Anticipatory versus Reactive Spatial Attentional Bias to Threat

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Abstract

Dot-Probe or Visual Probe Tasks (VPTs) are used extensively to measure attentional biases. A novel variant termed the cued VPT (cVPT) was developed to focus on the anticipatory component of attentional bias. The current study aimed to establish an anticipatory attentional bias to threat using the cVPT and compare its split-half reliability with a typical Dot-Probe task. 120 students performed the cVPT task and Dot-Probe tasks. Essentially, the cVPT uses cues that predict the location of pictorial threatening stimuli, but on trials on which probe stimuli are presented the pictures do not appear. Hence, actual presentation of emotional stimuli did not affect responses. The reliability of the cVPT was higher at most Cue-Stimulus Intervals and was .56 overall. A clear anticipatory attentional bias was found. In conclusion, the cVPT may be of methodological and theoretical interest. Using visually neutral predictive cues may remove sources of noise that negatively impact reliability. Predictive cues are able to bias response selection, suggesting a role of predicted outcomes in automatic processes.

Keywords: Threat; attentional bias; anticipatory; cued visual probe; predictive cue

Survival and mental health depend on the ability to efficiently and appropriately respond to threatening stimuli. Spatial selective attention contributes to this ability via attentional biases to threat, broadly defined as the preferential processing of information perceived as threatening (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Cisler & Koster, 2010; Mogg & Bradley, 2016). One of the most frequently used paradigms to assess biases in spatial attention is the Dot-Probe or Visual Probe Task (Cisler & Koster, 2010; MacLeod, Mathews, & Tata, 1986; Mogg & Bradley, 2016; Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes, 2011). In this task, two stimuli are presented simultaneously, usually one hypothetically salient and one neutral, with specific stimulus categories depending on the research question. After a short interval, a probe stimulus appears at one of the two stimuli's location, and participants have to respond to the probe. To infer an attentional bias, reaction times are compared between trials in which the probe appears at the location of the negative versus neutral stimulus. Attentional biases involving threat are of interest both as a general feature of human cognition and as a potential contributor to mental health problems such as aggression, anxiety, and post-traumatic stress disorder and depression (Aupperle, Melrose, Stein, & Paulus, 2012; Gladwin, 2017a; Kimonis, Frick, Fazekas, & Loney, 2006; Mogg & Bradley, 2016; Yang, Ding, Dai, Peng, & Zhang, 2015; Zinchenko et al., 2017).

However, measurement procedures involving spatial attentional biases evoked by emotional stimuli will involve a variety of processes, possibly contributing to a number of findings indicating low reliability (Brown et al., 2014; Dear, Sharpe, Nicholas, & Refshauge, 2011; Puls & Rothermund, 2017; Schmukle, 2005; Waechter, Nelson, Wright, Hyatt, & Oakman, 2014). The cues must be perceived, the emotional content must be detected, and this will evoke a subsequent mixture of responses. For example, participants may automatically shift attention towards the threat as expected, but as threatening stimuli are likely also to be aversive participants may tend to avoid them, or be distracted by the stimulus after focusing attention on it. Indeed, complex patterns of attentional shifting appear to occur in the emotional spatial attention tasks, involving time-dependent shifting, selective attention to the probe versus emotional cue after spatial attentional selection, and engagement versus disengagement with the emotional stimuli (Gladwin, Ter Mors-Schulte, Ridderinkhof, & Wiers, 2013; Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006; Mogg, Bradley, Miles, & Dixon, 2004; Mogg, Holmes, Garner, & Bradley, 2008; Noël et al., 2006; Townshend & Duka, 2007; Vollstädt-Klein, Loeber, von der Goltz, Mann, & Kiefer, 2009).

Moreover, there is a potentially important element of attention that is not included in this mixture of processes, namely the predictive aspect of threat-related biases. One function of spatial selective attention seems likely to be to focus attention on locations where a threatening stimulus may appear, but has not appeared yet. As an illustration, consider the experience of the person hiding in a room in a horror film, faced with two doors behind one of which the killer might be hiding. Although attentional shifts evoked by actually presented negative stimuli may also involve their predictive value for future events (such as physical harm from some nearby danger being predicted by fearful faces, cf., Hedger, Gray, Garner, & Adams, 2016), the psychological processes in this kind of anticipatory state are intuitively very different from those that occur when the killer actually opens the door, and indeed clear psychophysiological changes occur preceding threatening events (Bolstad et al., 2013; Gladwin, Hashemi, van Ast, & Roelofs, 2016; Kerr, McLaren, Mathy, & Nitschke, 2012; Sussman, Szekely, Hajcak, & Mohanty, 2016). The anticipatory state is of theoretical interest from the perspective of models of motivated cognition emphasising the understanding of cognitive processes as reinforcement-based response selection processes aiming to optimize outcome (Alexander, DeLong, & Strick, 1986; de Wit & Dickinson, 2009; Ernst et al., 2004; Gladwin & Figner, 2014; Gladwin, Figner, Crone, & Wiers, 2011; Seger, 2008). If even automatic processes involve at least some degree of outcome prediction to select cognitive actions, even if simple and heuristics-based, then attentional biases should also be found before a predicted emotional stimulus, and not only after the actual presentation of one.

Thus, Visual Probe Tasks (VPTs) designed to focus on this anticipatory attentional state could be of both methodological and theoretical interest. The cued VPT (cVPT), as distinguished from the reactive kind of VPT described above (rVPT), was previously developed to this aim in the context of alcohol-related biases (Gladwin, 2016; Gladwin & Vink, 2017). The cVPT, illustrated in Figure 1, in a sense combines the Dot-Probe task and Posner cueing tasks (Posner, 1980). In the cVPT trials are divided into Picture trials and Probe trials. On Picture trials, a pair of initially neutral cues (i.e., simple symbols) is replaced, after a variable Cue-Stimulus Interval, by an emotional and a neutral stimulus. One cue is always replaced by the emotional stimulus, and the other cue is always replaced by the neutral stimulus. These trials establish the predictive value of the cues during a training period and subsequently maintain the predictive value of cues. On Probe trials, the cues are followed by a probe stimulus instead of the emotional and neutral pictures, to which participants are required to react pressing a button on the keyboard following task instructions. Cue-related effects on performance on Probe trials are thus caused by the contingency between cues and predicted emotional stimuli (Le Pelley, Vadillo, & Luque, 2013;

Luque et al., 2016; Notebaert et al., 2011; Van Damme, Crombez, Hermans, Koster, & Eccleston, 2006), with no emotional stimulus actually being presented at all on that trial. The cVPT has been used to provide novel information on relationships between anticipatory attentional biases for alcohol stimuli, automatic associations and conflict between them, craving, and motives to drink or refrain from drinking (Gladwin & Vink, 2017). It has, however, not been established whether such anticipatory attentional biases exist for threatening stimuli. Further, the visually neutral cues may improve psychometric properties, as effects are due to only two easily distinguishable cues, with presumably no or relatively weak inherent associations that would affect attention, relative to the salience of emotional cues. Thus, the aims of the current study were, first, to determine whether there exists an overall threat-related anticipatory attentional bias; and second, to provide information on the reliability of the cVPT in comparison with an rVPT. We expected that responses would be faster to probes appearing at the location of cues predicting the location of possible threat stimuli versus non-threat stimuli, and that the reliability of attentional bias scores would be higher in the cVPT than in the normal VPT.

Methods

Subjects

120 healthy adult participants (92 female, 28 male, mean age 20, *SD* = 2.1) successfully completed the online experiment and were included in the analyses. An additional 11 participants were not included, as they either did not finish the full experiment or produced extremely low-quality data, quantified as below chance level (0.5) overall accuracy. Participants provided informed consent, and the study was approved by the institutional ethics committee.

Materials

The tasks were programmed in JavaScript, PHP, CSS and HTML; the code is available on request.

Cued Visual Probe Task (cVPT)

The structure of the cVPT was very similar to the alcohol-cVPT as described previously (Gladwin & Vink, 2017). There was a training phase (4 blocks of 24 trials each) and an assessment phase (24 blocks of 24 trials each, split into two halves to allow the ABBA procedure described below). The phases were identical except for the number of blocks. There were two trial types, randomly selected per trial: Picture and Probe trials. The background colour was black throughout the task. Picture trials started with a fixation cross presented for 100, 200, or 300 ms (all such varying durations in the task were selected randomly with equal probability). The fixation cross was followed by the presentation of two cues, located on the top-left and bottom-right of the screen, or on the bottom-left and top-right of the screen. These diagonals on which the cues were located alternated per trial. The cues were coloured blue and yellow and consisted of the symbols O O O O O and | | | | |. The colour-symbol mapping was randomised across participants. Cues were presented for 200, 400, 600, 800 or 1000 ms. The cues were then replaced by pictures representing angry and neutral faces (all male, and all facing forward). One of the cues was always replaced by an angry face centred on the cue location. The other cue was always replaced by a neutral face. The pictures remained onscreen for 1000 ms, followed by 200 ms of empty screen. Participants did not have to give any response on Picture trials. The stimulus set consisted of 44 faces selected from the Bochum Emotional Stimulus Set, BESST (Thoma, Soria Bauser, & Suchan, 2013). The mapping of cues to stimulus category was randomised over subjects.

On Probe trials, the fixation and cue parts of the trial were identical. Instead of pictures appearing at the cued locations, however, a probe stimulus, >><<, was presented at one of the locations, and a distractor stimulus, /\/\ or \/\/, at the other location. The probe stimulus was presented for 1000 ms, or until a response was given. The task was to quickly and accurately press a key corresponding to the probe location whenever it appeared. The keys were F R J I, pressed with the index and middle finger of the left and right hands, mapped to the corresponding position; e.g., the R-key was mapped to the top-left position and was pressed with the middle finger of the left hand. On catch trials (5% probability), no probe was presented, and subjects had to refrain from pressing; on these trials, both the presented stimuli were distractors. This was done in order to encourage searching for the probe stimulus rather than possibly attempting to infer the probe location based on viewing a distractor stimulus at the other location. Responses were followed by 200 ms feedback depending on accuracy: a green +1 for correct responses, a red -1 for incorrect responses, and a red “Too late!” if no response was given within the 1000 ms probe presentation duration.

The use of the two alternating diagonals to present stimuli was done to remove at least some sources of noise due to trial-to-trial carryover effects (Gladwin, 2017a), which were not of interest in the current study; for instance, effects due to giving the same or different response, or responding to the same or different location, on subsequent trials. The varying Cue-Stimulus Interval was included because of the possible time-dependence of attentional biases; for instance, the bias could shift or be stronger or weaker at different time periods following cue presentation.

Reactive Visual Probe Task (rVPT)

The rVPT consisted of a brief introductory phase (two blocks of 24 trials each) and an assessment phase (12 blocks of 24 trials each, split into two parts). The trials of the rVPT were identical to the half of the trials of the Probe trials of the cVPT, except for the use of pairs of an emotional and a neutral stimulus as cues, instead of the predictive cues. The stimuli were the same as those used as pictures in the cVPT.

Procedure

Participants performed the experiment online, starting with a page with instructions and an informed consent button. The questionnaires were then filled in. This was followed by the training phase of the cVPT and the introductory phase of the rVPT. Participants subsequently filled in an awareness check to assess whether they were aware of any contingencies between cue and probe location and between cue and pictorial stimuli. Participants were asked the following question: Did they think there was a relationship between cues and probe location? If so, which colour cue predicted the probe location? Did they think there was a relationship between cues and pictures? If so, which colour cue predicted the angry face? If participants did not know the answer, they were instructed to guess. Then the assessment phases of the cVPT and rVPT were then performed, in an ABBA scheme of the four half-parts of the two VPTs. The assignment of cVPT and rVPT to the "A" or "B" positions was randomised over participants. This was followed by a repeat of the awareness check. The whole procedure lasted 60 minutes.

Preprocessing and statistical analyses

The first four trials per block, inaccurate trials, and trials following inaccurate trials were removed as these trials are likely to involve abnormal processes.

An attentional bias score was calculated per participant as the difference between the median reaction time (RT) on probe stimuli appearing at the threat versus at the neutral location. The median was used, as previously in implicit measures of approach-avoidance bias (e.g., Wiers et al., 2016), in order to reduce the impact of outliers (tests using the mean RT are provided in Supplementary Materials, showing highly similar results). One-sample *t*-tests and repeated measures ANOVA were used to test whether there was any bias and whether there was an effect of CSI on bias, respectively. Split-half reliability was tested using the Spearman-Brown formula; the halves consisted of even versus odd blocks. For completeness, we further provide the same tests for effects of accuracy (mean proportion correct).

Additionally, exploratory analyses intended for future use in planning studies were conducted to investigate correlations between biases and a number of questionnaires. Those results are reported in Supplementary Materials together with their descriptive statistics.

Results

cVPT

As hypothesized, there was an anticipatory attention bias towards threat, $t(119) = -3.88$, $p < .001$, $d = -0.35$. The magnitude of the bias was -11 ms, indicating a bias towards threat: RT was 566 ms when probes appeared at the neutral location and 556 ms when probes appeared at threat location (although 556 – 566 is -10, the bias was -11 ms due to rounding). Essentially, this bias occurred in the absence of the predicted stimuli actually being presented, and must have been due to effects evoked by the predictive cues. There were no effects of CSI.

The split-half reliabilities were .56 over all CSIs; -.16 for the 200 ms CSI; .48 for 400 ms; .37 for 600 ms; .37 for 800 ms; and .41 for 1000 ms.

Accuracy data showed an effect of threat, responses to probes at the threat location being more accurate than responses to probes at the neutral location ($t(119) = 2.12$, $p = 0.036$. $d = 0.19$; the accuracy was .952 versus .944). This effect was modulated by CSI ($F(4, 476) = 4.1$, $p = 0.0042$, $\eta_p^2 = 0.033$), due to the threat-bias being strongest at 600 ms.

rVPT

There was also an attention bias towards threat in the reactive VPT, $t(119) = -4.11$, $p < .001$, $d = -0.38$. The magnitude of the bias was -9 ms, indicating an attentional bias towards threat as well; RT was 530 ms when probes appeared at the location of the neutral cue (the neutral face), and 521 ms when probes appeared at the location of the threat cue (the angry face). There were no effects of CSI.

The split-half reliabilities were .34 over all CSIs; .22 for the 200 ms CSI; .0047 for 400 ms; .031 for 600 ms; .19 for 800 ms; and .31 for 1000 ms.

Accuracy data showed no effects of threat.

In analyses combining the cVPT and rVPT data in a single model, no significant difference between the task types on attentional bias was found.

Discussion

The current study aimed to determine whether an anticipatory attentional bias to threat could be detected by the cued VPT (cVPT) and to compare its split-half reliability with that of a reactive VPT (rVPT). A clear attentional bias was found on both the cVPT and rVPT. On the cVPT, participants were quicker to respond to probes at the location where a threatening stimulus could have appeared. This anticipatory bias, therefore, does not reflect processes evoked by the viewing of an actual threatening stimulus. It appears that attention is consistently shifted towards a location predicted to reveal a threat. This would appear to make sense from an evolutionary perspective: survival would be enhanced by the ability to use predictive information to focus attention on locations where an as yet unobserved threat could appear. This aspect of *predictive* attentional biases involving emotional stimuli appears to have been understudied thus far, relative to *reactive* attentional biases. However, relatively recent lines of research have focused on anticipatory psychophysiological states under threat (Gladwin et al., 2016; Lojowska, Gladwin, Hermans, & Roelofs, 2015; Löw, Weymar, & Hamm, 2015; Mobbs et al., 2007; Nieuwenhuys & Oudejans, 2010; Wendt, Löw, Weymar, Lotze, & Hamm, 2017). For instance, in a task with a purely anticipatory period in which participants viewed a static screen but awaited a potential virtual attack, heart rate and body sway decreased, reflecting preparatory freezing (Gladwin et al., 2016). It may be fruitful to apply such psychophysiological approaches to threat-related spatial anticipation.

The prediction of anticipatory attentional biases to threat and the design of the cVPT were derived partly from the R^3 model of automatic versus reflective processing (Gladwin & Figner, 2014; Gladwin et al., 2011). In this model, cognitive functions, whether “top-down” or “bottom-up”, are selected as any other response, based on associations between stimuli, responses, and outcomes. The time allotted to refining the selection process differentiates relatively reflective from relatively automatic processes, as in the iterative reprocessing model of evaluation (Cunningham, Zelazo, Packer, & Van Bavel, 2007). From this perspective, predictive cues provide foreknowledge of the outcome of shifting attention to or from cued locations, and thereby affect the cognitive response selection process. However, the current data only establish the existence and cue-based measurability of the anticipatory attentional bias for threat, not the underlying mechanisms. An important direction for further study would appear to be clarifying whether anticipatory attentional biases can be attributed to sign-tracking or goal-tracking (Morrison, Bamkole, & Nicola, 2015), and perhaps whether there are interesting individual differences in this regard.

Split-half reliability was almost uniformly higher in the cVPT than the rVPT, with the exception of the shortest CSI (i.e., 200 ms). This finding was largely as expected, based on the rationale of the removal of noise related to the actual presentation of varying pairs of pictures as cues. One source of noise is that each picture and each picture-pair could have a different effect on bias. Further, as explained in the Introduction, the response to pictorial stimuli could be more noisy due to the complex mixture of processes that could be evoked by their presentation. For instance, a threatening stimulus could draw attention due to fundamental attentional functions (e.g., directing resources towards likely threat), but also be aversive and therefore cause attention to be shifted away from the stimulus. Unless the temporal dynamics of these processes happen to be such that they can be adequately disentangled by varying the Cue-Stimulus Interval, this would lead to uncontrolled noise might account for the poor reliability scores of the Dot-probe reported in previous psychometric studies (we note this does not imply that every instance of Dot-Probe reliability analyses will be low). By using visually neutral predictive cues, noise may have been reduced, resulting in a more reliable assessment. While the test-retest reliability of the cVPT was still not at the level considered acceptable for questionnaire scales, it was conspicuously higher, in particular at the 400 and 600 ms CSIs. This increase in process purity may, of course, lose interesting information. Recent work has even focused on using the variability itself of attentional bias as a measure of underlying processes (Gladwin, 2016; Iacoviello et al., 2014; Zvielli, Bernstein, & Koster, 2014), such as conflicting evaluative associations (Gladwin & Vink, 2017). Clearly separating such different processes and sources of information would appear to be of importance in future attentional bias studies. We briefly note that advances in behavioural measures for attentional biases are important, in addition to lines of research moving into eye tracking. First, from a theoretical point of view, not all attentional processes are overt and detectable as eye movements. Indeed, EEG studies of spatial attention for instance even depend on the eyes remaining focused on a central fixation point as attention moves covertly. Second, from a pragmatic perspective, behavioural measures allow research to be conducted in a wider range of settings than possible using eye tracking equipment. The field needs to remain open to multiple methods with different advantages and disadvantages. The cVPT will, hopefully, help address the methodological disadvantage of noisy behavioural bias measures.

A potential application of the cVPT is as a novel version of attentional bias modification (ABM). The same rationale as used in ABM based on manipulated versions of the Dot-Probe (Mogg, Waters, & Bradley, 2017) could be applied to training individuals to shift attention to or away from the predicted location of salient stimuli. Speculatively, an advantage of using the cVPT could be that the training would not paradoxically increase the task-relevance of stimulus categories. This has been termed the salience side-effect (Gladwin, 2017b); note that in usual ABM methods, even if the aim is to train attention away from, for example, threatening stimuli, such stimuli are actually highly salient because they remain informative on the location of the probe. In a training version of the cVPT participants would learn to shift attention based on abstract symbols as cues, not the undesirably salient stimuli themselves. Early results indicate the cVPT may indeed be useful as a training task, and much work indicates that cognitive functions can be assigned to arbitrary cues via reinforcement (McLoughlin & Stewart, 2017), but predictive cue-based ABM as yet remains a direction for future research. A potential issue to be careful of, however, would be the possibility that predictive cues could become aversive due to the training, which would be an undesirable side effect. This should at least be monitored during and following training.

A limitation of the study is that it remains to be determined whether the results generalise outside the student sample. This population may be relatively skilled at recognising predictive relationships. Even this population was however often unaware of the cue-stimulus contingencies. This does not imply they were unaffected by the contingencies; indeed, exploratory analyses (see Supplementary Materials) did not show any relationships between awareness and bias. Further, the current results do not indicate whether there would be clinical applications of using anticipatory attentional bias, although this would appear to be a clearly interesting direction for further study. An inherent limitation of the cVPT relative to the rVPT is the need for a training period, although it appears that the relatively short training phase used in the current study was sufficient to find a clear bias. However, the training period may also be of interest in itself, for instance by allowing analysis of the time course of the development of the bias. A limitation of the sample was the unequal distribution of female and male participants. It could be informative for future studies to focus on potential gender-related differences in the threat bias. The inclusion of female faces as stimuli could be of particular interest in such studies. A final limitation is that the current study cannot determine the exact mechanisms resulting in the bias. For instance, the current data cannot determine the degree to which the visual features of the cues themselves become emotional stimuli, and whether this plays a causal role in the bias rather than purely their predictive value.

In conclusion, an anticipatory attentional bias to threat was found using the cued Visual Probe Task. The split-half reliability of this bias was generally higher than the bias evoked by presented emotional cues, as used in more classical paradigms such as the Dot-Probe task. Further studies into the anticipatory attentional bias appear warranted, and the cVPT would appear to be a suitable method for such study.

DECLARATION OF INTEREST

The authors report no conflicts of interest.

References

Alexander, G. E., DeLong, M. R., & Strick, P. L. (1986). Parallel organization of functionally segregated circuits linking basal ganglia and cortex. *Annual Review of Neuroscience*, *9*, 357–81. https://doi.org/10.1146/annurev.ne.09.030186.002041

Aupperle, R. L., Melrose, A. J., Stein, M. B., & Paulus, M. P. (2012). Executive function and PTSD: Disengaging from trauma. *Neuropharmacology*, *62*(2), 686–94. https://doi.org/10.1016/j.neuropharm.2011.02.008

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychological Bulletin*, *133*(1), 1–24. https://doi.org/10.1037/0033-2909.133.1.1

Bolstad, I., Andreassen, O. A., Reckless, G. E., Sigvartsen, N. P., Server, A., & Jensen, J. (2013). Aversive event anticipation affects connectivity between the ventral striatum and the orbitofrontal cortex in an fMRI avoidance task. *PloS One*, *8*(6), e68494. https://doi.org/10.1371/journal.pone.0068494

Brown, H. M., Eley, T. C., Broeren, S., MacLeod, C. M., Rinck, M., Hadwin, J. A., & Lester, K. J. (2014). Psychometric properties of reaction time based experimental paradigms measuring anxiety-related information-processing biases in children. *Journal of Anxiety Disorders*, *28*(1), 97–107. https://doi.org/10.1016/j.janxdis.2013.11.004

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review*, *30*(2), 203–16. https://doi.org/10.1016/j.cpr.2009.11.003

Cunningham, W. A., Zelazo, P. D., Packer, D. J., & Van Bavel, J. J. (2007). The Iterative Reprocessing Model: A Multilevel Framework for Attitudes and Evaluation. *Social Cognition*, *25*(5), 736–760. https://doi.org/10.1521/soco.2007.25.5.736

Dear, B. F., Sharpe, L., Nicholas, M. K., & Refshauge, K. (2011). The psychometric properties of the dot-probe paradigm when used in pain-related attentional bias research. *The Journal of Pain : Official Journal of the American Pain Society*, *12*(12), 1247–54. https://doi.org/10.1016/j.jpain.2011.07.003

de Wit, S., & Dickinson, A. (2009). Associative theories of goal-directed behaviour: a case for animal-human translational models. *Psychological Research*, *73*(4), 463–76. https://doi.org/10.1007/s00426-009-0230-6

Ernst, M., Nelson, E. E., McClure, E. B., Monk, C. S., Munson, S., Eshel, N., … Pine, D. S. (2004). Choice selection and reward anticipation: an fMRI study. *Neuropsychologia*, *42*(12), 1585–97. https://doi.org/10.1016/j.neuropsychologia.2004.05.011

Gladwin, T. E. (2016). Attentional bias variability and cued attentional bias for alcohol stimuli. *Addiction Research and Theory*, *25*(1), 32–38. https://doi.org/10.1080/16066359.2016.1196674

Gladwin, T. E. (2017a). Carryover effects in spatial attentional bias tasks and their relationship to subclinical PTSD symptoms. *Traumatology*. https://doi.org/10.1037/trm0000121

Gladwin, T. E. (2017b). Negative effects of an alternating-bias training aimed at attentional flexibility: A single session study. *Health Psychology and Behavioral Medicine*, *5*(1), 41–56. https://doi.org/10.1080/21642850.2016.1266634

Gladwin, T. E., & Figner, B. (2014). “Hot” cognition and dual systems: Introduction, criticisms, and ways forward. In E. Wilhelms & V. F. Reyna (Eds.), *Frontiers of Cognitive Psychology Series: Neuroeconomics, Judgment and Decision Making* (pp. 157–180). New York: Psycholoy Press.

Gladwin, T. E., Figner, B., Crone, E. A., & Wiers, R. W. (2011). Addiction, adolescence, and the integration of control and motivation. *Developmental Cognitive Neuroscience*, *1*(4), 364–376. https://doi.org/10.1016/j.dcn.2011.06.008

Gladwin, T. E., Hashemi, M. M., van Ast, V. A., & Roelofs, K. (2016). Ready and waiting: Freezing as active action preparation under threat. *Neuroscience Letters*, *619*, 182–188. https://doi.org/10.1016/j.neulet.2016.03.027

Gladwin, T. E., Ter Mors-Schulte, M. H. J., Ridderinkhof, K. R., & Wiers, R. W. (2013). Medial parietal cortex activation related to attention control involving alcohol cues. *Frontiers in Psychiatry*, *4*, 174. https://doi.org/10.3389/fpsyt.2013.00174

Gladwin, T. E., & Vink, M. (2017). Alcohol-related attentional bias variability and conflicting automatic associations. *Journal of Experimental Psychopathology*.

Hedger, N., Gray, K. L. H., Garner, M., & Adams, W. J. (2016). Are visual threats prioritized without awareness? A critical review and meta-analysis involving 3 behavioral paradigms and 2696 observers. *Psychological Bulletin*, *142*(9), 934–968. https://doi.org/10.1037/bul0000054

Iacoviello, B. M., Wu, G., Abend, R., Murrough, J. W., Feder, A., Fruchter, E., … Charney, D. S. (2014). Attention bias variability and symptoms of posttraumatic stress disorder. *Journal of Traumatic Stress*, *27*(2), 232–9. https://doi.org/10.1002/jts.21899

Kerr, D. L., McLaren, D. G., Mathy, R. M., & Nitschke, J. B. (2012). Controllability Modulates the

Anticipatory Response in the Human Ventromedial Prefrontal Cortex. *Frontiers in Psychology*, *3*. https://doi.org/10.3389/fpsyg.2012.00557

Kimonis, E. R., Frick, P. J., Fazekas, H., & Loney, B. R. (2006). Psychopathy, aggression, and the processing of emotional stimuli in non-referred girls and boys. *Behavioral Sciences & the Law*, *24*(1), 21–37. https://doi.org/10.1002/bsl.668

Koster, E. H. W., Crombez, G., Verschuere, B., Van Damme, S., & Wiersema, J. R. (2006). Components of attentional bias to threat in high trait anxiety: Facilitated engagement, impaired disengagement, and attentional avoidance. *Behaviour Research and Therapy*, *44*(12), 1757–71. https://doi.org/10.1016/j.brat.2005.12.011

Le Pelley, M. E., Vadillo, M., & Luque, D. (2013). Learned predictiveness influences rapid attentional capture: Evidence from the dot probe task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(6), 1888–1900.

Lojowska, M., Gladwin, T. E., Hermans, E. J., & Roelofs, K. (2015). Freezing promotes perception of coarse visual features. *Journal of Experimental Psychology. General*, *144*(6), 1080–8. https://doi.org/10.1037/xge0000117

Löw, A., Weymar, M., & Hamm, A. O. (2015). When Threat Is Near, Get Out of Here: Dynamics of Defensive Behavior During Freezing and Active Avoidance. *Psychological Science*. https://doi.org/10.1177/0956797615597332

Luque, D., Vadillo, M. A., Pelley, M. E. Le, Beesley, T., Le Pelley, M. E., & Beesley, T. (2016). Prediction and uncertainty in associative learning : Examining controlled and automatic components of learned attentional biases. *The Quarterly Journal of Experimental Psychology*, *218*(May), 1–19. https://doi.org/10.1080/17470218.2016.1188407

MacLeod, C. M., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, *95*(1), 15–20. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3700842

McLoughlin, S., & Stewart, I. (2017). Empirical advances in studying relational networks. *Journal of Contextual Behavioral Science*, *6*(3), 329–342. https://doi.org/10.1016/J.JCBS.2016.11.009

Mobbs, D., Petrovic, P., Marchant, J. L., Hassabis, D., Weiskopf, N., Seymour, B., … Frith, C. D. (2007). When fear is near: Threat imminence elicits prefrontal-periaqueductal gray shifts in humans. *Science (New York, N.Y.)*, *317*(5841), 1079–83. https://doi.org/10.1126/science.1144298

Mogg, K., & Bradley, B. P. (2016). Anxiety and attention to threat: Cognitive mechanisms and treatment with attention bias modification. *Behaviour Research and Therapy*, *87*, 76–108. https://doi.org/10.1016/j.brat.2016.08.001

Mogg, K., Bradley, B. P., Miles, F., & Dixon, R. (2004). BRIEF REPORT Time course of attentional bias for threat scenes: Testing the vigilance-avoidance hypothesis. *Cognition & Emotion*, *18*(5), 689–700. https://doi.org/10.1080/02699930341000158

Mogg, K., Holmes, A., Garner, M., & Bradley, B. P. (2008). Effects of threat cues on attentional shifting, disengagement and response slowing in anxious individuals. *Behaviour Research and Therapy*, *46*(5), 656–67. https://doi.org/10.1016/j.brat.2008.02.011

Mogg, K., Waters, A. M., & Bradley, B. P. (2017). Attention Bias Modification (ABM): Review of Effects of Multisession ABM Training on Anxiety and Threat-Related Attention in High-Anxious Individuals. *Clinical Psychological Science*, 216770261769635.

https://doi.org/10.1177/2167702617696359

Morrison, S. E., Bamkole, M. A., & Nicola, S. M. (2015). Sign Tracking, but Not Goal Tracking, is Resistant to Outcome Devaluation. *Frontiers in Neuroscience*, *9*, 468. https://doi.org/10.3389/fnins.2015.00468

Nieuwenhuys, A., & Oudejans, R. R. D. (2010). Effects of anxiety on handgun shooting behavior of police officers: a pilot study. *Anxiety, Stress, and Coping*, *23*(2), 225–33. https://doi.org/10.1080/10615800902977494

Noël, X., Colmant, M., Van Der Linden, M., Bechara, A., Bullens, Q., Hanak, C., & Verbanck, P. (2006). Time course of attention for alcohol cues in abstinent alcoholic patients: the role of initial orienting. *Alcoholism, Clinical and Experimental Research*, *30*(11), 1871–7. https://doi.org/10.1111/j.1530-0277.2006.00224.x

Notebaert, L., Crombez, G., Van Damme, S., De Houwer, J., & Theeuwes, J. (2011). Signals of threat do not capture, but prioritize, attention: a conditioning approach. *Emotion (Washington, D.C.)*, *11*(1), 81–9. https://doi.org/10.1037/a0021286

Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, *32*(1), 3–25. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7367577

Puls, S., & Rothermund, K. (2017). Attending to emotional expressions: no evidence for automatic capture in the dot-probe task. *Cognition and Emotion*, 1–14. https://doi.org/10.1080/02699931.2017.1314932

Schmukle, S. C. (2005). Unreliability of the dot probe task. *European Journal of Personality*, *19*(7), 595–605. https://doi.org/10.1002/per.554

Seger, C. A. (2008). How do the basal ganglia contribute to categorization? Their roles in generalization, response selection, and learning via feedback. *Neuroscience and Biobehavioral Reviews*, *32*(2), 265–78. https://doi.org/10.1016/j.neubiorev.2007.07.010

Sussman, T. J., Szekely, A., Hajcak, G., & Mohanty, A. (2016). It's all in the anticipation: How perception of threat is enhanced in anxiety. *Emotion (Washington, D.C.)*, *16*(3), 320–7. https://doi.org/10.1037/emo0000098

Thoma, P., Soria Bauser, D., & Suchan, B. (2013). BESST (Bochum Emotional Stimulus Set)—A pilot validation study of a stimulus set containing emotional bodies and faces from frontal and averted views. *Psychiatry Research*, *209*(1), 98–109. https://doi.org/10.1016/j.psychres.2012.11.012

Townshend, J. M., & Duka, T. (2007). Avoidance of alcohol-related stimuli in alcohol-dependent inpatients. *Alcoholism, Clinical and Experimental Research*, *31*(8), 1349–57. https://doi.org/10.1111/j.1530-0277.2007.00429.x

Van Damme, S., Crombez, G., Hermans, D., Koster, E. H. W., & Eccleston, C. (2006). The role of extinction and reinstatement in attentional bias to threat: a conditioning approach. *Behaviour Research and Therapy*, *44*(11), 1555–63. https://doi.org/10.1016/j.brat.2005.11.008

Vollstädt-Klein, S., Loeber, S., von der Goltz, C., Mann, K., & Kiefer, F. (2009). Avoidance of alcohol-related stimuli increases during the early stage of abstinence in alcohol-dependent patients. *Alcohol and Alcoholism (Oxford, Oxfordshire)*, *44*(5), 458–63. https://doi.org/10.1093/alcalc/agp056

Waechter, S., Nelson, A. L., Wright, C., Hyatt, A., & Oakman, J. (2014). Measuring attentional bias to threat: Reliability of dot probe and eye movement indices. *Cognitive Therapy and*

Research, *38*(3), 313–333. https://doi.org/10.1007/s10608-013-9588-2

Wendt, J., Löw, A., Weymar, M., Lotze, M., & Hamm, A. O. (2017). Active avoidance and attentive freezing in the face of approaching threat. *NeuroImage*. https://doi.org/10.1016/j.neuroimage.2017.06.054

Wiers, C. E., Gladwin, T. E., Ludwig, V. U., Gröpper, S., Stuke, H., Gawron, C. K., … Bermpohl, F. (2016). Comparing three cognitive biases for alcohol cues in alcohol dependence. *Alcohol and Alcoholism*, *1*(7), 1–7. https://doi.org/10.1093/alcalc/agw063

Yang, W., Ding, Z., Dai, T., Peng, F., & Zhang, J. X. (2015). Attention Bias Modification training in individuals with depressive symptoms: A randomized controlled trial. *Journal of Behavior Therapy and Experimental Psychiatry*, *49*(Pt A), 101–111. https://doi.org/10.1016/j.jbtep.2014.08.005

Zinchenko, A., Al-Amin, M. M., Alam, M. M., Mahmud, W., Kabir, N., Reza, H. M., & Burne, T. H. J. (2017). Content specificity of attentional bias to threat in post-traumatic stress disorder. *Journal of Anxiety Disorders*, *50*, 33–39. https://doi.org/10.1016/J.JANXDIS.2017.05.006

Zvielli, A., Bernstein, A., & Koster, E. H. W. (2014). Dynamics of attentional bias to threat in anxious adults: bias towards and/or away? *PloS One*, *9*(8), e104025. https://doi.org/10.1371/journal.pone.0104025

Figure 1. Illustration of the cVPT. There were two kinds of trials. On Picture trials, a pair of abstract cues were presented and subsequently replaced by pictorial stimuli: an angry and a neutral face. One of the cues was always replaced by a neutral face, and the other always by an angry face. The location of the cues alternated between the top-left / bottom-right and the bottom-left / top-right diagonal. Picture trials did not require a response. On Probe trials, one of the cues was replaced by a probe stimulus and the other by a distractor stimulus. Participants were required to press the key associated with the probe stimulus.