BRIEF REPORT

Attentional asymmetries in a visual orienting task are related to temperament

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Spatial asymmetries are an intriguing feature of directed attention. Recent observations indicate an influence of temperament upon the direction of these asymmetries. It is unknown whether this influence generalises to visual orienting behaviour. The aim of the current study was therefore to explore the relationship between temperament and measures of spatial orienting as a function of target hemifield. An exogenous cueing task was administered to 92 healthy participants. Temperament was assessed using Carver and White's (1994) Behavioural Inhibition System and Behavioural Activation System (BIS/BAS) scales. Individuals with high sensitivity to punishment and low sensitivity to reward showed a leftward asymmetry of directed attention when there was no informative spatial cue provided. This asymmetry was not present when targets were preceded by spatial cues that were either valid or invalid. The findings support the notion that individual variations in temperament influence spatial asymmetries in visual orienting, but only when lateral targets are preceded by a non-directional (neutral) cue. The results are discussed in terms of hemispheric asymmetries and dopamine activity.

Keywords: Temperament; Attention asymmetry; Behavioural Inhibition System; Behavioural Activation System; Pseudoneglect.

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Abnormal asymmetries of spatial attention are an intriguing feature of human pathology, both neurologic (e.g., Mattingley et al., 2004) and psychiatric (Bellgrove et al., 2009). Subtle biases of directed attention, favouring the left hemifield and known as pseudo-neglect, are also reliably observed in healthy populations (Mattingley et al., 2004), supporting a dominant role for the right hemisphere in spatial processes. Recent observations suggest that the presence of pseudo-neglect may be linked to underlying temperament (Tomer, 2008). This association, however, has only been shown for asymmetries elicited under free-viewing conditions. A separate line of evidence suggests that temperament modulates spatial orienting (Fox, Derakshan, & Shoker, 2008). The current study therefore explored whether temperament was also associated with asymmetries in spatial orienting.

Although spatial orienting and temperament may seem disparate, converging evidence suggests a common link with dopaminergic function. Animal studies report that strong spatial biases reflect asymmetry in the dopamine system. For example, spatial bias for rats given foot-shock in a T-maze is associated with significantly higher dopamine content in the striata contralateral to the bias (Zimmerberg, Glick, & Jerussi, 1974). Additionally, responses to a foot-shock stressor modulates spatial biases in subsequent rotational behaviour elicited by a d-amphetamine challenge (Carlson, Glick, & Hinds, 1987). This latter finding indicates that spatial biases modulated by dopaminergic activity are correlated with individual differences in behavioural response to signals of punishment.

Research with humans also indicates that spatial biases in directed attention are associated with dopamine activity. Slagter, Davidson, and Tomer (2009) employed resting eyeblink rate as an indirect measure of central dopamine function and reported that individuals who blink more frequently at rest are more likely to display a rightward spatial bias under free viewing conditions. Spatial biases on a Posner cued-orienting task have also been associated with allelic variation in the dopamine transporter gene (DAT1) in children (Bellgrove et al., 2007), with individuals homozygous for alleles influencing DAT expression showing left-sided inattention relative to heterozygotes. Dopamine activity in humans has also been associated with individual differences in temperament. Allelic variation in the catechol-o-methyltransferase (COMT) gene has been found to interact with gender and startle reflex on the BIS, a temperament construct associated with sensitivity to punishment and conflict (Reuter, Schmidtz, Corr, & Hennig, 2006). These findings indicate an association between sensitivity to punishment and pre-frontal dopamine availability.

A further intriguing (and overlapping) feature between spatial attention biases and temperament is that both show patterns of hemispheric specialisation. As mentioned previously, a subtle bias to the left side of space in perceptual bisection tasks has been interpreted as support for right hemisphere dominance in spatial attention processes (Mattingley et al., 2004). Similarly, punishment sensitivity has been associated with greater anterior cortical activity in the right hemisphere (see Harmon-Jones, Gable, & Peterson, 2010, for the most recent review). Thus, both spatial attention and sensitivity to punishment show evidence for right-hemisphere dominance. This suggests that spatial attention biases and punishment sensitivity may co-vary via this overlap.

To our knowledge, only one study to date has addressed individual differences in spatial biases and temperament measures. Tomer (2008) administered the Greyscales Task to participants over two testing sessions between three and seven days apart. The Greyscales Task requires participants to judge the darker of two left-to-right mirror-reversed brightness gradients under free-viewing conditions (Mattingley et al., 2004). The tendency to judge brightness gradients that are shaded from the left as darker than gradients shaded from the right is interpreted as a perceptual bias to the left side of space. Conversely, the opposite pattern indicates a rightward perceptual bias. When bias scores were correlated with novelty-seeking scores, a significant positive correlation was found with more rightward spatial biases being associated with high reported levels of novelty-seeking.
of novelty seeking. This indicates that individual differences in temperament may modulate spatial attention biases.

Although spatial biases have been associated with individual differences in sensitivity to reward (Tomer, 2008), this evidence arises from a perceptual task employed under free-viewing conditions. The nature of the stimuli employed in these tasks (e.g., shaded rectangles) provides a measure of spatial bias that taps both object-based and spatial-based processes (Thomas & Elias, in press). It has long been accepted that separate cortical pathways extract object-based and spatial-based information from the environment (see Ungerleider & Haxby, 1994, for a review). Therefore, it is currently unclear whether object-based or spatial-based attention processes are associated with temperament. It has been suggested that anxiety traits, which are associated with temperamental differences in punishment and reward sensitivity (Gray & McNaughton, 2000), are specifically linked to rapid spatial orienting of attention. For example, highly anxious individuals show enhanced early electrophysiological responses to threat stimuli that serve as spatial cues (Fox et al., 2008). It is therefore possible that temperament-related spatial biases are indicative of covariance between punishment sensitivity and spatial-attention processes that occur in the right hemisphere. In light of this, the current study investigated the influence of temperament on spatial biases using a task that assessed visual orienting across space.

In order to investigate this question, a version of the Posner Cued-Orienting Task (Posner, Walker, Friedrich, & Rafal, 1984) was administered along with Carver and White’s (1994) BIS/BAS scales to assess sensitivity to punishment and reward respectively. Participants were grouped according to median splits on the BIS/BAS scales in order to form two groups, one that was higher in punishment sensitivity and another that was higher in reward sensitivity. Response times to targets in each hemifield were compared under valid, invalid and neutral cueing conditions. We reasoned that because previous findings indicate a dominant role of the right hemisphere for both punishment sensitivity and spatial attention processes, individuals with high punishment sensitivity should show greater leftward biases evidenced by faster reaction times to targets presented in the left hemifield. If associations between temperament and spatial biases are due, at least in part, to both processes being served by right hemisphere dominant activity, then we would not expect to see an influence of reward sensitivity on spatial bias, as reward sensitivity is associated with activity in the left hemisphere.

METHOD
Participants

Ninety-two participants (38 male; $M_{age} = 19.11$ years, $SD = 1.61$) were recruited from the University of Queensland. All were right handed (Oldfield, 1971), and had normal or corrected-to-normal vision.

BIS/BAS Questionnaire

Carver and White’s (1994) 20-item BIS/BAS scales were administered and responses across the seven BIS items assessing sensitivity to punishment were summed. The BAS comprises three subscales: Reward Responsiveness (BAS_RR, 5 items), Drive (BAS_D, 4 items) and Fun Seeking (BAS_FS, 4 items). Summing responses over these 13 items assessed overall sensitivity to reward.

The Cued-Orienting Task

We chose an orthogonal cueing procedure so that we could assess spatial orienting independently of the confounding effect of response bias (Driver & Spence, 1998). Participants began each trial by fixating on a cross presented centrally on the screen (500 ms). One placeholder ($2.6^\circ$) appeared in each of the four corners of the screen (the centre of the placeholder was positioned 9.8$^\circ$ horizontally from fixation on either side and separated on the vertical plane by 6.4$^\circ$). A 100% increase in luminance for 150 ms of two
placeholders on either side of the screen, or of all four placeholders, served as the cue. Cues occurred at a location that was informative of the upcoming target location (valid cue; 1/3 trials), uninformative (invalid cue; 1/3 trials) or were bilateral and, therefore, neutral with respect to target location (neutral cue; 1/3 trials). Cue validity and target side (left vs. right) were counterbalanced across the 288 trials. At cue offset, the target (an upright or inverted T) appeared in one of the placeholders for 350 ms, and a distractor (+ sign) appeared in the other placeholder within the same hemifield. Participants were instructed to indicate the orientation of the target as quickly and as accurately as possible by using two designated buttons. For a schematic representation of the cued-orienting trials refer to Figure 1.

RESULTS

Outliers were defined as reaction times that were more than three standard deviations from the mean within each condition for each participant. These were replaced with the mean $\pm 3 \times SD$. Outliers accounted for $<2\%$ of the data only.

An analysis of the data with outliers excluded rather than replaced yielded the same pattern of results.

BIS/BAS

Internal reliability of the BIS and BAS scales was assessed using Cronbach’s alpha. Scores for BIS (.85), and the BAS subscales of Reward Responsiveness (.71), Fun Seeking (.73), and Drive (.82) all indicated good reliability. Indeed, when the three BAS subscales were combined, Cronbach’s alpha was .85. To examine the influence of BIS and BAS on measures of spatial attention, a median split was performed on the BIS and BAS scores, thus categorising individuals as scoring relatively higher or lower on each dimension. Participants were included for further analysis if they scored relatively lower on the BAS and higher on the BIS (low BAS/high BIS group, $N = 30$; 9 male; $M_{age} = 19.4$, $SD = 1.87$, BAS mean $= 35$, $SD = 4.1$, BIS mean $= 23$, $SD = 2.4$), or if they showed the opposite pattern (high BAS/low BIS group, $N = 19$, 11 male; $M_{age} = 18.74$, $SD = 0.93$, BAS mean $= 44$, $SD = 3.5$, BIS mean $= 16$, $SD = 2.9$).

![Figure 1. Schematic representation of the cued orienting task. Participants indicated the orientation of the target T (in this example, the target is upright and in the left hemifield). A 100% increase in luminescence of two or all four of the placeholders served as a visual cue that was valid, neutral, or invalid with regard to the target’s upcoming location. The orthogonal nature of the cueing procedure enables mechanisms of spatial attention to be assessed independently of any confounds related to response bias (Driver & Spence, 1998).](image-url)
Cued orienting

RT data were subjected to a 2 (Group) × 2 (Target Side) × 3 (Validity) mixed analysis of variance (ANOVA). There was a main effect of Validity, $F(2, 94) = 57.835$, $p < .001$. Participants were significantly faster when responding to valid trials ($M = 640$ ms, $SD = 93.52$) relative to neutral trials ($M = 668$ ms, $SD = 104.3$), $t(91) = 5.61$, $p < .001$, and invalid trials ($M = 715$ ms, $SD = 125.58$), $t(91) = 10.92$, $p < .001$. In addition, participants were significantly faster to respond on neutral trials relative to invalid trials, $t(91) = 9.66$, $p < .001$. There were no other significant main effects (all $p$s > .3). Therefore the current paradigm elicited the standard pattern of performance observed in the Posner Cueing Tasks.

Crucially, there was a significant Group × Target Side × Validity interaction, $F(2, 94) = 4.69$, $p < .01$. To investigate this three-way interaction, a 2 (Target Side) × 3 (Validity) repeated-measures ANOVA was conducted separately for each group. For the low BAS/high BIS group there was a main effect of validity, $F(2, 58) = 26.15$, $p < .01$, and a significant Target Side × Validity interaction, $F(2, 58) = 6.18$, $p < .005$. This was followed up with post hoc paired-samples $t$-tests. Low BAS/high BIS participants were significantly faster to respond to left-sided targets relative to right-sided targets on neutral trials, $t(29) = 2.40$, $p < .05$ (see Figure 2). There were no significant differences for left and right targets on valid and invalid trials ($p$s > .10).

Response times to right targets on valid trials were significantly faster than those to neutral trials, $t(29) = 3.52$, $p < .001$, which were in turn faster than invalidly cued targets on the right, $t(29) = 2.98$, $p < .01$. Although RTs for left targets in the invalid condition were slower than those for the neutral condition, $t(29) = 6.35$, $p < .001$, no difference was observed between the neutral and valid cue conditions ($p < .3$). Thus the hypothesis that individuals with relatively higher sensitivity to punishment and lower sensitivity to

![Figure 2](https://example.com/image.png)

**Figure 2.** Mean response times to targets appearing in the left and right hemifields for each cueing condition (valid, neutral and invalid) for the two groups (BAS = Behavioural Activation System, BIS = Behavioural Inhibition System). Error bars = ± SEM; *$p < .05$. 

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reward would show leftward biases in directed attention was supported, but only under neutral cueing conditions.

For the high BAS/low BIS group, there was a main effect of Validity, $F(2, 36) = 36.85$, $p < .001$, which reflected the fact that reaction times for invalid trials were slower than for neutral trials, which in turn were slower than for valid trials. There were, however, no other significant main effects or interactions.

**DISCUSSION**

The aim of the current study was to explore whether temperament associated attention asymmetries influenced visual orienting behaviour. It was found that individuals with higher sensitivity to punishment relative to reward displayed leftward asymmetries of directed attention only when the target was preceded by a neutral and not a valid or invalid cue. Thus, it appears that temperament does not affect orienting behaviour.

The current results compliment previous findings showing an association between temperament traits and asymmetries of attention elicited under free-viewing conditions. Here, individuals who showed high sensitivity to punishment showed a leftward asymmetry of attention that was apparent only in the neutral cue condition. The neutral condition of the current study involved bilateral cues that distributed across the hemifields. Tomer (2008) employed the Greyscales Task, a free-viewing perceptual measure of attentional bias, and found that higher scores on novelty seeking were associated with rightward attentional bias. It is worth noting that the BIS scores of our participants were negatively correlated with scores on a novelty-seeking scale (Cloninger, Przybeck, & Svrakic, 1991; $r = -.51$, $p < .001$). Thus our results indicate that individuals who show increased sensitivity to punishment, in relation to decreased novelty seeking, show spatial asymmetries in the opposite direction to individuals who report higher levels of novelty seeking.

We speculate that the association between temperament and spatial biases is underpinned by a hemispheric dopamine imbalance for a number of reasons. First, a rightward asymmetry of directed attention has been shown to vary with dopamine transporter genotype in children with attention-deficit hyperactivity disorder (ADHD; Bellgrove et al., 2009). Additionally, patients with Parkinson’s disease show reduced novelty seeking when dopamine degradation occurs in the left hemisphere only (Tomer & Aharon-Peretz, 2004). As mentioned previously, sensitivity to punishment has been associated with the right hemisphere (see Harmon-Jones et al., 2010), although non-replications of the right hemisphere/sensitivity to punishment association have been reported (Coan & Allen, 2003). Conversely, high reward sensitivity is associated with left hemisphere dominance, and was not found to influence spatial biases on the cued-orienting task. This indicates that the association between temperament and spatial biases is modulated by hemispheric dopamine imbalances that affect right-hemisphere function.

The current results indicate that when individuals with high punishment sensitivity are required to distribute their attention across both hemifields (neutral cue condition), spatial biases are revealed. These biases are not present when participants are given a directional cue to which they can orient directed attention. This accords well with previous evidence that shows that negative emotion reduces the breadth of attention relative to positive emotion (Rowe, Hirsh, & Anderson, 2007). Individuals with higher punishment sensitivity, and, thus, higher salience of negativity, may find the neutral cueing condition more challenging and therefore, rather than distributing attention across the screen, may retain a focused state of attention that is biased to the left side of space. However, this bias is ameliorated under conditions where attention can be localised to a specific spatial location, which accords well with the narrowed attention focus that is typically present in these groups.

It may also be the case that individuals with relatively higher sensitivity to punishment and lower reward sensitivity are more sensitive to the alerting properties of the bilateral neutral cue than
those with lower sensitivity to punishment and higher reward sensitivity. Indeed, according to reinforcement sensitivity theory (Gray & McNaughton, 2000), a functional output of the sensitivity to punishment system is heightened arousal. In support of this argument, the low BAS/high BIS group responded faster to neutral trials on the left, such that differences between the neutral and valid cue conditions were no longer apparent. In contrast, responses to right targets in this group showed the typical cuing pattern with validly cued trials responded to faster than neutrally cued trials. According to the activation-orienting hypothesis (Kinsbourne, 1970), attention is allocated contralaterally to the more active hemisphere. Spatial orienting and alertness are both associated with right lateralised parietal activity (see Corbetta, Patel, & Shulman, 2008). It has been suggested that alertness plays a modulatory role upon spatial attention as individuals who perform poorly on measures of alertness show attenuated leftward spatial asymmetries (Bellgrove, Dockree, Aimola, & Robertson, 2004), and, interestingly, recent findings indicate a link between striatal dopamine availability and neural activity in brain areas associated with alertness during a demanding visual attention task (Tomasi et al., 2009). We therefore speculate that conditions increasing alertness, such as the neutral cue condition in the current study, would preferentially activate right parietal cortices, increasing activity in this hemisphere, speeding responses and driving attention leftwards.

The current study explored whether temperament-associated asymmetries in directed attention were present in visual-orienting behaviour. Individuals who showed relatively higher sensitivity to punishment and lower reward sensitivity showed leftward asymmetries of directed attention under neutral cueing conditions, but not under valid or invalid cueing conditions. We suggest that the biological underpinnings of this effect involve asymmetrical activation of right hemisphere arousal/attention networks that are potentially influenced by dopamine function.

REFERENCES


