inter-trial effects, or other differences between trial types. This is especially important given that we elected to use non-lexical control trials rather than congruent trials, which is unusual in conflict-adaptation research: these last results increase our confidence that this change did not confound or bias our conflict adaptation effects.

Discussion

Overall, Stroop interference was not significantly related to anxiety; conflict adaptation effects were specifically related to state anxiety. The results suggest that state anxiety weakens attentional control, but only when other sources of top-down control are minimised: specifically, when top-down control relaxes following a low-conflict control trial, more anxious individuals show more Stroop interference. In this situation state anxiety's influence on interference is not small, accounting for one-sixteenth of the variance in interference. However, when top-down control is boosted following a high-conflict incongruent trial, more anxious individuals are able to overcome their weakened control and show equivalent levels of Stroop interference to less anxious individuals, so state anxiety's influence on interference is non-significant. These results were very similar whether social desirability concerns were controlled or not. Although conflict adaptation is thought to be more reactive than strategic (Notebaert et al., 2006), these results are reminiscent of processing-efficiency effects whereby more anxious individuals can achieve equivalent performance to less anxious individuals by expending extra processing resources (see Eysenck et al., 2007; Hayes et al., 2009). In the present study, more anxious individuals' performance deficits only become apparent when other sources of attentional control (i.e., reactive conflict adaptation) were weak. We do not claim this is a motivated or intentional strategic modulation of attentional control, but the parallels between these data and those of e.g. Hayes et al. – who found that anxiety's effects on learning performance disappeared when participants were able to improve their performance by expending effort – suggest that anxiety-related performance decrements will be most visible when top-down control, intentional or otherwise, is least active.

Together with other recent studies (Basten et al., 2011; Derakshan, Ansari, et al., 2009; Derakshan, Smyth, et al., 2009), these results show that either trait or state anxiety can be associated with attentional control deficits in different situations (see below; cf. Pacheco-Unguetti et al., 2010). However, these deficits may be subtle, and their detection may depend on task parameters (Hayes et al., 2009). This may explain why the literature on non-clinical anxiety and Stroop interference is inconsistent. In particular, anxiety effects will be difficult to detect when trials are blocked by type (as in e.g. Alansari, 2004), as every incongruent trial will follow another incongruent trial, maximising top-down conflict adaptive control (although see Dorahy et al., 2006; Kofman et al., 2006).

It is somewhat surprising that attentional control was related to state but not trait anxiety in this study. Studies similar to ours (Osinsky et al., 2010; Osinsky et al., 2012) have found that trait anxiety was related to conflict adaptation. One feature which differentiates our study from these is that we did not present congruent (e.g. RED in red print) trials. Booth and Sharma (2009) found that including such trials in a Stroop task exaggerated the effects of a stress manipulation: it may be that trait anxiety effects on cognitive control are likewise exaggerated when congruent trials are present. One possible mechanism is that congruent trials, because the word and colour both map to the same response, do not reinforce the task goal of ignoring the word; this means active goal maintenance becomes more important for effective Stroop task performance (Kane & Engle, 2003). There is some evidence that such goal maintenance is indeed impaired in trait anxiety (see Spielberg et al., 2014), so it may be that trait anxiety affects Stroop interference by weakening goal maintenance more than it does by directly weakening control itself. Note that all the studies cited here included congruent trials in Stroop or Stroop-like interference tasks (Basten et al., 2011; Osinsky et al., 2010; Osinsky et al., 2012).

This correlational study leaves causation ambiguous: it is possible that weak cognitive control can lead individuals to pay undue attention to minor threats and dangers in their everyday environments, increasing their vulnerability to anxiety. An experimental replication, confirming that state anxiety causes the selective attention impairment, would be valuable. Another potential issue with this study is that the psychopathological measures were given first, before the Stroop task. This raises the possibility that the reported effects were exaggerated because state anxiety had been elevated by completing the psychopathological measures. This seems unlikely given that conflict adaptation effects were only related to state anxiety, which was always assessed first. As trait anxiety indexes a predisposition towards feeling anxiety, one would expect such sensitisation effects to correlate with trait anxiety too. Finally, although controlling social desirability is not uncommon in anxiety and cognition research and helps to resolve weakening effects of biased responding, there is the possibility that doing so controls specific aspects of anxiety, such as social anxiety. Similarly, the reliability of the social desirability scale was somewhat low in this study, potentially making it unclear whether only social desirability was controlled in our partial correlations. However, the zero-order correlations were so similar to the partial correlations that these problems seem negligible.

Conflict adaptation experiments typically use congruent trials (in a Stroop task, this means trials in which the word and colour match) as their baseline, rather than the nonlexical control trials used here. We designed our study in this way because including congruent trials may moderate the relationship between state anxiety and Stroop interference (Booth & Sharma, 2009), and because congruent trials may weaken goal maintenance (Kane & Engle, 2003), which is thought to be a particular weakness in anxious individuals (Spielberg et al., 2014). However, this does allow the possibility that anxiety was related to some aspect of lexical processing, rather than to conflict adaptation. Similarly, distracter words were more visually variable on our incongruent trials than they were on our control trials, which may have been more distracting for more anxious participants. This might be especially concerning given that anxiety has been related to poor shifting of attention or task set (Eysenck et al., 2007). To address this point, and to further probe the relationships between trait anxiety and different facets of Stroop interference (see above), a replication with a Stroop task including congruent trials would be valuable.

To summarise, this study demonstrates that associating poor attentional control specifically with trait anxiety is premature. Understanding the relationships between anxiety and cognition requires attention to the temporal dynamics, and multiple sources, of control.

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Table 1

Partial correlations between variables of interest, controlling for social desirability. Zero-order correlations are presented in parentheses. Stroop interference is the difference in performance between incongruent and control trials; conflict adaptation is the difference in Stroop interference following incongruent vs. following control trials. Variables 7, 8 and 9 are calculated based on complete alternations only.

	2.	3.	4.	5.	6.	7.	8.	9.	*M*	*SD*
1. State anxiety	.521**(.571**)	.436**(.482**)	.572**(.588**)	.037(-.018)	.049(.060)	.307**(.278**)	-.116(-.150)	.256**(.189†)	39.16	9.18
2. Trait anxiety		.600**(.643**)	.638**(.641**)	.030(-.050)	.148(.154)	.044(.017)	.053(-.008)	.098(.012)	43.64	8.63
3. Worry			.402**(.427**)	.012(-.044)	.055(.067)	.191*(.166)	-.054(-.092)	.175(.111)	46.64	11.10
4. Depression				.059(.026)	.123(.129)	.062(.052)	.043(.019)	.111(.077)	11.35	8.29
5. Stroop interference (RT)					.349**(.333**)	.195*(.202*)	.581**(.592**)	.743**(.752**)	81.75	70.32
6. Stroop interference (accuracy)						.114(.111)	.202*(.194*)	.313**(.298**)	.005	.026
7. Conflict adaptation (RT)							-.557**(-.543**)	.677**(.675**)	36.39	118.97
8. Stroop interference (RT), following incongruent trials								.234*(.253**)	56.81	90.76
9. Stroop interference (RT), following control trials									93.20	103.29

Note. *p < .05; **p < .01; †p = .05. N = 107. RT = response time.

Figure 1 – Relationship between state anxiety and Stroop interference (calculated as mean response time to incongruent trials – mean response time to control trials), on trials following a control trial (circles and solid fit line) and on trials following an incongruent trial (crosses and broken fit line).