CHAPTER 5

WORKING MEMORY LOAD ELICITS ATTENTIONAL BIAS TO THREAT

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Anxious individuals tend to show attentional bias to threats and dangers; this is usually interpreted as a specific bias in threat-processing. However, they also tend to show general working memory and cognitive control impairments. We hypothesised that the lack of working memory resources might contribute to attentional bias, by limiting anxious individuals' ability to regulate their responses to emotional stimuli. If this is true, then loading working memory should elicit attentional bias to threat, even in non-anxious participants. We tested this hypothesis in two experiments, with participants unselected for anxiety. In Experiment 1, a phonological working memory load (remembering a string of digits) elicited an attentional bias to fear-conditioned Japanese words. In Experiment 2, a visuo-spatial working memory load (remembering a series of locations in a matrix of squares) elicited an attentional bias to emotional schematic faces. Results suggest that working memory and cognitive control may moderate the attentional bias to threat commonly observed in anxiety.

Introduction

Anxious individuals often show attentional bias toward threat (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). This is typically measured in the dot-probe task (MacLeod, Mathews, & Tata, 1986), in which participants are presented with one negative/threat and one neutral stimulus, followed by a probe. Anxious participants tend to respond faster when the probe appears in the threat stimulus' location, compared to when it appears in the non-threat stimulus' location. This is assumed to reflect some difference in the way anxious people process and/or respond to threats (e.g., Fox, Russo, & Dutton, 2002; Williams, Watts, MacLeod, & Mathews, 1997). Indeed, this assumption underpins cognitive bias modification, a currently-developing family of treatments for anxiety and depression (e.g., Hallion & Ruscio, 2011). However, anxious participants also tend to show a general deficit in working memory (WM) and cognitive control (e.g., Ashcraft & Kirk, 2001; Crowe, Matthews, & Walkenhorst, 2007). For example, anxious participants perform more poorly in dual-task situations than do non-anxious participants (Calvo & Eysenck, 1996; Derakshan & Eysenck, 1998), and seem to be particularly impaired on tasks requiring inhibitory processing or shifting between mental sets (Eysenck, Derakshan, Santos, & Calvo, 2007).

Recent work suggests that WM, aside from cognitive control, also contributes to emotion regulation (see Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008; Ochsner, Bunge, Gross, & Gabrieli, 2002, for similar arguments). For example, Schmeichel (2007) has found that regulating responses to an unpleasant video reduced available WM resources, and that participants with higher WM capacities could better regulate emotional responses (Schmeichel, Volokhov, & Demaree, 2008). As a result of their low WM capacity, anxious individuals may therefore experience threats as more severe than do non-anxious individuals, which would tend to exacerbate attentional bias (Wilson & MacLeod, 2003). If correct, this implies two related conjectures: firstly, that differences in attentional bias may be partially attributable to differences in WM rather than differences in threat processing per se (Eysenck et al., 2007; Ouimet, Gawronski, & Dozois, 2009); and secondly, that loading WM should increase attentional bias. Although previous studies looking for a link between processing of emotional stimuli and WM or cognitive control have yielded contradictory results (Schmeichel et al., 2008; Van Dillen & Derks, 2012; Van Dillen, Heslenfield, & Koole, 2009), we do not know of previous studies which have examined WM load’s effects on attentional bias in the dot probe task.

To see whether WM capacity is partially responsible for attentional bias to threat in anxious individuals, we measured bias under high and low WM load. In Experiment 1, we used fear-conditioned Japanese characters as threat stimuli (Van Damme, Crombez, Hermans, Koster, & Eccleston, 2006), to avoid visual or lexical artefacts. Participants were unselected for anxiety, so they should normally show little or no bias; we predicted that WM load should increase bias.

Experiment 1

Method

Participants. Nineteen psychology undergraduates (16 females, aged 19-34) participated to provide data for a class exercise. All were native Turkish speakers, with normal or corrected-to-normal vision and hearing, and no knowledge of Japanese. The mean trait anxiety (Öner & LeCompte, 1985; Spielberger, Gorsuch, & Lushene, 1970) was 41.16 (*SD* = 9.03).

Design. A repeated measures design was used, with WM load (high: 5 items; low: 1 item) and probe position (probe replaces threat CS+; probe replaces non-threat CS-) as factors, and response time as the dependent variable.

Apparatus and Materials. The experiment was run using E-Prime, and a 17” CRT monitor. Twenty-four Japanese kanji characters were taken from KanjiLearn (http://www2.gol.com/users/jpc/Japan/Kanji/KanjiLearn/) to serve as conditioned stimuli (CS). The unconditioned stimulus (US) was a 1000ms, 9100Hz tone at 92dBA, delivered via headphones.

Procedure. Participants completed a high load and a low load block, in a counterbalanced order. Each block included a conditioning phase and a dot probe phase.

During the conditioning phase, participants passively viewed 12 randomly-selected kanji for one second each, each followed by a two-second pause. Four kanji were randomly-selected as CS+, and were followed by the US; the remainder were CS-. During the dot probe phase, participants completed dot probe and WM tasks simultaneously. The WM study stimuli were presented (5 digits for 2000ms in the high load block, 1 digit for 500ms in the low load block), then masked with an “X” (2500ms for the high load block, 750ms for the low load block). Timing varied between conditions to equate encoding difficulty (Lavie, Hirst, de Fockert, & Viding, 2004).

Following a 1000ms fixation, one CS+ and one CS- were presented on the left and right sides of the screen for 750ms, followed by a small dot probe, which appeared in the position previously occupied by either the CS+ or the CS-. Participants pressed the Z key if the probe appeared on the left of the screen, and M if it appeared on the right, as quickly as possible. CS+ and probe position were randomised. A single digit was then presented: if this digit appeared in the WM study stimulus, participants pressed Z, otherwise they pressed M. A new digit was presented on 50% of trials. Thirty-two trials were presented in each load block.

Results

Response times were retained if participants responded correctly to both the dot probe and the subsequent WM stimulus. A 2 (high vs. low load) × 2 (probe replaces CS+ vs. CS-) repeated measures ANOVA revealed a significant interaction, $F(1,18) = 5.46$, $\eta^2_p = .23$, $p = .03$, see Figure 1. As predicted, participants showed significant bias for threat under high load, $t(18) = 1.89$, $p = .04$ (one-tailed), and non-significant bias away from threat under low load, $t(18) = -1.57$, $p = .07$. The main effects of load and probe position were not significant (F’s < .05).

Discussion

As predicted, WM load affected attention allocation to threat. Participants showed non-significant bias away from threat under low load (this is not unexpected, see Bar-Haim et al., 2007), and started to show bias towards threat under high load. This raises the possibility that attentional biases shown by anxious participants may be partially attributable to general WM deficits, rather than purely reflecting differences in threat processing.

Experiment 2

In Experiment 2, we sought to extend the findings of Experiment 1 in three ways. Firstly, we wished to replicate our findings using a different threat stimulus (schematic angry faces). Secondly, we wished to test whether WM load elicited attentional bias specifically to threats, or a more general bias to any emotional stimulus, and therefore the dot-probe task now included happy faces. Finally, the digit load used in Experiment 1 could be considered a phonological WM load (Baddeley, 1992); we wanted to see whether a visuo-spatial WM load would elicit attentional bias in the same way.

Method

Participants. Thirty-seven undergraduates (17 females, aged 18-26; $M = 20.41$, $SD = 1.91$) participated for 10 Turkish Lira. All were native Turkish speakers with normal vision. Mean trait anxiety was 41.35 ($SD = 11.73$).

Design. A repeated measures design was used, with WM load (high: 3 items; low: 1 item), valence of the emotional face (angry; happy) and probe position (probe replaces emotional/neutral face) as factors, and response time as the dependent variable.

Apparatus and Materials. The apparatus was the same as in Experiment 1. Pictures of angry, happy and neutral schematic faces were taken from Hietanen and Lappänen (2003).

Procedure. Participants completed high load and low load blocks in a counterbalanced order. In this experiment, there was only a dot probe phase. After a 500ms fixation cross, participants were presented with one emotional (happy or angry) and one neutral face, at the top and bottom of the screen for 100ms. These were followed by the cue, which took the form of a small arrow (< or >). The arrow replaced either the emotional face or the neutral face; positions of the emotional face (top or bottom of the screen) and the probe (emotional face's location or neutral face's location) were counterbalanced. Participants indicated with a key-press, as fast as possible, the direction in which the arrow was pointing.

As in Experiment 1, participants also completed a WM task at the same time as the dot probe. Before each dot probe trial, participants were presented with a 4 × 4 matrix of squares. In the high load condition, a series of three randomly-determined squares turned red for 1000ms each, with a 500ms interval between squares. Participants were asked to remember which squares had turned red. Following their response to the dot probe, participants again saw the matrix, with a single square coloured; they were asked to indicate with a key-press whether that square had turned red before the dot probe trial. A new square was presented on 50% of trials. The low load condition was identical, except that only one square turned red before the dot probe. Visuo-spatial WM load was therefore three items in the high load condition and one item in the low load condition.

Results

A 2 (high vs. low load) × 2 (emotional face is angry vs. happy) × 2 (probe replaces emotional face vs. neutral face) repeated measures ANOVA revealed that participants showed more attentional bias toward emotional faces under high load than they did under low load, $F(1,36) = 7.99$, $\eta^2_p = .18$, $p = .01$. Simple main effects indicated that participants did not show attentional bias to emotional faces under low load, $F(1,36) = 1.24$, $\eta^2_p = .03$, $p = .27$, but showed significant bias under high load, $F(1,36) = 7.81$, $\eta^2_p = .18$, $p = .01$. However, this effect was not significantly different for angry vs. happy faces, as indicated by a non-significant three-way interaction, $F(1,36) = 1.09$, $\eta^2_p = .03$, $p = .30$. See Figure 2.

Aside from a tendency to respond more slowly under high load, $F(1,36) = 3.30$, $\eta^2_p = .08$, $p = .08$, no other effects approached significance, all *F*s < 2.57, all *p*s > .11.

Discussion

Again, the application of a WM load created an attentional bias toward emotional stimuli, where such a bias was not otherwise apparent. Here, we showed that both a phonological and a visuo-spatial WM load can have this effect, and the resulting bias is not restricted to fear-conditioned threat stimuli. However, the attentional bias elicited by WM load was not specific to threat, but seemed to generalise to emotional stimuli of both positive and negative valence.

It is not clear why WM's effect on bias did not vary between happy and angry faces. Previous studies have occasionally found attentional bias to both negative and positive stimuli in anxiety (e.g. Fox et al., 2002); it could be assumed that a smiling face might be interpreted as contemptuous or mocking by an anxious individual, or that a happy face is threatening to an anxious individual because it reminds them that they are not happy. Neither of these accounts fit the present data, which were not collected from especially high-anxious participants. It could simply be that WM load increases attention allocation to all emotionally-salient stimuli. If this is true, the fact that similarly non-specific biases to emotional stimuli are also found in anxiety again suggests that attentional bias is not purely a function of threat-processing. Instead, this occurrence may be partially attributable to general cognitive control deficit common in anxious individuals (Eysenck et al., 2007).

Another possible account of these data is that WM load increased attention to more novel stimuli, rather than to emotional stimuli. In this experiment, the emotional stimulus varied unpredictably between an angry and a happy face, whereas the neutral stimulus was always the same neutral face. We accept this possibility. However, in Experiment 1 the emotional CS+ and neutral CS- changed on every trial, yet WM load still elicited an attentional bias toward the CS+. Given the results of Experiment 1, we interpret those of Experiment 2 as reflecting a bias toward emotional, rather than novel, stimuli.

General Discussion

In two experiments, WM load was seen to elicit an attentional bias to emotional stimuli. Attentional bias is considered a hallmark of anxiety, and has been observed in several anxiety disorders (Bar-Haim et al., 2007; Williams et al., 1997). However, the participants in the present experiments were not selected for anxiety, so their showing attentional bias would not be predicted by extant theories of cognition in anxiety (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997). The present results prompt a re-conceptualisation of attentional bias, as resulting from an interaction between emotion-specific information processing and more cognitive control. Future research must continue to probe the relationships between WM, cognitive control, and other cognitive biases in anxiety.

One alternative account of the results is to suggest that the WM loads we applied, as they involved assessment of participants' performance on a difficult task, increased the participants' state anxiety, and that this state anxiety was responsible for the increase in bias. We accept this possibility, but doubt its veracity for two reasons. Firstly, we have conducted several experiments involving WM loads with this participant group, and participants tend to complain of boredom during such experiments, rather than distress. Secondly, studies have not clearly demonstrated that state anxiety increases bias in the same way that trait anxiety does (Bar-Haim et al., 2007), particularly in unselected samples such as these (Egloff & Hock, 2001). The fact that WM load has yielded consistent effects in these two relatively small samples leads us to conclude that the WM load affected our participants' cognitive control ability, and did not directly affect their anxiety levels.

Our findings are important because the assumption that anxious people process threats differently is dominant in extant theories of anxiety, and especially in currently-developing treatments such as cognitive bias modification. The current results suggest that more general cognitive deficits in anxiety may be equally important for understanding the condition.

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