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Spatial Anticipatory Attentional Bias for Threat: Reliable Individual Differences with RT-based Online Measurement

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TEG and MV contributed to the conception and design of the study and data collection and approved the manuscript. TEG programmed the task, analysed and interpreted the data and drafted the article.

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Abstract

Cues that predict the future location of emotional stimuli may evoke an anticipatory form of automatic attentional bias. The reliability of this bias towards threat is uncertain: experimental design may need to be optimized or individual differences may simply be relatively noisy in the general population. The current study therefore aimed to determine the split-half reliability of the bias, in a design with fewer factors and more trials than in previous work. A sample of 63 participants was used for analysis, who performed the cued Visual Probe Task online, which aims to measure an anticipatory attentional bias. The overall bias towards threat was tested and split-half reliability was calculated over even and odd blocks. Results showed a significant bias towards threat and a reliability of around .7. The results support systematic individual differences in anticipatory attentional bias and demonstrate that RT-based bias scores, with online data collection, can be reliable.

Keywords

Attentional bias; dot-probe; reliability; cued Visual Probe Task; threat.

1. Introduction

Selective attention refers to the selection of a subset of signals for further processing, as has been computationally modelled via saliency maps (Soltani & Koch, 2010). While traditionally bottom-up salience occurs due to low-level visual features, there is also a bottom-up form of emotional salience: Certain stimulus categories may involuntarily draw attention due to their emotional or motivational content. Intuitively, consider looking down and seeing, close to your hand, a mug, a pencil, and a spider; where will attention swiftly be directed? A spatial attentional bias refers to a tendency for selective attention to be automatically drawn to the location of such emotional categories of stimuli (Cisler & Koster, 2010). Spatial attentional bias can be assessed using the dot-probe task (MacLeod et al., 1986; Mogg & Bradley, 1999), in which pairs of task-irrelevant cue stimuli, one salient and one non-salient, are used to hypothetically shift attention. This is usually tested by following the cue stimuli with a probe stimulus, presented at the location of either the salient or the non-salient cue. Bias scores can be calculated as reaction times to probes when they appear at the location of the salient cue versus the non-salient cue. These biases are then taken as a measure of attentional bias towards/away from the salient cues, which can then be used in further analyses linking the bias to other individual differences. For instance, attention towards threat has been linked to anxiety (Bantin et al., 2016; Cisler & Koster, 2010), and complex patterns of attentional bias have been linked to risky drinking and alcohol addiction (Field et al., 2004; Field & Cox, 2008; Townshend & Duka, 2001, 2007). However, the reliability of bias scores has been found to be very low (in some cases near zero) in a number of studies (Ataya et al., 2012; Brown et al., 2014; Chapman et al., 2017; Dear et al., 2011; Kappenman et al., 2014; Puls & Rothermund, 2018; Schmukle, 2005; Waechter et al., 2014), questioning whether such bias scores should be used to study individual differences (Christiansen et al., 2015; McNally, 2018; Rodebaugh et al., 2016). We briefly note that the issue of whether individual differences can be reliably measured must be separated from the question of whether there is a strong average effect, i.e., whether within-subject effects are strong; these are even somewhat opposing aims, as reliable individual differences benefit from relatively large variation between individuals in a population, while such variation would be noise in the context of within-subject effects (De Schryver et al., 2016; Goodhew & Edwards, 2019; MacLeod et al., 2019).

However, there may be ways to improve reliability of spatial attentional bias scores. One approach involves an adaptation of the dot-probe that uses visually neutral cues that predict the locations of upcoming salient stimuli, termed the "predictive" or "cued" Visual Probe Task, cVPT (Gladwin, 2016; Gladwin & Vink, 2018). The task is illustrated in Figure 1. The essential feature of the task is that it presents two different, randomly intermixed trial types: picture and probe trials. On picture trials, a pair of abstract, visually neutral predictive cues are presented, followed by a pair of stimuli, one from a hypothetically salient stimulus category and one from a control stimulus category. The locations of the salient and control stimuli are fully determined by the predictive cues. These trials thus serve to establish and maintain the predictive value of the cues. On probe trials, probe stimuli requiring responses are presented *instead of* the pictures, to assess whether the predictive cues evoke a bias. Note that the task-irrelevant stimuli do not occur on those trials on which behavioural responses are given, and any bias must be due to the predicted stimulus categories. This differs from traditional tasks in which the measurement of automatic biases relies on the actual presentation of emotional stimuli, which are then expected to evoke an automatic stimulus-response response. The rationale for using predictive cues to evoke an anticipatory form of automatic processes was based on a variant of dual-process models called the Reprocessing/ Reentrance and Reinforcement model of Reflectivity, or R3 model (Gladwin et al., 2011; Gladwin & Figner, 2014). This model was developed in response to criticisms of dual-process/dual-system models (Keren, 2013; Keren & Schul, 2009). Its overall aim is to provide a theoretical space based as closely as possible on relevant elements of neuroscientific knowledge and concepts. One specific element of the model was a definition of reflectivity versus automaticity as a continuum based on the amount of processing performed in an outcome-based response-selection loop. Automatic processes could then involve predictive and outcome-related processes, simply with less reprocessing time (Cunningham et al., 2007). In the cVPT, the predictive cues were therefore hypothesized to evoke an automatic bias towards the predicted stimulus category, termed the anticipatory attentional bias. A number of studies have confirmed and explored this expected effect. A high reliability of around .75 was found for an alcohol-related anticipatory attentional bias (Gladwin, 2019), which could not be explained merely by individual differences involving cue features not related to their predictive value (Gladwin, Banic, Figner, et al., 2019); and which furthermore has shown correlations with risky drinking (Gladwin, 2019; Gladwin & Vink, 2018). An overall bias towards threat has been found which had relatively good reliability compared to the stimulus-evoked bias (Gladwin, Möbius, Mcloughlin, et al., 2019) and was robust to reversing the specific cues' predictive value (Gladwin, Figner, & Vink, 2019), but not as high – in the range of .4 to .56 - as for alcohol-related bias. This may be due to use of multiple cue-probe intervals in previous work, reducing the number of trials per interval and possibly introducing a source of noise. Finally, in a training study (Gladwin, Möbius, & Becker, 2019), it was found that performing a cVPT that was designed to train attention towards versus away from the predicted threat category induced a stimulus-evoked bias in the trained direction. This suggests that the cVPT for threat indeed involves outcome-focused processes; otherwise, the training would merely have affected responses to the particular predictive cues used during training, and would not have affected biases involving the predicted stimulus categories.

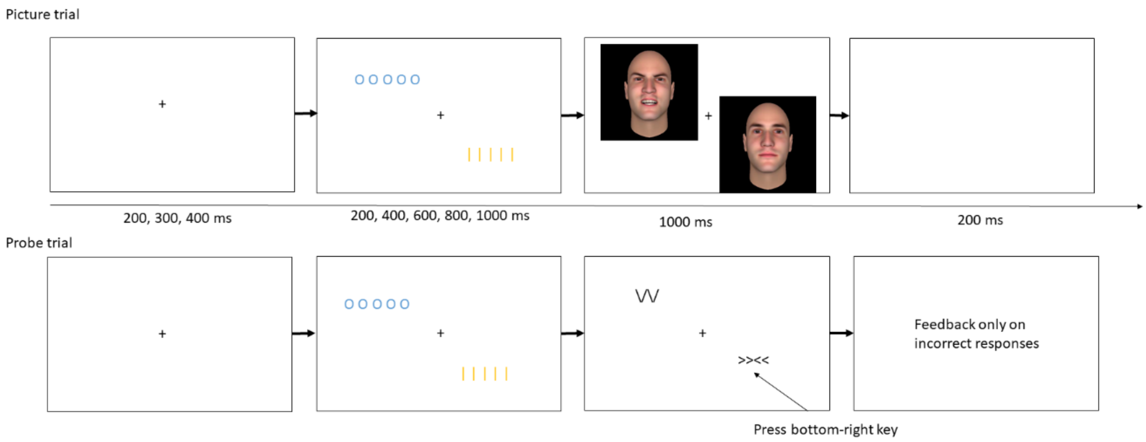

Figure 1. Illustration of the cued Visual Probe Task.

A gap in the currently available information is that it has not yet been shown that the split-half reliability of the anticipatory attentional bias for threat is not only relatively high but can reach similar levels as for alcohol. This may reflect designs that were suboptimal for providing reliable scores, or it may indicate that the underlying individual differences within the general population are less robust. The primary aim of the current study was therefore to assess the reliability of the threat-related bias using a single cue-probe interval and twice the number of assessment trials as in a previous study (Gladwin, Figner, & Vink, 2019). This effectively increased the number of trials used to calculate the bias by a factor of four. This increase of trial numbers was predicted to result in a similar level of reliability as for the alcohol-related bias.

2. Materials and Methods

2.1. Participants

The sample consisted of 64 students who enrolled for credit. One participant was removed for having very low overall accuracy (below .5, clearly indicating insufficient task engagement). In the analysis sample there remained 52 female and 11 male participants, mean age 20, SD = 4.

2.2. Materials

The cVPT was programmed using JavaScript, PHP and HTML. The task consists of two types of trials, Picture and Probe trials; trial type is randomly selected per trial. Picture trials started with a fixation period of 150, 200, or 250 ms (randomly selected with equal probability). This was followed by a pair of predictive cues, onscreen for 400 ms. The cues were the letter strings OOOOO and XXXXX, coloured yellow (RGB values 250, 250, 10) or light blue (RGB values 10, 250, 250); which colour was assigned to which letters was randomized per participant. The two cues were presented either at the top-left and bottom-right diagonal of the screen, or on the bottom-left and top-right diagonal of the screen; the diagonals alternated per trial. Which cue was presented at which location on the diagonal was randomized per trial. Each of the cues was replaced by a picture centred on the cues' positions. One of the cues was always replaced by an angry face, and the other was always replaced by a neutral face; which cue predicted which expression was randomized per participant. Faces were selected (without replacement until all exemplars had been used, and then reshuffled such that faces were never repeated) from 36 photographs of faces per category, taken from the Karolinska Directed Emotional Faces set (Lundqvist et al., 1998). Pictures remained onscreen for 1000 ms. Trials ended with an inter-trial interval of 200 ms during which the screen was empty. Probe trials were identical to Picture trials up to the presentation of the pictures. Instead of pictures, probe stimuli were presented at the cue locations: a target, >><<, and a distractor, /\/\ or \/\/. The distractor was used to reduce the ability of detecting targets regardless of the direction of attention. Which of the locations the target was presented at was randomized per trial. Participants were instructed to press the response key corresponding to the target's location whenever it appeared. The keys were R for top-left, F for bottom-left, J for bottom-right, and I for top-right; these were to be pressed with the index (bottom positions) and middle (top positions) finger of the left and right hands, resulting in a simple stimulus-response mapping. Note that in this task design, due to the diagonalization and target detection type of probes, responses, stimulus locations and probe locations never repeated from one trial to the next, removing potential sources of noise. Incorrect responses were followed by the text “Incorrect!” in red for 200 ms. Late responses were followed by the text “Too late!”.

2.3. Procedure

The experiment was performed online as part of a set of studies performed in the same session for practical purposes. Participants first completed demographic and other questionnaires not of interest to the current study, followed by two training runs of the cVPT (each two blocks of 48 trials) and then the assessment run of the cVPT (16 blocks of 48 trials). Following each run, participants were given awareness checks in which they were asked which of the cues was followed by the angry face.

2.4. Analyses

During preprocessing, the following trials were removed: The first four trials of the run, the first trial per block, error trials, trials following an error, and trials with an RT more than 3 SD away from the mean of the experimental condition the trial was in. Of the remaining probe trials, the median RT per condition was used for further analyses. These preprocessing steps were the same as those used in a recent set of similar studies on the cVPT (Gladwin, Banic, Figner, et al., 2019).

The anticipatory attentional bias was defined per participant as the difference in RT to targets at the predicted location of angry faces minus neutral faces. Split-half reliability was calculated using the Spearman correlation between the bias on even and on odd blocks, with Spearman-Brown correction. Further, we tested via a one-sided paired-sample t-test whether there was an overall within-subject bias towards threat.

3. Results

The accuracy on the three awareness checks was .65, .89 and .92. There was an overall bias towards threat, $t(62) = -2.13$, $p = .038$, $d = -0.27$. The mean RT over participants was 531 ms when the target was on the threat location and 536 ms when the target was on the neutral location.

The split-half reliability of the bias was .71 (Figure 2). To assess sensitivity of this to extreme cases, data points were removed with an absolute z-score of the bias over 2 on either even or odd blocks. The reliability for this restricted dataset was .69.

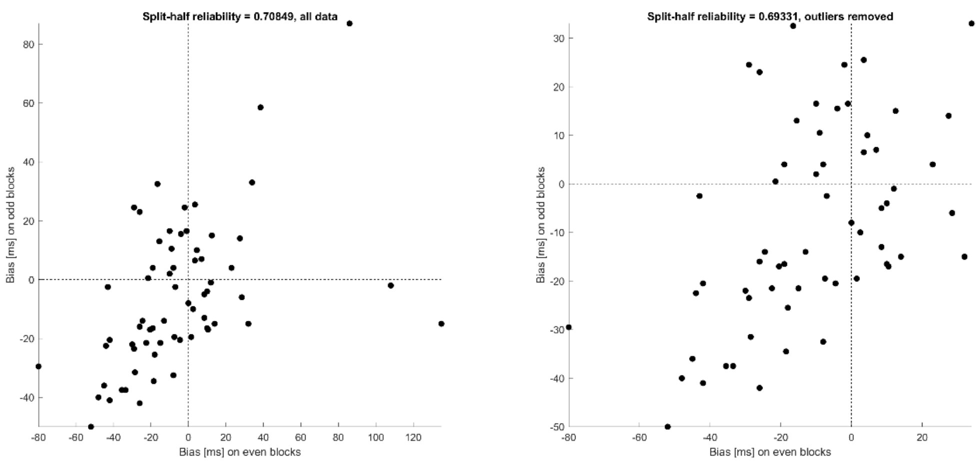

Figure 2. Split-half bias scores. The figure shows the scatterplots for the bias scores found for even and odd blocks, used for the split-half correlations. The left figure shows all data points. In the right figure, data points with an absolute z-score above two for either the

even or odd bias have been removed, to explore whether the reliability was dependent on extreme cases driving a high correlation. This did not appear to be the case.

4. Discussion

The aim of the current study was to determine whether the anticipatory attentional bias for threat could achieve similarly high split-half reliability as the bias for alcohol. A single cue-probe interval and a relatively high number of trials were used for this. Reliability was confirmed to be high for this type of task, around .7. This would be in the acceptable range for individual difference studies. Further, there was an overall bias towards threat as expected, although the size of this effect was small.

The results thus confirm that a behavioural measure of attentional bias, involving task-irrelevant salient stimuli, can achieve high reliability; furthermore, this was found with online data collection. This approach to measurement did involve some changes to the usual task design. Perhaps most fundamentally, predictive cues were used. The use of these cues was originally based on the R^3 model, in which asymmetries in outcome-focused response-selection processes could induce anticipatory biases (Gladwin et al., 2011). We acknowledge that there may of course be alternative views and frameworks that could be used to understand attentional bias evoked by predictive cues. Importantly, however, the bias does seem to involve processes related to the predicted outcomes of attentional shifts rather than merely the conditioned cues (Gladwin, Möbius, & Becker, 2019). Further, reliability does not appear to be due to systematic attentional preferences involving the cues themselves, as reversing the cue-outcome mapping did not strongly diminish the expected reliability in previous work (Gladwin, Figner, & Vink, 2019) and cues with a randomized relationship to subsequent stimuli did not result in high reliability in the context of alcohol

(Gladwin, Banic, Figner, et al., 2019). Further, from the perspective of task features, the use of predictive cues may also increase reliability due to the removal of trial-to-trial noise present in usual spatial attentional bias tasks due to the particular combination of stimulus exemplars used as cues on each trial. We reiterate that the reliability of the bias is a separate issue from whether the average bias is large or small; in the current study, the average bias was small but in the direction of threat, in line with previous studies (Gladwin, Figner, & Vink, 2019; Gladwin, Möbius, Mcloughlin, et al., 2019).

Limitations include the use of a student sample. Given the findings of high reliability for both alcohol and threat, it would seem appropriate to apply the cVPT to studying attentional bias in other samples, e.g., clinical samples. This may reveal between-group relationships with mental health, which have thus far not been found correlationally within unselected samples of heathy participants for the threat-related bias. Further, although we would argue that online collection plays a valid and important role in research, the methods used in the current study are yet to be tested in a laboratory setting. Finally, the threatening stimuli consisted of photographs of angry and neutral faces. There are many other forms of threatening stimuli and other kinds of salient stimuli that could be tested; the current results of course provide information only on stimulus categories sufficiently similar to the images used.

In conclusion, satisfactory reliability for an online behavioural measure of spatial attentional bias for threat can be achieved. This bias was related to cued future outcomes of attentional shifting rather than actually presented stimuli. The current results may thus be of use in further development of theories on automatic processes and attentional biases and may help design future studies aimed at testing relationships between the bias and individual differences.

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