

Watching for gains and losses: The effects of motivational challenge and threat on attention allocation during a visual search task

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Abstract This experiment tests predictions based on research and evidence around the biopsychosocial model (BPSM) that people in a challenge state have faster, more gain orientated search patterns than those in a threat state. Participants ($n = 44$) completed a motivated performance task involving the location of a target appearing in one of two search arrays: one associated with gaining points and the other associated with avoiding the loss of points. Midway through the task, participants received a false feedback prime about their performance invoking either challenge or threat. We found that participants receiving a challenge prime (high performance feedback) spent longer searching the gain array and made fewer fixations on the loss array. Those receiving a threat prime (low performance feedback) made fewer fixations on the gain array. These findings are in line with the BPSM and provide evidence that allocation of attention (measured using eye movement data) is related to challenge and threat.

Keywords Biopsychosocial · Challenge · Vigilance · Visual search · Attention allocation

Introduction

Attention can be directed towards specific aspects of our environment using both internal and external cues. Internal cues tend to require maintenance of the current task goal within working memory which requires motivation and, sometimes, cognitive effort. Despite the widespread interest in attention, relatively few empirical studies have

explored the role of motivational influences without using self-report measurements. This is important as motivational states can be experienced without conscious awareness (Mendes et al. 2007). In the current study we explore the role of two fundamental motivational states—*challenge* and *threat*—and their contribution to attention allocation during a visual search task.

The biopsychosocial model of challenge and threat (BPSM; Blascovich and Mendes 2000; Blascovich and Tomaka 1996) has shaped much of our knowledge about the role of challenge and threat in motivated performance situations. Such situations include those in which individuals wish to achieve a particular outcome in a task for a material gain (e.g. in a test or competition) or where they wish to present themselves positively to others (e.g. during a speech or interpersonal interaction). The BPSM argues that the balance of perceived demands (e.g. danger, effort required, uncertainty) and resources (e.g. knowledge and abilities, external support) dictate whether people experience a challenge state or a threat state in such situations. A challenge state is associated with more positive emotions, attempts to achieve goals by approaching potential gains proactively and overall better performance. A threat state, on the other hand, is associated with more negative emotions, attempts to achieve goals by avoiding mistakes and generally poorer performance (Blascovich 2008). Motivational states of challenge and threat are seen as an outcome of the appraisal process (see Seery 2011). The benefits of a challenge state over a threat state (for cognitive and motor performance) have been demonstrated in a variety of experimental studies (see, for example, Blascovich et al. 2004; Moore et al. 2012; Turner et al. 2012).

Challenge and threat are motivational states that can be measured through their effects on the cardiovascular system. In order to mobilize energy for performance the body

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activates the sympathetic adrenal medullary (SAM) and hypothalamic pituitary adrenocortical (HPA) axes (Dienstbier 1989) and these are sensitive to states of challenge and threat. Both challenge and threat are hypothesized to result in heightened SAM activation, but a threat state also results in heightened HPA activation (Blascovich and Tomaka 1996). During a challenge state, SAM activation leads to an increase in heart rate (HR), dilation of arteries [lower total peripheral resistance (TPR)], and increased blood flow [higher cardiac output (CO)]. During a threat state, SAM activation increases HR, but HPA activation inhibits the TPR decrease and the CO increase (Blascovich 2008). Challenge and threat are operationalized as relative measures, differentiated principally by differences in TPR, and therefore can be conceived of as being at opposite ends of a bipolar continuum (with threat linked to higher relative TPR and challenge to lower relative TPR; Blascovich et al. 2004). These cardiovascular indexes have been established as markers of challenge-threat motivational states in over 30 published studies (i.e. Frings et al. 2012; Weisbuch et al. 2009).

One area in which the BPSM can make meaningful and novel predictions regarding attention is in the study of attention allocation during visual search tasks. Such tasks require searching for a pre-defined target amongst distractor stimuli and provide a laboratory-based measure of everyday search tasks requiring active maintenance of the target object within working memory. Visual search tasks vary in difficulty. In ‘pop-out’ searches, the target usually has one clearly defined feature amongst dissimilar distractors (e.g. a circle amongst squares). In more difficult searches the target will be similar to the distractors, differing in only one feature (e.g. a rectangle amongst squares). The task used in the current experiment required participants to use an effortful, serial search strategy (Treisman and Gelade 1980; Wolfe 1998), looking for an upside down ‘T’ in an array of upright ‘T’s. Serial searches such as these appear to require an ordered, strategic search strategy that requires working memory resources. For instance, Butter (2004) found that repeated searches for the same target increased activation within the working memory of the participant. Other authors have found dual tasks that require working memory resources also impact on our ability to successfully perform serial searches (e.g. Oh and Kim 2004; Woodman and Luck 2004). Finding the target on tasks like this should require active maintenance of the task goal and also be affected by underlying motivational processes.

Some recent research has begun to explore how states of challenge and threat relate to attention processes. In one study, participants’ responses to positive and negative feedback, in terms of cognitive adjustment, were greater in

a challenge state compared to a threat state (Kassam et al. 2009). More recently, participants performing a simulated medical operation were found to lock visual attention on the target area, relative to other areas, when in a challenge state compared to a threat state (Vine et al. 2013). In addition to attention being affected by states of challenge and threat, manipulating attention can also contribute to changes in motivational states. Research (e.g. Chalabaev et al. 2009; Seery et al. 2009) has demonstrated that states of challenge and threat can be invoked through outcome framing (i.e. directing attention towards potential gains to induce challenge, and potential losses to induce threat) and by providing false feedback that participants are strong or weak task performers (through reducing self-efficacy and thus decreasing resources, or making the task seem difficult and thereby increasing demands).

This research suggests an important connection between states of challenge and threat and attention processes in humans. However, little is known about the mechanisms underpinning these connections. One possibility is that participants in a challenge state seek out, or are sensitive to, gain related stimuli in their environment, whereas participants in a threat state seek out, or are sensitive to, loss related stimuli. Indeed, recent neuroendocrine studies (relating to the HPA axis) suggest a possible link between threat-related neurological effects and attention to gains and losses. In one study, participants with low anxiety who were administered 40 mg of cortisol (which dampens HPA reactivity) showed lower bias towards attending to threatening stimuli relative to placebo (Putman et al. 2010). In another study, individuals (with social anxiety disorder) that had greater levels of cortisol production showed a tendency to bodily avoid angry faces through an arm movement approach-avoidance task (Roelofs et al. 2009). Thus, based on the evidence reviewed and predictions within the BPSM, we can make a novel prediction that challenged and threatened individuals will differ in their strategies for detecting gains and avoiding losses. One way of measuring these strategies is by observing the eye movements of people who are experiencing states of challenge and threat.

Recording eye movements during visual search provides greater insight into how attention is allocated than can be obtained by measuring simple detection accuracy or reaction times. Effortful, as opposed to ‘pop-out’ or parallel searches, require voluntary control over the programming of saccades (Findlay and Gilchrist 2003). Whilst it is possible to covertly shift attention to regions that are not currently being fixated (Posner 1980), the focus of visual attention during active tasks appears to be closely linked to the end point of saccades. Attention shifts to the intended end point of the next saccade just prior to the eye movement taking place (Hoffman and Subramanian 1995;

Deubel and Schneider 1996). Thus, the number of fixations made during the search can provide insight into how attention allocation may change under states of challenge or threat. In this experiment we measure performance (reaction time and accuracy) and also eye movement (fixations and dwell time).

To summarize, people in a challenge state actively approach goals (as opposed to trying to avoid losses) and their visual search strategies should be aimed at proactively maximizing gains, even if this increases the risk of incurring some losses. In contrast, people in a threat state should be more averse to making an error and their visual search strategies should be aimed towards minimizing losses. These two strategies are likely to manifest through differences in attention allocation, in particular, with the time participants spend looking at, and the number of fixations they make within, search arrays associated with gains and losses (i.e. an area of the visual field in which identifying a target leads to a gain, or an area of the visual field in which failure to identify a target leads to a loss). Specifically, we hypothesize that a challenged state will lead to an increase in attention allocation focused upon the ‘gain’ array (more fixations/longer dwell time in the gain array or fewer fixations/shorter dwell time in the loss array) and a threatened state will lead to attention allocation focused upon the ‘loss’ array (the reverse pattern). As challenge is associated with more successful performances, we also hypothesize that challenge states will be linked with lowered response times and increased rates of accuracy.

Method

Participants

Forty-four participants (29 women and 15 men) took part in the experiment.¹ The participants were all aged between 18 and 40 years.

Design

A 2(Phase: Pre-prime, Task phase) × 2(Prime: High performance feedback vs. Low performance feedback) × 2(Gain array: Gain, Loss) design was used. Prime condition was a between-participants factor and other independent variables were within-participants factors.

¹ No outliers were identified or excluded and complete physiological data was collected for these participants. An additional 23 participants also undertook the study but due to experimenter error did not complete the physiological aspects of data collection. These participants did not differ from the full data sample on dwell time, number of fixations or initial saccade latency in either phase in either array ($p > .15$) and were thus excluded from study altogether.

Dependent variables comprised of performance and attention data. For performance, accuracy (number of correct button presses made) and reaction time for correct responses were recorded. For attention, latency of first saccade (mean across all 60 trials), total number of fixations made in both the gain search array and the loss search array (see Visual search below and Fig. 1) and dwell time on both arrays were recorded. Dwell time was calculated from the mean amount of time in milliseconds spent fixating the gain or loss array during the first search, or series of eye movements, through that array. The manipulation check consisted of physiological measures of challenge and threat (HR, CO, PEP, TPR see Challenge/threat below).

Measures

Visual search task

Participants were seated 60 cm from a Dell 19" TFT monitor. Eye movements were recorded using an Eyelink 1000 Desktop (S-R Research Ltd, Canada) eye tracker. The task revolved around participants visually monitoring two search arrays (represented by areas of the screen, see right-hand screenshot in Fig. 1) across multiple trials to identify a target (an inverted ‘T’ amongst 19 upright ‘T’s) which appeared in one array (the other containing 20 upright ‘T’s). One array was consistently related to gaining points (spotting the target in this array led to a gain of 100 points, while failing to spot it led to a loss of 25 points) and the other was consistently related to avoiding the loss of points (spotting the target in this array led to winning 25 points, failing to spot it led to losing 100 points). Search arrays were 341×768 pixel rectangles, separated horizontally by 291 pixels. The target appeared on the gains or loss side an equal number of times, and never appeared on the same side more than three consecutive times. The location of the gains and loss side (i.e. gains on the right, losses on the left or vice versa) was fixed throughout within each phase (see below) and counterbalanced between participants. This was to avoid any additional cognitive demands caused by the gain and loss side changing from trial to trial. To capture performance data, participants were required to press a button indicating which side of the screen (gain or loss) side the target was on. Correct responses were coded as 1, incorrect responses as 0. To capture eye tracking data, regions of interest were defined around the border of each search array and fixations falling within the interest area were recorded (and from this dwell time, fixation frequency and latency derived subsequently).

Participants were initially instructed in the structure of the task and arrays and went through a practice trial. After this practice trial, the ‘pre-prime’ phase of the experiment began. As can be seen in Fig. 1, after presenting a fixation

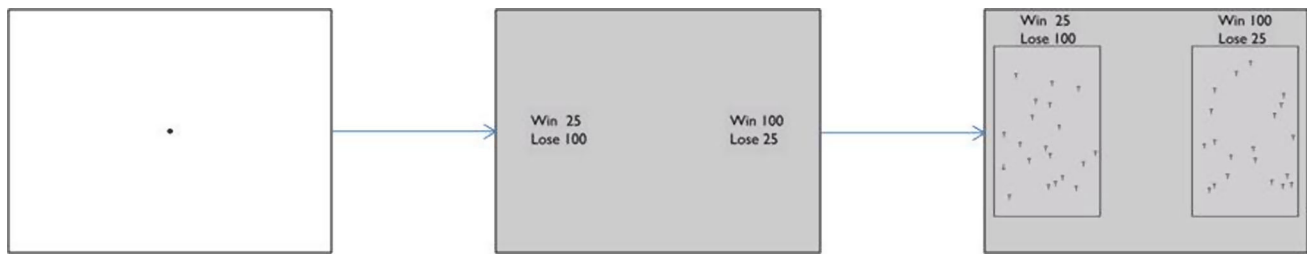


Fig. 1 Trial summary

point for drift correction, each trial started with a reminder of which array related to gaining points and avoiding losses. The reminder remained on the screen for one second and was then replaced by the search arrays. Participants completed 60 trials during the ‘pre-prime’ phase. They then went through the feedback phase.

The feedback phase aimed to prime participants to be either challenged or threatened by providing false feedback on performance. Participants in the challenge condition (high performance feedback) were told: “Thank you for completing the first part of the experiment. Below you can see how your performance so far compares to previous participants. You are currently ranked 5 out of 55 participants. Remember there is an extra payment to the participant with the highest score”. Participants in the threat condition (low performance feedback) received the same instructions, except that they were told they were ranked 51 out of 55 participants. Participants were not given information about their actual score in either condition.

Once participants indicated that they understood the feedback, they then completed another 60 trials—the ‘task’ phase of the experiment. In the pre-prime and task phases, all trials were presented in the same, fixed order for all participants.

Challenge/threat

A measure of challenge and threat was calculated using indexes derived from impedance cardiography (ICG), electrocardiography (ECG) and blood pressure monitoring equipment. Data was recorded using SPIKE software (version 6.10). Resting baseline physiological measurements were taken for 2 min (at the end of a 5 min rest phase which commenced after the measurement equipment was applied) before the participant was introduced to the task. Physiological measures were also taken for the first 2 min of the pre-prime phase and for the first 2 min of the task phase. As the measures used to derive challenge and threat are homeostatic in nature, it is standard practice to confine cardiac measurement to the first 2 min (Blascovich et al. 2004). Blood pressure and HR were measured continuously and non-invasively using an inflatable finger cuff

(Portapres 2.0) at 200 and 50 Hz respectively. ECG recordings were obtained using a Standard Lead II configuration on a Physio-control VSM 2 patient monitor (sample rate = 200 Hz). ICG measures were taken using a BIOPAC NICO100C amplifier (at 100 Hz) to provide basal transthoracic impedance (ZO) and its first derivative (dZ/dt). Outlying physiological measurements were winsorized to two standard deviations. These measures allow the calculation of CO, HR and pre-ejection period (PEP). TPR was calculated using the formula: $(\text{mean arterial pressure}/\text{CO}) \times 80$ (see Sherwood et al. 1990). The challenge-threat index was calculated using procedures specified in Blascovich et al. (2004). One index was calculated to compare resting baseline and the pre-prime phase and a second was calculated to compare pre-prime and task phase. For each index, TPR and CO reactivity (mean between times) was calculated and z scores computed. The z TPR was then subtracted from the z CO to create the challenge-threat index, with scores above zero indicating relative challenge, and scores below zero indicating relative threat. As CO (and associated measures) are linked to TPR (i.e. they are interdependent and thus share variance), it is preferable to use a single index accounting for the two than to conduct independent ANOVAs on each measure. Means levels of each cardiac index can be found in Table 1.

Procedure

After providing written informed consent, the baseline cardiovascular data was collected. Participants then had the visual search task explained to them through written instruction and verbal confirmation. Included in the instructions was a deception that the best performing participant would receive a monetary prize (in reality, all participants were given an extra payment to that which they expected, and no prize was awarded). Participants first completed the 60 pre-prime trials. During this time pre-prime cardiovascular measures were taken for 2 min. After completing these trials participants were given false feedback indicating that they were skilled or unskilled at the task (see above). Next, they completed the task phase comprising a further 60 trials. During this period, 2 min of

Table 1 Mean heart rate (HR), cardiac output (CO), pre-ejection period (PEP) and total peripheral resistance (TPR) as a function of prime condition and phase

Prime condition	Phase	Cardiac index			
		HR	CO	PEP	TPR
Challenge condition (high performance feedback)	Baseline	78.91 (10.38)	8.07 (1.69)	121.78 (4.97)	692.57 (220.55)
	Pre-prime	80.51 (10.56)	9.51 (2.07)	121.25 (5.47)	643.03 (185.30)
	Task	84.59 (13.08)	11.17 (3.24)	121.04 (5.48)	596.42 (174.19)
Threat condition (low performance feedback)	Baseline	80.39 (14.47)	7.53 (1.86)	120.35 (2.46)	656.86 (130.61)
	Pre-prime	82.64 (14.88)	9.72 (2.91)	120.41 (2.55)	586.93 (129.54)
	Task	83.77 (13.34)	9.89 (2.92)	120.13 (2.67)	578.76 (130.74)

HR is reported in beats per minute, CO in liters per minute, PEP in tenths of a second, and TPR in dynes sec/cm⁵

Standard deviations in parentheses

task phase cardiovascular measures were recorded. Eye movement data were taken during the period of time when the search arrays were displayed on the screen until the button was pressed. For all measures the values reported are the means taken from all 60 trials in the pre-prime and task phases respectively. Upon study completion, all participants undertook a verbal funnel debriefing (see Bargh and Chartrand 2000) to ensure they were oblivious to the specific hypotheses of the study and had no suspicions of the feedback manipulation. No participants expressed suspicions. On average participants spent between 2 and 3 min on each task phase (dependent on the amount of time spent on the drift correct between trials).

Results

Analytical strategy

With the exception of the manipulation checks, all tests employed a mixed ANOVA approach. For accuracy, reaction time and saccade latency, a 2×2 ANOVA was used with Prime condition (Challenge vs. Threat) as a between-subjects independent variable and Phase (Pre-prime vs. Task) as a within-subjects variable. For total number of fixations and dwell time, Array (Gain vs. Loss) was also included as a within-subject independent variable. In each instance, planned comparisons were undertaken comparing pre-prime and task performance separately for challenged and threatened participants. This was to account for potential baseline differences in attention allocation. Baseline differences in cardiovascular measures are accounted for in the calculation of the challenge-threat index (see above). As all contrasts conducted were linked to a priori (directional) hypotheses, no adjustment was made for potential family wise error due to the number of comparisons undertaken.

Manipulation checks

Task engagement

To ensure participants were engaged in the task (indicated by increased HR and decreased PEP) two within-participants *t*-tests were performed. HR increased significantly between the pre-prime phase ($M = 81.37$, $SD = 12.99$) and the task phase ($M = 84.14$, $SD = 13.07$), $t(43) = 2.74$, $p = .009$, and PEP decreased significantly between the pre-prime phase ($M = 120.80$, $SD = 4.11$) and the task phase ($M = 120.54$, $SD = 4.16$), $t(43) = 2.05$, $p = .046$. This pattern of results suggests that participants were engaged in the attention task.

Challenge/threat

To check that participants did not differ in their motivational responses to the task before the motivational prime occurred, an ANOVA was conducted with the pre-prime index of challenge and threat (reactivity between resting baseline and pre-prime phase) as the dependent variable, and Prime as the independent variable. There was no effect of Prime condition on the index, $F(1, 42) = 2.06$, $p = .16$, $\eta^2 = .05$, suggesting that participants did not have different motivational responses to the task before the prime was presented.

To check that participants in the challenge condition (high performance feedback) exhibited physiological patterns associated with challenge, and those in the threat condition (low performance feedback) exhibited physiological patterns associated with threat, an ANOVA was performed with the second index of challenge and threat (reactivity between pre-prime and task phases) set as the dependent variable and Prime as the independent variable. Scores on the challenge-threat index were higher in the challenge condition ($M = .86$, $SD = 2.18$) than in the threat condition ($M = -.72$, $SD = 1.26$), $F(1,42) = 9.09$,

$p < .004$, $\eta^2 = .18$. This suggests that the manipulation successfully primed participants to be challenged or threatened.

Attention measures

Accuracy

To test the hypothesis that challenged participants would be more accurate, accuracy scores were examined. For accuracy, there was a significant main effect for Phase, $F(1, 42) = 135.47$, $p < .001$, $\eta^2 = .76$, that reflects greater accuracy during the pre-prime phase ($M = 50.52$, $SD = 8.02$) than during the task phase ($M = 42.98$, $SD = 5.67$). There was no significant main effect for Prime ($p = .84$) and no significant interaction ($p = .89$). This shows that participants were more accurate in the pre-prime phase of the experiment than in the task phase, but that accuracy was unaffected by the motivational prime.

Response time

To test the hypothesis that challenged participants would be faster at the task, response times (in trials that participants responded correctly) were examined. There was a significant main effect for Phase, $F(1, 42) = 34.12$, $p < .001$, $\eta^2 = .45$, reflecting faster responses in the task phase ($M = 1327.60$, $SD = 211.00$) compared to the pre-prime phase ($M = 1437.93$, $SD = 182.96$). There was no significant main effect for Prime ($p = .50$) and no significant interaction ($p = .48$). A similar pattern of results was found when response time (for correct responses) was replaced with response time during trials where participants responded erroneously. Thus, participants responded quicker in the task phase than in the pre-prime phase. Taken in conjunction with the decreased accuracy in the task phase, this suggests that a speed-accuracy trade off; In the task phase, participants were both faster and less accurate, regardless of motivational prime.

Latency of first saccade

The latency of first saccade indicates how quickly participants started searching for the target. There was no significant main effect for Prime or Phase (p 's $> .34$), but there was a marginal interaction between conditions, $F(1,42) = 3.32$, $p = .075$, $\eta^2 = .07$. Simple effects analysis showed that, during the pre-prime phase, there was a marginal difference between the challenge condition ($M = 573.86$, $SD = 52.20$) and the threat condition ($M = 546.10$, $SD = 54.16$, mean diff. = 27.77, $p = .093$), but not during the task phase (challenge $M = 557.33$, $SD = 74.51$; threat $M = 552.65$, $SD = 58.18$, mean diff. = -4.71 , $p = .81$). There was also a marginal

difference between phases for participants in the challenge condition (mean diff = 16.53, $p = .08$) but not those in the threat condition (mean diff. = 6.55, $p = .47$). These data patterns indicate that during the pre-prime phase, there was a trend towards participants in the threat condition to start searching for the target more quickly and not changing this strategy following the motivational prime. Participants in the challenge condition showed some indication of a change in attention allocation following the prime, in that they started searching for the target more quickly after the search array appeared.

Number of fixations

To test the hypothesis that challenged participants should focus more on gains than on losses, the number of fixations across Prime, Phase and Array conditions were examined (Table 2). The ANOVA revealed a significant main effect for Phase, $F(1, 42) = 4.56$, $p = .038$, $\eta^2 = .10$, reflecting more fixations during the pre-prime phase ($M = 389.64$, $SD = 70.78$) than during the task phase ($M = 371.61$, $SD = 71.77$). However, this main effect was superseded by a three-way interaction between Prime, Phase and Array, $F(1, 42) = 4.44$, $p = .041$, $\eta^2 = .10$. To explore this interaction, simple effects analysis was conducted separately on the total number of fixations in the gain array and loss array. In the gain array, there was a borderline significant interaction between Phase and Prime, $F(1, 42) = 3.03$, $p = .089$, $\eta^2 = .07$. During the pre-prime phase, participants in the challenge condition produced fewer fixations than those in the threat condition (mean diff = 65.80, $p = .018$). This difference was not apparent in the task phase (mean diff = 34.32, $p = .31$). Also, participants in the threat condition had fewer fixations during the task phase than during the pre-prime phase (mean diff = 25.28, $p = .045$) with no simple effect of phase in the challenge condition (mean diff = 6.20, $p = .64$).

In the loss array, there was a significant interaction between Phase and Prime, $F(1, 42) = 3.96$, $p = .05$, $\eta^2 = .09$. During the pre-prime phase, participants in the threat condition made fewer fixations than those in the challenge condition (mean

Table 2 Mean of total number of fixations across all trial in the loss and gain search arrays, according to Prime and Phase conditions

	Prime	Pre-prime	Task
Gain array	Challenge condition	176.40 (85.76) ^a	182.60 (117.10)
	Threat condition	242.20 (89.77) ^{ab}	216.92 (106.96) ^b
Loss array	Challenge condition	205.95 (103.85) ^{†c}	178.40 (120.14) ^c
	Threat condition	153.67 (77.01) [†]	163.54 (109.65)

Standard deviations in parentheses. Means sharing a superscript differ ^a $p = .018$; ^b $p = .045$; ^c $p = .05$; [†] $p = .06$

diff = 52.28, $p = .06$) with no significant difference between conditions in the task phase (mean diff = 14.86, $p = .67$). Also, participants in the challenge condition made fewer fixations during the task phase than during the pre-prime phase (mean diff = 27.55, $p = .05$) with no significant effect in the threat condition (mean diff = 9.87, $p = .44$). These data patterns suggest that in the challenge condition people made fewer fixations in the loss area after the prime, while in the threat condition participants made fewer fixations in the gain area after the prime.

Dwell time

The final analysis also tested the hypothesis linking challenge and gains and threat and losses. Specifically, it explored the total amount of time spent searching for the target in the gain or loss area. Findings are reported in Table 3. There were no significant main effects or two-way interaction effects. However, there was a significant three-way interaction between Prime, Phase and Array, $F(1,42) = .68, p = .036, \eta^2 = .10$. To explore this interaction further, simple effects analyses were conducted separately in the gain array and the loss array. In the gain array, there was a significant interaction between Phase and Prime $F(1,42) = 4.13, p = .048, \eta^2 = .09$. Simple effects revealed a marginal increase in dwell time between the pre-prime and task phase in the challenge condition (mean diff = 72.52, $p = .08$) and no simple effect between the pre-prime and task phase in the threat condition (mean diff = 37.99, $p = .31$). There were no significant effects for Prime. In the loss array, there was no significant effect for Phase ($p = .48$), no significant effect for Prime ($p = .58$) and no interaction between the conditions ($p = .85$). This demonstrates that the motivational prime had no effect on how long participants spent searching the loss area. These data patterns suggest that challenged participants spent longer searching the gain area after the prime, whereas threatened participants dwell times did not change.

Table 3 Mean dwell time (in milliseconds) in the loss and gain search arrays, according to Prime and Phase conditions

	Prime	Pre-prime	Task
Gain array	Challenge condition	923.09 (166.51) [†]	995.61 (259.18) [†]
	Threat condition	1034.09 (271.01)	996.10 (273.70)
Loss array	Challenge condition	977.40 (274.14)	990.98 (289.12)
	Threat condition	933.93 (200.75)	958.08 (217.41)

Standard deviations in parentheses. Means sharing a superscript differ [†] $p = .08$

Discussion

This experiment sought to test the prediction, derived from research around the BPSM, that participants who are challenged should have an attention allocation targeted towards gains, in contrast to threatened participants, who should focus more on avoiding losses (Blascovich and Tomaka 1996). The prime manipulation was successful with participants in the challenge condition (high performance feedback) showing physiological patterns consistent with a challenge state compared to participants in the threat condition (low performance feedback).² Findings from the eye movement data revealed that attention allocation differed according to whether participants were challenged or threatened.

Participants in a challenge state began searching for the target more quickly after the motivational prime, than they did prior to the motivational prime, as indicated by faster saccade latencies in the task phase. These participants did, however, show a trend toward slower saccade latencies during the pre-prime phase than those in a threat state. Despite differences between the two conditions at baseline, the changes seen after the motivational prime suggest an increased focus on gaining points amongst challenged participants and a decreased focus on making gains (and an increase in avoiding losses) amongst threatened participants. Specifically, participants in the challenge condition showed a decrease in the number of fixations made in the loss area and an increase in their dwell time on the gain area from pre-prime to task phase. In contrast, participants in the threat condition made fewer fixations in the gain array from pre-prime to task phase.

These findings are important for theoretical development in the study of both motivation and attention, and in particular visual search strategy. Challenge and threat states have been linked to differences in physical performance (Blascovich et al. 2004; Turner et al. 2012), stigmatization towards out-group members (Mendes et al. 2002), and group performance (Cleveland et al. 2011). The current experiment suggests that perceiving oneself as being a high or low performer (in this case, induced by providing false feedback) is linked with challenge and threat respectively (also see Chalabaev et al. 2009; Kassam et al. 2009). The study also builds on research that has

² There was a decrease in TPR and a small increase in CO in the threat condition as well as in the challenge condition. We note that an alternative interpretation is thus that participants in the threat condition exhibited a physiological response pattern associated with being *less challenged* than those in the challenge condition, rather than threatened. However, as challenge and threat are conceived as being at opposite ends of a bipolar continuum (such that being more threatened is equivalent to being less challenged, and vice versa) we refer to these participants as being threatened (relative to those in the challenge condition).

linked challenge and threat to the motivation to avoid losses or approach gains (Seery et al. 2009) by showing how these motivational states can affect attention allocation. In particular, the experiment demonstrates that challenge and threat can affect directly the way in which we search out information in the environment.

It is possible that attention allocation acts as a mechanism through which challenge and threat are not only invoked but also maintained. Those in a threat state appear to direct their attention toward the detection of threats (in the form of potential losses) while those in a challenge state appear to direct their attention toward possible gains. This could lead to threatened participants perceiving a greater number of threats in the environment and challenged participants a greater number of gains. For example, a stockbroker monitoring various aspects of their stock portfolio might, when challenged, attend to stocks that are rising in value, and when threatened, attend to stocks that are falling. This could lead to resources being more salient in the environment than demands. Thus, once an individual is challenged or threatened, their search patterns may be more likely to identify features of the environment that maintain this particular motivational state and less likely to identify features that change it. We would encourage future research to test this possibility directly by recording subjective estimates of the frequency of gain or loss targets.

The majority of research into visual search has focused on cognitive components such as the role of working memory and level of activation of the target stimuli (see, for example, Butter 2004; Woodman and Luck 2004). The contribution of motivation to visual search has rarely been the focus of research in this area. However, one exception is a study into perceived powerlessness (Weick et al. 2011). The experiment found that powerlessness led to enhanced identification of target objects when a simpler, perceptual, distinction had to be made between targets and distractors. If powerlessness can be described as invoking a feeling of threat, rather than challenge, this would imply that threat can enhance visual discrimination of objects. The key differences between our experiment and that of Weick et al. (2011) are the cognitive demands of the search task and the separation of opportunity to gain points versus avoiding losing points. We found that when demanding situations required a decision to be made on strategic allocation of attention (gains vs. losses) threat did not decrease performance.

Whilst there was no difference between the groups in accuracy of target identification, challenge and threat did result in differing patterns of eye movements that reflect allocation of attentional resources. This suggests that a persons' current motivational state can influence how they choose to focus their attentional resources but that this may not necessarily result in a reduction in task performance. This might be explained by participants in a threat state

drawing on additional cognitive resources that can counteract the aversive threat response (see Eysenck et al. 2007). It is important to note that both challenge and threat are theorized to be goal orientated states (which differ in the approaches a given participant employs), and we assume that both challenged and threatened participants' goal was to achieve the highest score. In the current study, a performance detriment in one area (e.g. decreased focus on gains) may have been compensated for by performance improvements in another (e.g. a higher loss avoidance rate). One feature of the current study which makes this likely is that, in the task, the target appeared an equal number of times in each array. In real world situations, this balance may be absent and a threat (or challenge) orientation may have a detrimental effect on performance. This leads to an interesting implication that when task priorities focus on avoiding mistakes or losses (for example, amongst ethical review boards) a threat state may be preferable. On the other hand, when gains are key performance indicators, and instances of losses less influential (perhaps amongst elite athletes), a challenge state may be preferable.

The BPSM is not the only framework that includes approach and avoidance tendencies and our findings may be considered in relation to other motivational frameworks. In particular, the regulatory focus theory (RFT; Higgins 1997; Crowe and Higgins 1997) and the cognitive-motivational-relational theory (CMRT; Lazarus 1991) emphasize the importance of motivation for attention. RFT argues that motivation can have a promotion focus (where one emphasizes achievement needs and a focus on gains) or prevention focus (where one emphasizes security and safety and avoiding losses). More successful performances are generally observed when the requirements of a situation match focus. From this perspective, the current results suggest an intriguing possibility that each focus would have measurably distinct patterns of attention allocation (and eye movements) which could potentially be used as a non-invasive and non-reactive measure of regulatory focus.

Cognitive-motivational-relational theory argues that if a situation is self-relevant [due to whether it is a challenge (potential gains are present) or threat (potential losses are present)] then an evaluation of coping abilities and possible courses of action determine people's responses. In the context of CMRT, the current findings could reflect a change in primary appraisals affecting attention allocation. The BPSM was chosen as a basis for this experiment as motivational states can be measured with distinct patterns of cardiovascular reactivity. The above discussion of the fit between the importance of loss/gain priority and preferential attention allocation highlights potential synergies between RFT, CMRT and the BPSM.

There are a number of limitations in our study that should be addressed in order to place the findings firmly in

context. First, both HR and PEP reactivity were in line with patterns demonstrating task engagement, but the changes were not as large as those observed in previous research (e.g. Meijen et al. 2013) suggesting that the task was only moderately arousing. Future research could address this by using more personally relevant activities such as a public speaking or cognitive task (tasks that have been shown to be linked to greater cortisol production, see Dickerson and Kemeny 2004). Further, the use of controlled laboratory conditions might be considered a strength of the study, in terms of limiting external influences, but it is also a potential limitation in terms of ecological validity. In more complex environments, other factors (e.g. effort required, control variables) may moderate the relationship between motivational states and visual search (see, for example, Jones et al. 2009). One way of testing multiple factors simultaneously would be to use more complex stimuli providing a closer analogue to real-world visual searches. More immediate rewards or losses, such as pleasant or unpleasant auditory feedback on button presses, may also motivate participants to maintain accuracy in light of feeling challenged or threatened. Alternatively, researchers might conduct experiments in outdoor environments and on real-world tasks using moveable eye-tracking technology (see, for example, Wood and Wilson 2010).

To conclude, this experiment suggests that false performance feedback is a useful approach to manipulating challenge and threat (also see Chalabaev et al. 2009; Kassam et al. 2009) and that allocation of attention (measured using eye movement data) can be affected by states of challenge and threat. In particular, a challenge state can increase attentional focus towards gains whilst a threat state can increase attentional focus towards losses. These findings have implications for how people react to situational demands that entail high-gain/low-risk or high-risk/low-gain outcomes.

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