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BRIEF REPORTS

Motivation Sharpens Exogenous Spatial Attention

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Although both attention and motivation affect behavior, how these 2 systems interact is currently unknown. To address this question, 2 experiments were conducted in which participants performed a spatially cued forced-choice localization task under varying levels of motivation. Participants were asked to indicate the location of a peripherally cued target while ignoring a distracter. Motivation was manipulated by varying magnitude and valence (reward and punishment) of an incentive linked to task performance. Attention was manipulated via a peripheral cue, which correctly predicted the presence of a target stimulus on 70% of the trials. Taken together, our findings revealed that the signal detection measure d', reflecting perceptual sensitivity, increased as a function of incentive value during both valid and invalid trials. In addition, trend analyses revealed a linear increase in detection sensitivity as a function of incentive magnitude for both reward and punishment conditions. Our results suggest that elevated motivation leads to improved efficiency in orienting and reorienting of exogenous spatial attention and that one mechanism by which attention and motivation interact involves the sharpening of attention during motivationally salient conditions.

Keywords: visual attention, motivation, monetary reward, orienting, reorienting

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Two systems are critical for successful performance during goal-directed behavior: (a) visual attention, which allocates limited processing resources to stimuli that are central to current behavioral goals (Corbetta & Shulman, 2002; Kastner & Ungerleider, 2000), and (b) the reward system, which is responsible for defining goals, encoding incentive value, and motivating goal-directed behavior (Robbins & Everitt, 1996; Schultz, 2000). Although these two systems have been characterized in much detail, the interaction between them has received relatively little attention.

Evidence for such interaction is suggested by studies demonstrating that stimuli carrying motivational significance preferentially engage attention, including stimuli with positive emotional valence such as pictures of food items (LaBar et al., 2001; Mogg, Bradley, Field, & De Houwer, 2003; Mogg, Bradley, Hyare, & Lee, 1998) and stimuli with negative emotional valence such as threatening pictures (Armony & Dolan, 2002; Mogg & Bradley, 1999). Furthermore, findings from recent electrophysiological studies suggest that structures typically thought to be involved in attention, such as the monkey lateral intraparietal area, also process information related to reward contingencies (Platt & Glimcher, 1999; Sugrue, Corrado, & Newsome, 2004) and may be involved in the integration of attention and motivation (Bendiksby & Platt, 2006). Finally, a recent neuroimaging study demonstrated that monetary incentives enhanced responses in areas associated with visuospatial expectancy as well as areas associated with the disengagement of attention (Small et al., 2005).

Although previous studies have indicated that attention and motivation interact, the nature of such interaction remains unclear. In the present study, we tested the hypothesis that motivation interacts with exogenous attention by enhancing perceptual sensitivity. In two related experiments, we used a spatially cued localization task, in which a peripheral cue predicted target location on 70% of the trials (Figure 1A). Spatial cues provide a performance benefit when they validly predict target location during orienting and produce a performance cost during invalid trials, which require reorienting (Posner, Snyder & Davidson, 1980). Thus, by using both valid and invalid spatial cues, we probed the effects of monetary incentives on both the orienting and reorienting attentional systems, respectively (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005; Posner, Walker, Friedrich, & Rafal, 1984). Motivation was manipulated by varying the magnitude and the valence of a monetary incentive expected by participants for performing well on the task. We hypothesized that the reward system informs the exogenous attentional system about the incentive

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magnitude associated with the detection of task-relevant stimuli in the environment. Evidence for this hypothesis would be provided by an increase in detection sensitivity (d') as a function of incentive magnitude. We investigated both the effects of reward (i.e., cash reward) and punishment (i.e., losing money) on task performance.

Experiment 1

Method

Participants. Thirty-five Brown University students participated in Experiment 1 (15 women, ages 19 to 34 years). All participants had normal or corrected-to-normal vision and gave written informed consent. Data of 2 participants were excluded from analysis (equipment malfunction in one case; exclusion criteria were not met in another case).

Materials. The image database consisted of 880 gray-level face and house images (width = 4°; height = 5.5°). The target stimulus was a faint red dot that was superimposed on task-irrelevant face or house images, which provided background noise to increase task difficulty (Figure 1A). The red-dot target was semitransparent, with opacity set to a level that produced 85% correct overall performance in pilot studies. Face–house pairs were presented to the left and right of fixation (4° eccentricity). Target type (face or house) and location were varied randomly and counterbalanced, and all images were repeated an equal number of times in each location and experimental condition. The cue was a white asterisk (width = 1.5°, height = 1.8°) that was presented at 4° from the central fixation cross (Figure 1A). All stimuli were presented via Presentation software (Neurobehavioral Systems, Albany, CA).

Procedure. Participants were instructed that the goal of the task was to win as much money as possible. Participants completed 10 training blocks (110 trials), followed by the actual experiment (100 test blocks: 1,100 trials, consisting of 700 valid trials, 300 invalid trials, and 100 catch trials). During training, reaction time (RT) and accuracy feedback were provided; no feedback was provided during the experiment.

The behavioral task is depicted in Figure 1A. At the beginning of each block, participants were informed about reward–punishment contingencies via pie charts that reflected reward probability, magnitude, and valence (Figure 1B). Participants were told that they had a 50% chance of winning (reward condition, green background; Figure 1B, top) or avoiding losing (punishment condition, red background; Figure 1B, bottom) an incentive (value indicated in the pie chart) if they maintained adequate levels of accuracy and RT. Winning thus depended on a combination of chance and average performance (at least 7 of

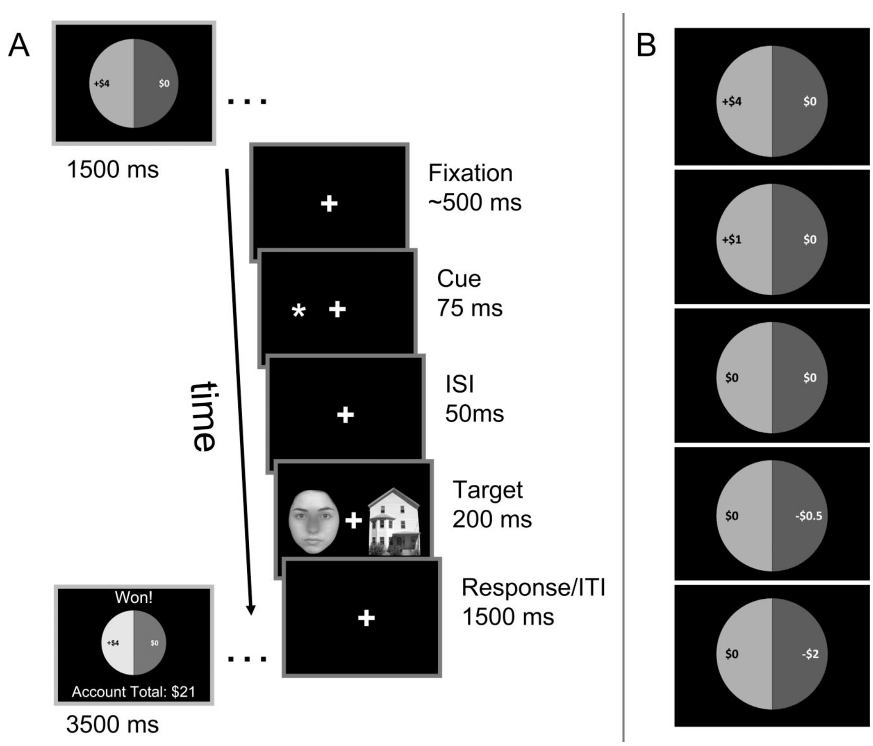

Figure 1. (A) Illustration and timing of an example trial sequence with a valid cue. The red-dot target is shown in gray in the center of a face background image and is exaggerated for illustration purposes. Blocked incentive condition and outcome phase are shown on the left. (B) Reward (top two), control (middle) and punishment (bottom two) conditions used in the current study. Participants had a 50% chance of winning or avoiding to lose an incentive as reflected by equal slice sizes. Positive incentives were always shown in green (light gray) on the left, negative incentives appeared in red (dark gray) on the right. ISI = interstimulus interval; ITI = intertrial interval. (See Figure S3 in supplemental material for a color version of this figure).

11 trials correct and mean RT below 605 ms for each block; the latter reflected the mean RT plus 2 *SD*s as obtained in pilot studies). Participants could win either $1.00 or $4.00 and avoid losing either $0.50 or $2.00. This asymmetry between incentive values was used because in the context of gambles, losses are valued higher than gains by a factor of about 2 (e.g., Tversky & Kahneman, 1992). Zero-dollar blocks (no cash won or lost) were used as the neutral condition. At the end of each block, participants were informed about the reward–punishment outcome via an animated pie chart presented together with the updated account total.

Although motivation was manipulated in each block, covert exogenous attention was manipulated on a trial-by-trial basis. Participants were presented with a peripheral spatial cue for 75 ms, which correctly predicted target location on 70% of the trials (Figure 1A). After a 50-ms delay, a face–house stimulus pair was shown for 200 ms. As stated, the target was a faint red dot presented in the center of one of the task-irrelevant stimuli (shown for 200 ms). During catch trials (see below), a stimulus pair was presented, but no red-dot target. After stimulus offset, participants were given 1,500 ms to respond. Participants were asked to report the target location as quickly and as accurately as possible by pressing the left button when the target was on the left and the right button when the target was on the right. Buttons were not counterbalanced to avoid spatial conflict (Fan, McCandliss, Sommer, Raz, & Posner, 2002). Catch trials were used to discourage guessing and alternative behavioral strategies and occurred at a rate of 1 per block (9.1% of all trials). Participants indicated the presence of a catch trial by pressing the spacebar. After reinforcement, participants were asked to rate "happiness" on a scale ranging from 1 to 7 (see supplemental material).

Behavioral performance. The sensitivity measure d' (Green & Swets, 1966) was used in statistical analyses. In our spatial task, hits and false alarms were defined in terms of targets appearing on the left side of the display; hit rate was defined as the conditional probability that the participant responded "left" given that the target was on the left [P_{HIT} = P("Target Left" | <Target Left, Distractor Right>)] and false alarm rate as the conditional probability that the participant responded "left" given that the target was on the right [P_{FA} = P("Target Left" | <Target Right, Distracter Left>)] (Green & Swets, 1966; Macmillan & Creelman, 2005). The d' scores were obtained by entering hits and false alarms into the following equation:

$$d' = \frac{1}{\sqrt{2}}[z(H) - z(F)].$$

Given the spatial symmetry of our design, hits and false alarms could naturally have been defined in terms of targets appearing on the right side of the display (Macmillan & Creelman, 2005); hit rate would be defined as the conditional probability that the participant responded "right" given that the target was on the right [P_{HIT} = P("Target Right" | <Target Right, Distracter Left>)] and false alarm rate as the conditional probability that the participant responded "right" when the target was on the left [P_{FA} = P("Target Right"|<Target Left, Distracter Right>]. Results from analyses repeated with these alternative definitions supported those reported below and are not reported here.

In all analyses, Huynh-Feldt corrected *p* values are reported where appropriate (decimal degrees of freedom indicate that a correction was used). To mitigate the multiple-comparisons problem, post hoc *t* tests involving the neutral condition and all other reward–punishment conditions were Bonferroni corrected, such that the alpha level for statistical significance was 0.0125 (four comparisons). Likewise, for linear trend analyses considering reward and punishment separately, the alpha level for statistical significance was 0.025 (two comparisons). We use the abbreviation *nsbc* to indicate *p* values that did not survive Bonferroni correction. Exact *p* values are provided when values do not reach significance level; *p* values less than .1 (or less than .05 when Bonferroni correction is involved) are referred to as near significant.

Exclusion criteria. To screen for participants who may have ignored task instructions and followed the simple strategy of reporting cue rather than target location, we examined those participants who reliably failed the task during the invalid condition. We excluded participants with significant, negative d' values (higher false alarm rates than hit rates) as indicated by a significant *Z* test performed on d' values for invalid trials pooled across conditions (Macmillan & Creelman, 2005).

Results

Detection sensitivity. The d' values were entered into a three-way repeated measures analysis of variance (ANOVA), with incentive ($0.00, $0.50, $1.00, $2.00, or $4.00; only the absolute incentive value was used in this analysis), validity (valid or invalid), and target type (house or face) as within-subjects factors. A significant main effect of incentive was obtained, $F(2.9, 92.5) = 9.20$, $p < .001$, with d' increasing linearly as a function of absolute incentive value as indicated by a significant linear trend, $F(1, 32) = 16.20$, $p < .001$ (Figure 2A). There was a significant main effect of validity, $F(1, 32) = 65.60$, $p < .001$, with larger d' values in the valid condition ($d' = 2.63$) than in the invalid condition ($d' = 1.68$); average performance for valid trials was 92% correct; for invalid trials, it was 73% correct. A main effect of target type was also observed, $F(1, 32) = 22.05$, $p < .01$, with larger d' values during house targets ($d' = 2.27$) compared with face targets ($d' = 2.04$). No significant interactions were obtained, although a near-significant interaction between validity and incentive, $F(4, 128) = 2.19$, $p = .07$, was observed. Tests of simple main effects showed that incentive significantly affected d' values during both valid, $F(2.8, 88.2) = 3.70$, $p < .05$, and invalid, $F(3.7, 117.4) = 8.48$, $p < .001$, trials. To further explore simple main effects, post hoc pairwise *t* tests comparing d' values during the neutral condition and the reward–punishment conditions were used (other pairwise differences were not explicitly tested). These comparisons indicated that, for valid trials, there were no significant differences between neutral and reward conditions or between neutral and punishment conditions ($0.00 vs. −$2.00, $p = .03$, nsbc; $0.00 vs. −$0.50, $p = .57$; $0.00 vs. $1.00, $p = .09$; and $0.00 vs. $4.00, $p = .03$, nsbc), whereas for invalid trials, d' values for the neutral condition differed significantly from those of all reward and punishment conditions ($0.00 vs. −$2.00, $p < .001$; $0.00 vs. −$0.50, $p < .001$; $0.00 vs. $1.00, $p < .001$; and $0.00 vs. $4.00, $p < .001$; Figure 2B).

The above omnibus ANOVA revealed main effects of incentive, validity, and target type. In particular, this analysis allowed us to test the effect of reward–punishment on detection performance

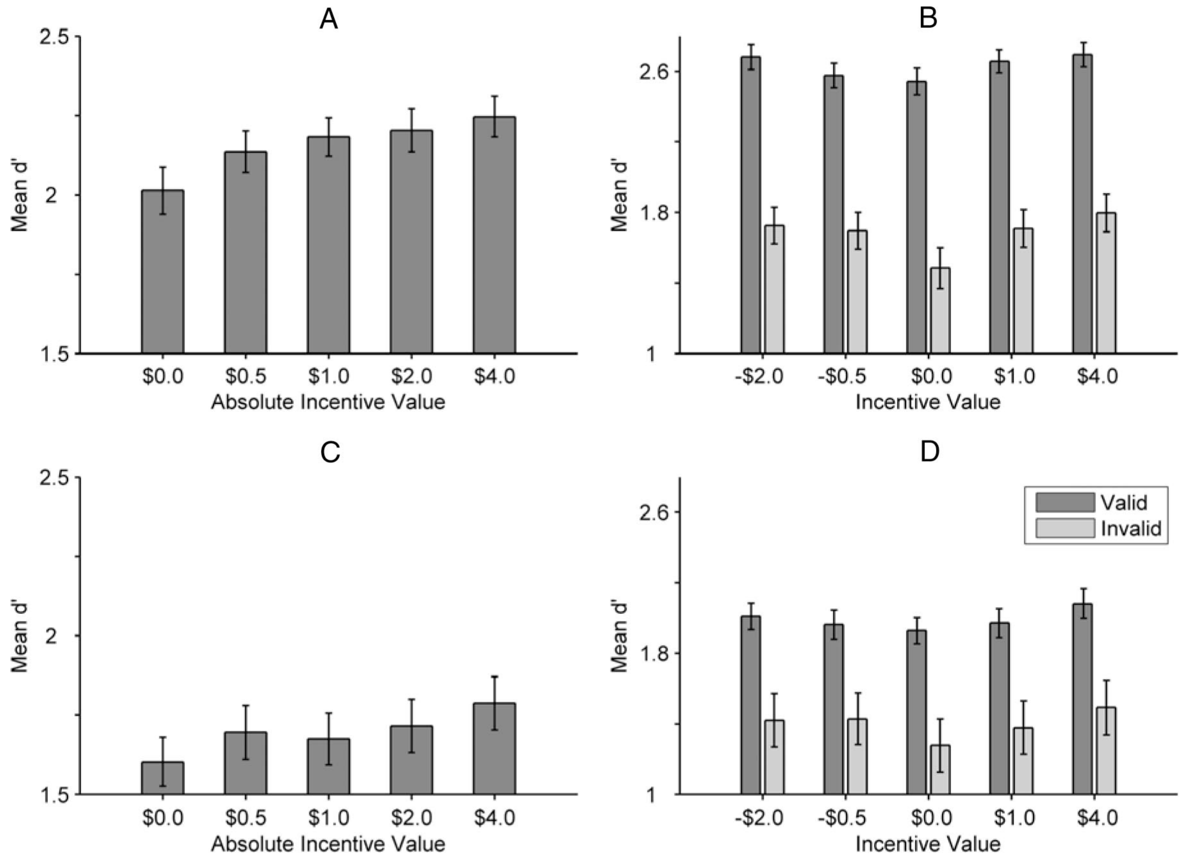

Figure 2. Detection performance (d') as a function of absolute incentive value in Experiment 1 (A) and Experiment 2 (C) and detection performance as a function of incentive value and validity (valid or invalid) in Experiment 1 (B) and Experiment 2 (D). Detection sensitivity increased linearly with increasing incentive value (B, D). In both experiments, increased perceptual sensitivity was observed as a function of increasing incentive magnitude during valid and invalid cue conditions (in Experiment 2, the latter was significant only during reward conditions).

during validly and invalidly cued trials. To further investigate differential effects of valence (positive vs. negative), the data were split into reward and punishment conditions. The same neutral \$0.00 condition was included in separate reward and punishment ANOVAs. In addition, the data were collapsed across the factor target type for two reasons: (a) No significant interaction between target type and other factors was obtained in the omnibus ANOVA and (b) we had no a priori hypothesis about target type. Thus, below, d' values were entered into two two-way repeated-measures ANOVAs, with incentive and validity as within-subjects factors.

Reward ANOVA. A significant main effect of incentive was obtained, $F(1.7, 55.0) = 12.17$, $p < .001$, with d' increasing linearly as a function of incentive value (\$0.00, $d' = 2.01$; \$1.00, $d' = 2.18$; and \$4.00, $d' = 2.25$), as indicated by a significant linear trend, $F(1, 32) = 16.47$, $p < .001$. There was also a significant main effect of validity, $F(1, 32) = 63.50$, $p < .001$. A near-significant interaction between incentive and validity was observed, $F(2, 64) = 2.58$, $p = .08$. To further investigate this near-significant interaction, separate post hoc trend analyses were conducted for valid and invalid conditions. A significant linear trend was obtained in the invalid reward condition, $F(1, 32) = 18.95$, $p < .001$, but only a near-significant linear trend was obtained in the valid reward condition, $F(1, 32) = 5.1$, $p = .03$, nsbc.

Punishment ANOVA. There was a significant main effect of incentive, $F(1.7, 54.5) = 10.02$, $p < .001$, with d' increasing linearly as a function of punishment value (\$0.00, $d' = 2.01$; −\$0.50, $d' = 2.14$; and −\$2.00, $d' = 2.20$), as indicated by a significant linear trend, $F(1, 32) = 13.58$, $p < .001$. There was also a significant main effect of validity, $F(1, 32) = 69.08$, $p < .001$. Finally, a significant interaction between incentive and validity was found, $F(2, 64) = 4.23$, $p < .05$. Trend analyses were conducted as specified above. A significant linear trend was obtained in the invalid punishment condition, $F(1, 32) = 15.41$, $p < .001$, but only a near-significant linear trend was obtained in the valid punishment condition, $F(1, 32) = 5.19$, $p = .03$, nsbc.

Experiment 2

In Experiment 1, the most robust effects of monetary incentives on perceptual sensitivity were observed during invalid trials, suggesting that motivation and attention interact during exogenous reorienting processes. However, it is possible that the valid condition was not taxing enough to reveal an effect of monetary incentives during such trials. To probe the role of motivation during exogenous orienting processes, we increased the difficulty of valid trials by adjusting each participants' red-dot target appearance via a staircase procedure.

Method

Participants. Thirty-four Brown University students participated in Experiment 2 (18 women, ages 19 to 49 years). All participants had normal or corrected-to-normal vision and gave written informed consent. Data of 2 participants were excluded from analysis (equipment malfunction in one case; exclusion criteria [see Experiment 1] were not met in another case).

Materials. All aspects were the same as Experiment 1, except that in Experiment 2 only face images were used (440 stimuli); thus, stimuli appeared as face–face pairs. The opacity level of the red-dot target was determined by a staircase procedure. Location was varied randomly and counterbalanced, and all images were repeated an equal number of times in each location and experimental condition, except for the first 5 participants, for whom the right:left ratio was 1.2:1 for invalid trials only, owing to a programming error.

Procedure. All aspects were the same as in Experiment 1, except that participants completed a training session in Experiment 2 that included a threshold estimation procedure. In Experiment 2, only face targets were presented.

Threshold estimation procedure. During training, an adaptive "one-up three-down" staircase procedure was used to approximately track the 79% correct level for valid and, separately, invalid trials for each participant. Opacity levels of the red-dot target were decreased (easier) for each incorrect response and increased (harder) for every three consecutive correct responses. To avoid participant expectancies, two staircase algorithms were used per condition (i.e., two for valid and two for invalid trials), one starting at the highest opacity level and one starting at the lowest opacity level. The training session was terminated after all four staircases completed 12 reversals, or after 100 blocks were completed (the length of Experiment 1). The opacity values of the two same-condition staircases were then averaged. These final opacity values were used during testing and remained fixed.

Results

Accuracy. Accuracy values were entered into a three-way mixed ANOVA with experimental group (Experiment 1 or Experiment 2) as between-subjects factor and incentive and validity as within-subjects factors (the target type factor from Experiment 1 was collapsed). A significant effect of group indicated that Experiment 2 (mean accuracy = 75%) was significantly more difficult than Experiment 1 (mean accuracy = 82%), $F(1, 63) = 10.53$, $p < .01$. A significant interaction between validity and group, $F(1, 63) = 7.88$, $p < .01$, was also observed. Tests of simple main effects showed that the staircase procedure significantly decreased average accuracy during valid trials compared with Experiment 1 (Experiment 1, 92%; Experiment 2, 78%), $F(1, 63) = 30.80$, $p < .001$, but not during invalid trials (Experiment 1, 73%; Experiment 2, 72%), $F(1, 63) = 0.06$, $p = .81$. Similar results were obtained for d' values in a combined analysis of Experiments 1 and 2 (see supplemental material).

Detection sensitivity. The d' values were entered into a two-way repeated measures ANOVA, with incentive ($0.00, $0.50, $1.00, $2.00, or $4.00) and validity (valid or invalid) as within-subjects factors. Consistent with Experiment 1, significant main effects of incentive and validity, $F(1, 31) = 12.20$, $p < .001$, were obtained, $F(3.90,120.83) = 3.85$, $p < .01$. Accordingly, d' increased linearly as a function of absolute incentive value, as indicated by a significant linear trend, $F(1, 31) = 14.77$, $p < .001$ (Figure 2C), and larger d' values were obtained in the valid condition ($d' = 1.99$) compared with the invalid condition ($d' = 1.40$). No significant interaction between incentive and validity was obtained, $F(4, 124) = 0.49$, $p = .74$. However, to compare the effects of monetary incentives on valid and invalid trials, tests of simple main effects were conducted. These showed that incentive significantly affected d' values during invalid trials, $F(4, 124) = 2.54$, $p < .05$, whereas only a near-significant result was obtained during valid trials, $F(3.8, 117.2) = 2.19$, $p = .078$. Post hoc pairwise *t* tests comparing d' values for the neutral condition to the reward–punishment conditions were used to further explore simple main effects. These comparisons indicated that, for both valid and invalid trials, there was a significant difference between the neutral and the $4.00 reward condition only (valid: $0.00 vs. −$2.00, $p = .09$; $0.00 vs. −$0.50, $p = .6$; $0.00 vs. $1.00, $p = .52$; $0.00 vs. $4.00, $p < .01$; invalid: $0.00 vs. −$2.00, $p = .03$, nsbc; $0.00 vs. −$0.50, $p = .04$, nsbc; $0.00 vs. $1.00, $p = .12$; $0.00 vs. $4.00, $p < .01$; see Figure 2D).

Reward ANOVA. In agreement with Experiment 1, significant main effects of incentive, $F(2, 62) = 7.23$, $p < .01$, and validity were observed, $F(1, 31) = 12.17$, $p < .001$. Mean d' increased linearly as a function of incentive value ($0, $d' = 1.60$; $1, $d' = 1.68$; and $4, $d' = 1.79$), as indicated by a significant linear trend, $F(1, 31) = 12.50$, $p < .001$. There was no significant interaction between incentive and validity, indicating that incentive influenced orienting and reorienting in a similar manner, $F(1.95, 60.34) = 0.29$, $p = .74$. For comparison with Experiment 1, trend analyses were conducted for valid and invalid conditions. Significant linear trends were obtained in both the valid, $F(1, 31) = 8.30$, $p < .01$, and invalid conditions, $F(1, 31) = 7.83$, $p < .01$.

Punishment ANOVA. There was a near-significant main effect of incentive, $F(1.84, 57.10) = 2.77$, $p = .08$, with d' increasing linearly as a function of punishment value ($0.00, $d' = 1.60$; −$0.50, $d' = 1.70$; and −$2.00, $d' = 1.72$); the test for the linear trend actually reached significance, $F(1, 31) = 7.09$, $p < .05$. Consistent with Experiment 1, a significant main effect of validity was obtained, $F(1, 31) = 12.34$, $p < .001$. No significant interaction between incentive and validity was obtained, suggesting that incentive influenced orienting and reorienting in a similar manner, $F(2, 62) = 1.37$, $p = .26$. A significant linear trend was observed in the invalid punishment condition, $F(1, 31) = 5.53$, $p = .025$, but only a near-significant linear trend in the valid punishment condition, $F(1, 31) = 3.12$, $p = .09$.

Discussion

In two related experiments, we used a spatially cued detection task involving monetary reward and punishment to investigate potential interactions between attention and motivation. We showed that d' scores increased linearly as a function of absolute monetary incentive value, revealing that monetary incentives enhanced detection sensitivity.

By using both valid and invalid trials, we probed the effects of monetary incentives on orienting and reorienting exogenous attentional mechanisms, respectively. In Experiment 1, an improvement of detection sensitivity was observed in all reward and punishment conditions compared with the neutral condition during invalid trials. Similar trends were observed during valid trials, although the effect was not statistically significant. Because valid trials in Experiment 1 were not sufficiently demanding, in Experiment 2 we used a more challenging version of the task to explore potential differences between valid and invalid trials. Results from Experiment 2 confirmed and extended those obtained in Experiment 1. Trend analyses from Experiment 2 and a combined analysis of Experiments 1 and 2 (supplemental material) confirmed the effect of reward and punishment on detection sensitivity during invalidly cued trials. Although rewards and punishments had a smaller effect on detection sensitivity during validly cued trials, sensitivity improvements during both valid and invalid trials in the largest reward condition ($4.00) were revealed in Experiment 2. The enhancement of sensitivity by reward during valid trials was confirmed by trend analyses. We suggest that the observed differences in performance enhancement during valid and invalid conditions may be due to differences in how reward information is relayed to attentional orienting and reorienting systems, respectively. Alternatively, it could simply be more difficult to further strengthen an already present benefit during validly cued trials compared with counteracting the cost of invalid cuing. Note that in both experiments, observed changes in sensitivity were not due to speed–accuracy trade-offs (supplemental material).

A distinction between two attentional systems has been made in previous research, with one system orienting attention to a cued location and the other disengaging attention to enable reorienting to behaviorally relevant stimuli (Corbetta & Shulman, 2002; Posner et al., 1984). Some neuroimaging studies have supported this distinction by revealing that orienting and reorienting are processed by distinct functional networks (Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005; Kincade et al., 2005; Thiel, Zilles, & Fink, 2004). On the one hand, valid task-relevant cues are known to guide attention to a specific location (Posner et al., 1980) and have been suggested to be processed by the orienting network (Corbetta et al., 2000; Thiel et al., 2004). Results from the current experiments indicating that monetary rewards and punishments increase detection sensitivity during orienting of exogenous attention support and extend previous findings of motivational effects on attentional orienting (Derryberry, 1989). On the other hand, the detection of an invalidly cued target stimulus involves multiple processes, including disengagement of attention and shifting of attention to a novel location (Posner, Choate, Rafal, & Vaughn, 1985), which are thought to be mediated by the reorienting network (Corbetta et al., 2000; Kincade et al., 2005). Activation of the reorienting network is influenced by behavioral relevance (Downar, Crawley, Mikulis, & Davis, 2001), as well as novelty and frequency of occurrence of a given stimulus (Downar, Crawley, Mikulis, & Davis, 2002). Our findings suggest that a further factor can enhance the efficacy of the reorienting system, namely, the incentive magnitude associated with target detection.

Our findings are consistent with a recent neuroimaging paper, which demonstrated a neural interaction between endogenous attention and motivation using a RT task of low difficulty. Findings from Small et al. (2005) revealed that monetary incentives increased activations in the posterior cingulate cortex during orienting of attention and in the inferior parietal lobule during reorienting of attention. Their findings suggest that incentives differentially enhanced neural processing within the attentional system during orienting and reorienting and may provide a neural basis for our findings.

The present results demonstrate that monetary rewards and punishments improve detection sensitivity. Consistent with our hypothesis, the improvement in performance involved enhanced detection sensitivity during both orienting and reorienting of exogenous visuospatial attention, suggesting that one mechanism by which attention and motivation interact involves the sharpening of attention during motivationally salient conditions. Overall, the present findings add to a growing literature that reveals that attention and motivation closely interact in the generation of complex behavior.

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