Attentional Bias to Threat in Anxiety Has an Extremely Brief Time Course

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Abstract

Background and Objectives: Attentional bias to threat is a much-studied feature of anxiety; it is typically assessed using response time (RT) tasks such as the dot probe. Findings regarding the time course of attentional bias have been inconsistent, possibly because RT tasks are sensitive to processes downstream of attention. *Methods:* Attentional bias was assessed using an accuracy-based task in which participants detected a single digit in two simultaneous rapid serial visual presentation (RSVP) streams of letters. Before the target, two coloured shapes were presented simultaneously, one in each RSVP stream; one shape had previously been associated with threat through Pavlovian fear conditioning. Attentional bias was indicated wherever participants identified targets in the threat's RSVP stream more accurately than targets in the other RSVP stream. *Results:* In 87 unselected undergraduates, trait anxiety only predicted attentional bias when the target was presented immediately following the shapes, i.e. 160ms later; by 320ms the bias had disappeared. This suggests attentional bias in anxiety can be extremely brief and transitory. *Limitations:* This initial study utilised an analogue sample, and was unable to physiologically verify the efficacy of the conditioning. The next steps will be to verify these results in a sample of diagnosed anxious patients, and to use alternative threat stimuli. *Conclusions:* The results of studies using response time to assess the time course of attentional bias may partially reflect later processes such as decision making and response preparation. This may limit the efficacy of therapies aiming to retrain attentional biases using response time tasks.

Keywords: Attentional bias; anxiety; time course; RT vs. accuracy

Brief Time Course of Trait Anxiety-Related Attentional Bias to Fear-Conditioned Stimuli: Evidence From the Dual-RSVP Task

1. Introduction

Trait anxiety is the long-term tendency to experience anxious states (Spielberger, Gorsuch, & Lushene, 1970). Both clinical and high trait anxiety are characterised by *attentional bias*: more anxious individuals tend to pay more attention to threat-related stimuli than neutral stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). In recent years, this is most frequently demonstrated using the dot probe task (MacLeod, Mathews, & Tata, 1986), where threat and non-threat stimuli are simultaneously presented; when these stimuli disappear, one is replaced by a target 'probe'. More anxious participants tend to respond faster when the probe replaces the threat stimulus, suggesting they were preferentially attending to that location before the probe appeared. The concept of attentional bias is crucial to theories of anxiety (e.g. Mathews & MacLeod, 2005; Mobini & Grant, 2007), and to experimental attention-retraining treatments (cognitive bias modification, or CBM; see Hakamata et al., 2010; Hallion & Ruscio, 2011).

One ambiguous issue is the bias's time course. This has been studied by varying the stimulus-probe interval. Several studies found stronger attentional bias with a shorter interval, consistent with the view that anxious individuals detect threats quickly (Williams, Watts, MacLeod, & Mathews, 1997). However, how short this interval needs to be varies between studies: some found anxiety-related biases with intervals less than 250 ms (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006; Mogg & Bradley, 2006; Onnis, Dadds, & Bryant, 2011), others with intervals of 500 ms (Koster, Verschuere, Crombez, & Van Damme, 2005; Mogg, Bradley, Miles, & Dixon, 2004; Mogg, Philippot, & Bradley, 2004), others with intervals over 1 second (Bradley, Mogg, Falla, & Hamilton, 1998; Mogg, Bradley, De Bono, & Painter, 1997). This is important because, when the dot probe is adapted for CBM therapies, intervals of at least 500ms are typically used; CBM is ineffective with shorter intervals (Koster, Baert, Bockstaele, & De Raedt, 2010; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). This difference in time course might suggest that CBM is actually operating on some later process, rather than on attention.

One important issue is that the dot probe, being a response time (RT) task, is potentially sensitive to processes downstream of attention (Olatunji, Ciesielski, Armstrong, Zhao, & Zald, 2011, make a similar argument). Santee and Egeth (1982; see also Mordkoff & Egeth, 1993; Pashler, 1989) demonstrated that performance on RT tasks is limited by processing resources, and therefore is sensitive both to input processes like attention, and to later processes such as decision-making and response preparation. Performance on accuracy tasks, where responses are not speeded but stimuli are presented briefly, is limited by the information the participant was able to glean from the stimuli, and is therefore a more pure measure of attention.

Evidence that dot probe performance is affected by processes downstream of attention is provided by Koster, Crombez, Verschuere, and De Houwer (2004), and Salemink, van den Hout, and Kindt (2007), who included a baseline with only neutral stimuli in their tasks. Participants showed normal attentional bias, but responded fastest on no-threat baseline trials. This suggests a threat stimulus, regardless of its effects on attention, slows responding. Furthermore, the extent of slowing depends on the threat's severity (Koster, Crombez, Verschuere, et al., 2004; Yiend & Mathews, 2001). Furthermore, the nature of the response – e.g., whether participants are localising or identifying the probe – influences the task's sensitivity (Salemink et al., 2007), which is strong evidence that processes downstream of attention influence dot probe performance. Therefore, it is important to measure the time course of attentional bias with an accuracy task, which can more purely assess attention.

Klein and Dick (2002; although see Prinzmetal, Park, & Garrett, 2005) made similar arguments in their investigation of exogenous cuing. Their solution was to present two rapid serial visual presentation (RSVP) streams of stimuli, with a target embedded in one of the streams. Klein and Dick cued one stream's location, to observe how this affected target detection at various positions in both RSVP streams. In the present study, their task was combined into the dot probe: one threat and one neutral stimulus appeared simultaneously in two RSVP streams, followed by a single target at randomly-varying positions in either stream, i.e. at varying stimulus-probe intervals. In addition to being an accuracy task, this task uses seven stimulus-probe intervals to thoroughly assess the time course of attentional bias; dot-probe studies have tended to use two or three (see comments by Mogg, Philippot, et al., 2004).

Coloured shapes were used as threat and neutral stimuli; Pavlovian fear conditioning associated some shapes with threat (Booth, Mackintosh, & Sharma, 2016; Booth & Sharma, 2014; see also Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2005). This technique has the advantage that, since different stimuli are conditioned for each participant, perceptual confounds between threat and nonthreat stimuli are controlled. Since freshly-conditioned shapes directly signal an imminent aversive stimulus and are easily recognised parafoveally, they may provide a more powerful test of attentional bias than do angry faces or threat words (see Discussion sections of Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004; Koster, Crombez, et al., 2005).

It was predicted that the dual-RSVP measure would detect a relationship between anxiety and attentional bias to threatening conditioned stimuli. Specifically, more anxious participants were predicted to be more likely to show higher probe-detection accuracy when the probe appeared in the threat stimulus's RSVP stream relative to when it appeared in the neutral stimulus's stream. Based on the dot probe literature on the time course of attentional bias (e.g. Koster et al., 2006; Mogg & Bradley, 2006), it was predicted that this relationship would be clearest at shorter stimulus-probe intervals.

2. Method

2.1 Participants and Procedure

Eighty-seven psychology undergraduates (67 females, *M* age = 21.38, *SD* = 1.65) from a private university in Istanbul gave informed consent, and were rewarded with course credit. The study was approved by the institutional review board, and was conducted in accordance with the provisions of the World Medical Association's Declaration of Helsinki.

Participants were tested individually, using E-Prime 2 on a PC and HP7540 CRT monitor running at 60Hz. First they completed the scales on the computer, then the conditioning phase, then the dual-RSVP task. Participants sat approximately 60cm from the screen. All administered scales and measures are reported.

2.2 Scales

Participants completed the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1970) in Turkish (Öner & LeCompte, 1985). This assesses both state anxiety, i.e. current mood, and trait anxiety, i.e. general predisposition towards anxiety. Both scales include 20 items, such as *I am worried* (state anxiety) and *I feel nervous and restless* (trait anxiety); participants respond on a 1 (*never*) to 4 (*always*) scale. Both showed good internal consistency, Cronbach's α = .89 and .83.

Participants then completed the Marlowe-Crowne social desirability scale (Crowne & Marlowe, 1964; translation by Ural & Özbirecikli, 2006). Controlling social desirability often increases power when assessing anxiety, but it did not affect these results, so it is not discussed further.

2.3 Conditioning phase

Participants were presented with 14 differently-coloured shapes. Half were randomly designated as CS1s (which would become threat stimuli in the dual-RSVP) and presented with a US, half were designated as CS2s (neutral stimuli) and presented without a US. The shapes were presented once, in a random order, against a white background. Each CS subtended approximately 6° square in visual angle (6 cm) and was presented for 2000 ms, followed by a blank screen for 4500 ms. The US was a 95dBA tone, presented for 1000 ms following each CS1. This US's efficacy has been physiologically confirmed by Booth et al. (2016); a very similar procedure was used successfully by Booth & Sharma (2014; see also Koster, Crombez et al., 2005).

2.4 Dual-RSVP

This consisted of three blocks of 56 trials, interspersed with rest periods. On each trial, two RSVP streams of letters were presented, which appeared 7.13° (75 mm) left and right of a central fixation. In each stream, 15 letters randomly chosen from the list A, C, D, E, F, G, H, J, K, L, M, N, P, R, S, T, U, V, Y, and Z, were presented 1.15° (12 mm) high, in black against the white background, for 160 ms each. One CS1 and one CS2 appeared at 2.25° (24 mm) square for 160 ms between the 5th and 6th letters. One probe, a digit between 2 and 9, then appeared in one of the streams between 0 and 6 letters later. The sides on which each CS and the probe appeared, the probe digit, and the stimulus-probe interval, were counterbalanced and the trials were presented in a random order. Timing errors were maintained at 7 ms or less. See Figure 1.

Following each trial, participants indicated which digit they saw by pressing the appropriate key. Participants were told speed of response was unimportant, and to guess when they missed the probe.

3. Results

Participants' overall accuracy rates varied from .12 to .96 (M = .74, SD = .14). There was no overall difference in accuracy when the probe appeared in the threat vs. the neutral location at any stimulus-probe interval (all ts < 1.70, all ps > .09). This does not invalidate the correlations with anxiety below; the dot probe also does not typically show this main effect in unselected participants (Kappenman, Farrens, Luck, & Proudfit, 2014). See Supplementary Materials for more analyses of the raw accuracy rates.

Bias was calculated for each stimulus-probe interval by subtracting, for each participant, the accuracy to probes in the neutral location from the accuracy rate to probes in the threat location. This index, when positive, indicates participants allocated more attention towards the threat location. See Table 1.

Trait anxiety only predicted attentional bias when the stimulus-probe interval was zero, i.e. when the probe immediately followed the CSs, r (85) = .29, 95% CI [.08, .47], p = .007. This correlation was due to trait anxiety's negatively predicting accuracy when the probe appeared in the neutral location, r (85) = -.21, 95% CI [-.41, -.00], p = .05, but not when the probe appeared in the threat location, r (85) = .05, 95% CI [-.16, .26], p = .65. Trait anxiety did not predict bias at any other stimulus-probe interval, all $|r|$s < .07, all ps > .54. See Figure 2.

State anxiety did not predict bias at any stimulus-probe interval, all $|r|$s < .20, all ps > .06. See Supplementary Materials for more analyses and discussion.

4. Discussion

The dual-RSVP task detected a trait anxiety-associated attentional bias toward threatening CSs. However, this bias only operated on probes presented directly after the CSs. That more anxious participants should allocate relatively more attention to threat stimuli is not surprising (Bar-Haim et al., 2007); that this effect should be absent for longer probe-stimulus intervals, despite the study having approximately .79 power to detect a correlation of .30 between bias and trait anxiety for each interval, is unexpected and striking. It suggests that, contrary to conclusions drawn from RT studies, trait anxiety's influence on attention can dissipate within 320 ms of threat being perceived (see also Koster et al., 2006; Mogg & Bradley, 2006; Onnis et al., 2011). By using an accuracy-based task, the present study measured attentional bias more purely, through being less affected by decisional and output processing. This is important because current thinking on anxiety's aetiology (Mathews & MacLeod, 2005; Mobini & Grant, 2007) and CBM treatments (Hakamata et al., 2010; MacLeod et al., 2002) depend heavily on the concept of attentional bias. These results, if replicable in clinical samples, suggest the bias is rather transitory; together with the fact that CBM is less effective when short stimulus-probe intervals are used (e.g. Koster et al., 2010), this suggests that CBM may not actually directly affect the spatial allocation of attention, and may instead affect some later process, such as response-preparation, or interpretation. CBM might be more effective if it directly focuses on retraining these later processes, rather than initial orienting towards threat. Indeed, Hallion and Ruscio (2011; see also Christea, Kok, & Cuijpers, 2015) suggested that attention-retraining therapies have a somewhat unreliable effect on anxiety, and are less effective than retraining of interpretive bias (see Mathews & Mackintosh, 2000).

Based on the theory that anxious individuals quickly detect threats in their environment (Williams et al., 1997), attentional bias should commence immediately after threats are presented. It is less clear why its time course should be so brief: this is not a result of restricted range in anxiety (see Table 1). It is possible that the conditioning procedure was unsuccessful in eliciting strong fear responses to the otherwise-neutral coloured shapes; although very similar conditioning procedures have worked well in the past (Booth et al., 2016; Booth & Sharma, 2014; Koster, Crombez, et al., 2005), it was not possible to physiologically verify the conditioning's efficacy in this study. It is therefore important to replicate these results with other categories of threat stimulus, such as angry faces, threat words, or snake images. Furthermore, this study used stimuli which could be quickly identified parafoveally: anxiety's influence on bias may appear later, or continue for longer, when stimuli require more processing. Although the time course of attentional bias may be longer in patients outside the laboratory, this does not change the conclusion that the time course of attentional bias in other laboratory studies – or at least, the purely attentional component of the bias – might be much shorter than has been previously realised.

Some RT-based studies have found that attentional bias remained significant when the stimulus-probe interval extended over 1 second (Bradley et al., 1998; Mogg et al., 1997). These results are difficult to reconcile with those of the current study. One possibility is that RT attentional bias measures have been affected by a general slowing of responding. Threat stimuli slow responding, both in dot probe (Koster, Crombez, Verschuere, et al., 2004; Salemink et al., 2007) and other paradigms (Algom, Chajut, & Lev, 2004; McKenna & Sharma, 2004). Future research must decompose attentional bias, to understand the extent to which decisional processes and response competition contribute to the effect, and how much these contributions vary with stimulus and task parameters.

The dual-RSVP task presented here has much to recommend it, beside the facts that it is an accuracy task, and that it assesses attentional bias at multiple stimulus-probe intervals. Another advantage is that, because participants are not required to make a speeded response, participants who are under-motivated or less physically able to respond quickly can still be tested.

Attentional bias in anxiety is one of the most-studied phenomena in affective cognition. However, some details of this bias remain poorly understood, especially its time course. The present study shows this time course can be extremely short, at least in nonclinical samples, and complements accumulating evidence suggesting the RT-based dot probe task measures processes other than attention. Addressing these issues can improve our understanding of the cognitive hallmarks of anxiety, and improve our design of cognitive and attentional training therapies.

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Declaration of Interest

The author declares that he has no conflicts of interest regarding this work.

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Table 1

Pearson Correlations and Descriptive Statistics for Trait Anxiety, State Anxiety, and Attentional Bias at Stimulus-Probe Intervals of 0 – 6

	0	1	2	3	4	5	6	Mean	*SD*	Min.	Max.
Trait anxiety	.288*	-.046	.023	.033	-.065	-.059	.033	41.70	8.14	23	59
State anxiety	.157	-.072	-.096	-.125	-.196	.024	.043	38.18	9.15	23	70
Mean	.002	-.003	-.034	.018	-.015	-.006	.004				
SD	.161	.161	.184	.178	.162	.148	.179				
Min.	-.33	-.42	-.50	-.42	-.50	-.50	-.42				
Max.	.50	.42	.42	.50	.66	.33	.67				

*$p < .01$

Figure Captions

Figure 1: *Example dual-RSVP trial.*

Figure 2: *Pearson correlations between trait anxiety and attentional bias at each of the seven stimulus-probe intervals. Error bars reflect 95% confidence intervals.* N = *87.*

Figure 1

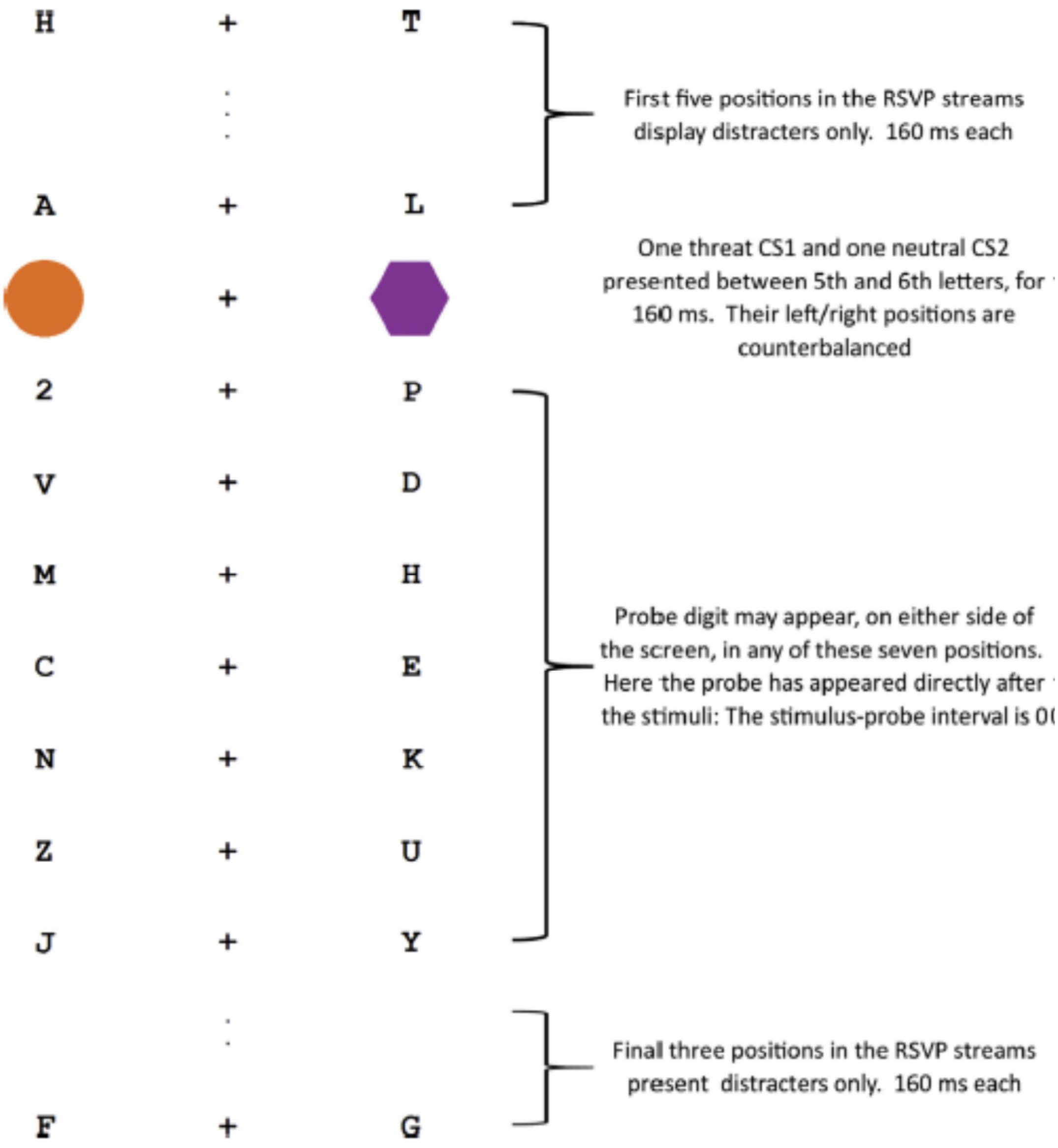
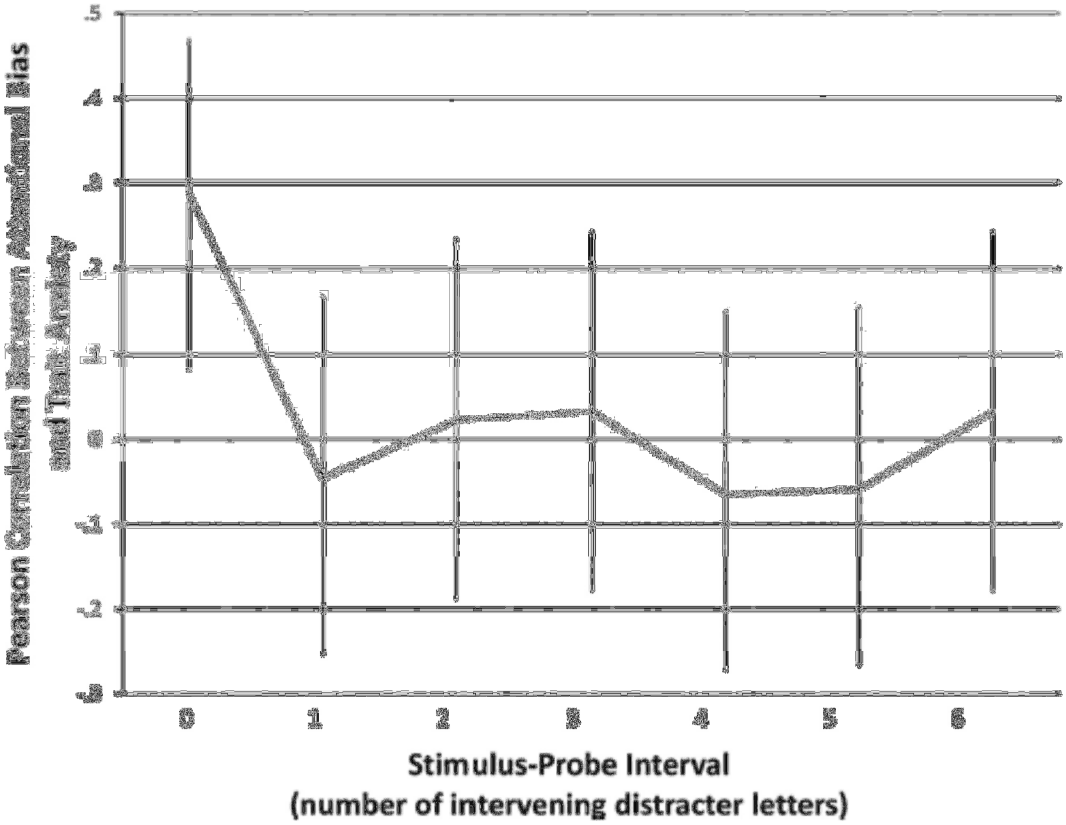

H + T
A + L
+
2 + P
V + D
M + H
C + E
N + K
Z + U
J + Y
F + G
First five positions in the RSVP streams display distracters only. 160 ms each
One threat CS1 and one neutral CS2 presented between 5th and 6th letters, for 160 ms. Their left/right positions are counterbalanced
Probe digit may appear, on either side of the screen, in any of these seven positions. Here the probe has appeared directly after the stimuli: The stimulus-probe interval is 0
Final three positions in the RSVP streams present distracters only. 160 ms each

Figure 2


Pearson Correlation Between Attentional Bias and Trait Anxiety
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
0
1
2
3
4
5
6
Stimulus-Probe Interval
(number of intervening distracter letters)