

# Smile! Social Reward Drives Attention

Dana A. Hayward  
Concordia University

Effie J. Pereira, A. Ross Otto, and Jelena Ristic  
McGill University

Human social behavior is fine-tuned by interactions between individuals and their environments. Here we show that social motivation plays an important role in this process. Using a novel manipulation of social reward that included elements of real-life social exchanges, we demonstrate the emergence of attentional orienting for coincidental spatial associations that received positive social reward. After an interaction with the experimenter, participants completed a computerized task in which they received positive, negative, or no social reward for their performance to spatially congruent, spatially incongruent, and neutral cue–target pairings, respectively. Even though cue–target spatial correspondences remained at chance, attentional benefits emerged and persisted a day later for targets that received positive social reward. Our data further revealed that participants’ level of social competence, as measured by the Autism-Spectrum Quotient scale, was predictably related to the magnitude of their reward-driven attentional benefits. No attentional effects emerged when the social interaction and social reward manipulations were removed. These results show that motivational incentives available during social exchanges affect later individual cognitive functioning, providing one of the first insights into why seemingly ambiguous social signals produce reliable and persistent attentional effects.

## **Public Significance Statement**

Humans pay attention to arbitrary links between events when they are accompanied by positive social reward (e.g., social feedback, praise). Individuals with higher social competence derive more attentional benefits from available social reward relative to those with lower social competence. These data provide new insight into how humans “read” complex social signals from their environments and why those signals preferentially drive human attention.

*Keywords:* reward, social motivation, social attention

Attending to social information (e.g., faces, eye gaze) is often considered to be one of the key building blocks of the human sociocognitive system (e.g., Boggia & Ristic, 2015; Dawson, Melt-

zoff, Osterling, Rinaldi, & Brown, 1998; Farroni, Csibra, Simion, & Johnson, 2002; Friesen & Kingstone, 1998). As such, this behavior influences both simple and complex social functions, including social perception, language development, and theory of mind (e.g., Boggia & Ristic, 2015; Dawson et al., 1998; Farroni et al., 2002; Friesen & Kingstone, 1998). Research has shown that the spontaneous following of social signals, often termed *social attention*, can reliably be assessed in both real-world behaviors (Gallup et al., 2012; Hayward, Voorhies, Morris, Capozzi, & Ristic, in press) and laboratory-based procedures (Friesen & Kingstone, 1998), with reduced social attention abilities found in individuals with autism (Birmingham, Ristic, & Kingstone, 2012) and in typically developing individuals with low social competence (Bayliss & Tipper, 2005; Hayward & Ristic, 2017).

Although social attention remains a well-documented phenomenon, the reasons for *why* humans spontaneously pay attention to social signals remain relatively unexplored. This question becomes particularly puzzling when one takes into account that in natural settings, social cues are ambiguous, fleeting, and largely uninformative about events in the environment (Gallup et al., 2012; Kennedy & Adolphs, 2012). A likely candidate for facilitating attentional biasing under such conditions are processes associated with social motivation, an idea that dovetails with recent theories implicating social motivational factors as one of the critical elements underpinning typical sociocognitive development (Cheval-

---

Dana A. Hayward, Department of Psychology, Concordia University; Effie J. Pereira, A. Ross Otto, and Jelena Ristic, Department of Psychology, McGill University.

Dana A. Hayward and Effie J. Pereira contributed equally to this research. Dana A. Hayward and Jelena Ristic developed the initial study concept; Dana A. Hayward and Effie J. Pereira implemented the study and oversaw data collection; Dana A. Hayward, Effie J. Pereira, and Jelena Ristic were involved in design, analyses, interpretations, and article preparation; and A. Ross Otto was involved in the article preparation. All authors approved the final version of the article.

This research was supported by Natural Sciences and Engineering Research Council of Canada (NSERC) fellowships to Dana A. Hayward and Effie J. Pereira and by NSERC (Jelena Ristic, A. Ross Otto), Social Sciences and Humanities Research Council of Canada (Jelena Ristic), and William Dawson (Jelena Ristic) funds. Many thanks to Isabel Gauthier for her thoughts and suggestions on previous versions of this article. We also gratefully acknowledge the contributions of M. Landry, C. Damiano, J. Morris, K. Stewart, M. Zhang, and T. Vogel to this project.

Correspondence concerning this article should be addressed to Jelena Ristic, Department of Psychology, McGill University, 1205 Dr. Penfield Avenue, Montreal, QC H3A 1B1, Canada. E-mail: jelena.ristic@mcgill.ca

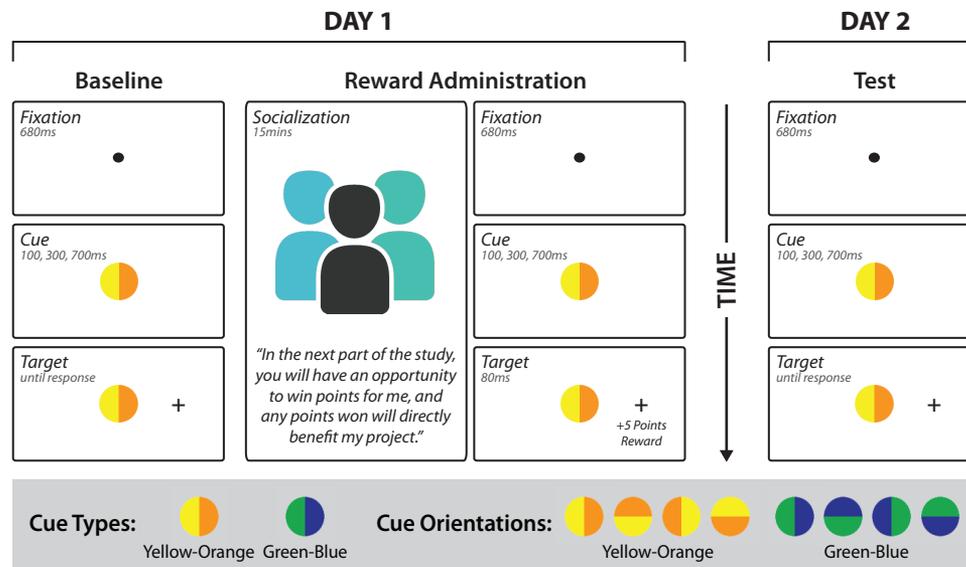
lier, Kohls, Troiani, Brodtkin, & Schultz, 2012). In this vein, it is possible that social reward, provided by interactions and/or feedback from others, may act to preferentially bias attention toward events that spatially coincide with rewarding social signals. As a result, the process of motivational highlighting of the spatial associations between social cues and their corresponding events may be one driving mechanism behind the robust social attention effects that are readily observable in life and in the laboratory.

Motivational incentives exert potent effects on attention. Rewarded targets, like colored shapes, capture attention preferentially, irrespective of physical salience and task goals. Such reward-driven capture has been demonstrated in both behavior (Anderson, Laurent, & Yantis, 2011; Bucker & Theeuwes, 2014; Chelazzi et al., 2014; Engelmann & Pessoa, 2007; Failing & Theeuwes, 2014; Shomstein & Johnson, 2013) and neural activity (Anderson et al., 2016; Anderson, Laurent, & Yantis, 2014; Hickey & Peelen, 2015; Hopf et al., 2015; MacLean & Giesbrecht, 2015; San Martín, Appelbaum, Huettel, & Woldorff, 2016). Behaviorally, data collected using variants of the visual search task have shown that stimuli that have previously been associated with monetary gains continue to capture attention for up to 3 weeks after reward removal (Anderson et al., 2011; see also Anderson, 2016, for capture effects with faces). Neurally, the benefits of reward have been associated with gains in early sensory processing, as reflected by an increased amplitude of the rewarded target's visually evoked P1 component (MacLean & Giesbrecht, 2015).

In contrast to attentional capture, where attention is attracted by a specific stimulus, the role of reward in attentional orienting

remains less well understood. Orienting refers to a process by which attention is shifted from one location to another, with a consequence of facilitated performance for attended locations or target events (e.g., Posner, 1980). Some evidence has suggested that monetary reward modulates attentional orienting. For example, Bucker and Theeuwes (2014) found that monetary incentives associated with the task's overall performance resulted in larger magnitudes of attentional orienting when participants were given ample time to interpret the meaning of the cue. Similarly, Shomstein and Johnson (2013) reported that administration of monetary reward could bias participants to strategically abandon some forms of attentional selection (e.g., object-based) in favor of others (e.g., space-based). Given our hypothesis that social orienting may reflect preferential biasing of attention for coinciding spatial events that receive social reward, here we assessed whether the manipulation of such motivational factors leads to the development of later social orienting.

To test this idea, as depicted in Figure 1, we utilized three experimental phases in our design: baseline, reward administration, and test. The baseline phase contained no reward and ensured that attentional cues did not inherently bias attention. In the reward administration phase, participants were first exposed to a real-life social interaction with the experimenter and were later given an opportunity to accrue social reward "points for the experimenter" based on their task performance in response to coincidental spatial pairings between a central cue and a peripheral target (e.g., Friesen, Ristic, & Kingstone, 2004; Posner, 1980). The test phase examined whether the previously rewarded cue-target combina-



*Figure 1.* Stimuli, task sequence, and design. An example task sequence for each experimental phase, with the yellow-orange cue accruing reward. All trials began with the presentation of a fixation cross for 680 ms. Then, either the yellow-orange or the green-blue circle cue was presented. After 100, 300, or 700 ms, a target "×" or "+" appeared in the periphery. In the baseline and test phases, participants were asked to detect the target by pressing the spacebar key. About 8% no-target trials were included in these two conditions to ensure target-related responses. For the computerized portion of reward administration, participants were asked to discriminate the target by pressing the Z or / key in response to "×" and "+" targets. Target presentation was restricted to 80 ms by a complex line pattern mask (measuring .9°), and the experimental sequence began with an initial presentation of the experimenter's photograph. Note that stimuli are not drawn to scale. See the online article for the color version of this figure.

tions resulted in attentional orienting 1 day later in the absence of reward. In Experiment 2, we assessed whether these effects reflected a general motivation to accrue points by removing the social interaction component from the experimental design (Miranda & Palmer, 2014; Shomstein & Johnson, 2013). In both studies, we assessed whether the participants' magnitudes of social reward-driven attentional benefits were related to their level of social function as measured by the standard Autism-Spectrum Quotient scale (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Hurst, Mitchell, Kimbrel, Kwapil, & Nelson-Gray, 2007).

If social reward has the power to bias spatial attention in the direction of rewarding events and to elicit subsequent attentional orienting for those events, we expected to observe attentional benefits for cue-target spatial combinations that received social reward in Experiment 1. No similar effects were expected in Experiment 2. Furthermore, reflecting past findings indicating strong links between social competence and the magnitude of social attention biases in the general population (Bayliss & Tipper, 2005), we also expected to observe larger social reward-driven attentional benefits in individuals with higher social competence in Experiment 1.

## Experiment 1

### Method

**Participants, apparatus, and stimuli.** Twenty-four undergraduate students (21 female, ages = 19–28 years,  $M = 20$ ,  $SD = 2$ ) with normal or corrected-to-normal vision participated in the study. We used G\*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) to estimate the sample size needed to detect the difference between attentional effects for positively versus negatively rewarded conditions. We estimated this effect size from the existing literature that investigated the effects of reward on attentional capture (i.e., Anderson, 2016; Anderson et al., 2011; Le Pelley, Pearson, Griffiths, & Beesley, 2015; Sha & Jiang, 2016) and attentional orienting (i.e., Bucker & Theeuwes, 2014; Pool, Brosch, Delplanque, & Sander, 2014). Cohen's standardized difference scores ( $d_z$ ), reflecting contrasts between reward versus no reward and/or low reward conditions, were estimated using the reported paired-sample  $t$  test values and sample sizes (i.e.,  $d_z = t/\sqrt{N}$ ; Cohen, 1988; Rosenthal, 1991). All power calculations reflected two-tailed probabilities and  $\alpha$  of 0.05. Effect sizes in the past literature were medium to large in magnitude, ranging from .414 to .816. As such, samples sizes between 14 and 48 participants would yield .80 power, whereas those between 22 and 78 would yield .95 power. Our sample size was selected to fall within these estimates. All experimental procedures were approved by the McGill University Research Ethics Board.

Experiments were presented on a 16-inch cathode ray tube (CRT) color monitor. The stimuli, shown in Figure 1, were a black fixation dot (subtending  $.46^\circ$ ), two bicolored circle cues (yellow-orange and green-blue, measuring  $1.81^\circ$  in diameter), and a "×" and a "+" (average width  $.76^\circ$ ) serving as targets. The cues were positioned at fixation, and targets were presented  $6.25^\circ$  away from fixation along the horizontal or vertical meridian.

**Design and procedure.** The experiment consisted of three phases: baseline, reward administration, and test, administered in

that order. Baseline and reward administration were run on Day 1; test and the AQ were administered the following day.

Attentional orienting was measured using a well-established cuing procedure (Posner, 1980). Figure 1 depicts a typical trial sequence for each phase. On each trial, a fixation dot presented for 680 ms was followed by the presentation of either a yellow-orange or green-blue central cue. As shown in the bottom panel of Figure 1, each central cue could be oriented along the horizontal or the vertical axis such that each colored side (e.g., orange) could coincide with a left, right, top, or bottom peripheral spatial location. After 100, 300, or 700 ms, a target was presented in a left, right, top, or bottom peripheral location. Each combination of cue identity (yellow-orange, green-blue), cue orientation (left, right, up, down), target location (left, right, up, down), cue-target duration (100, 300, or 700 ms), and target type ("×" or "+") occurred with equal probability. Thus, the cues were fully spatially uninformative about the target's location and its identity. Participants were informed about this task structure. Response time (RT) and accuracy were measured from target onset. Baseline and test employed a target-detection procedure to measure spatial orienting, whereas reward administration utilized a target-discrimination procedure to enable the administration of reward points based on performance accuracy (i.e., correct and incorrect target identification). Participants were instructed to respond quickly and accurately in all procedures.

**Baseline.** To assess any existing orienting biases, participants performed a target detection task by pressing the spacebar upon target appearance (e.g., Posner, 1980). No reward was administered; 832 trials were run, divided across 4 testing blocks.

**Reward administration.** To operationalize social reward, prior to conducting this experiment we asked 17 naïve participants to define *social reward*. *Recognition* ( $n = 6$ ), *praise/positive feedback* ( $n = 7$ ), *interaction with others* ( $n = 4$ ), and *being liked by others* ( $n = 5$ ) emerged as main themes in the responses, dovetailing with factors uncovered through recent efforts aimed at formalizing different facets of complex social reward (Foulkes, Viding, McCrory, & Neumann, 2014).

**Socialization.** To capture these facets, participants first took part in the socialization phase. Here they engaged in a 15-min conversation with the experimenter in a separate lounge. The conversation was semi-scripted but flowed naturally. It began with the experimenter asking the participants about their experiences at the university (capturing *interaction with others* and *recognition*). During the conversation, the experimenter told the participants that she was conducting this project as part of her honors degree requirements and expressed an appreciation for their time (*being liked by others*). After the conversation, participants were taken back to the testing room, where they were informed that they would have an opportunity to win "points for the experimenter" and that "any points won would directly benefit the experimenter's project" (*praise* and *positive feedback*). The open-ended nature of these instructions ensured that any reliable modulation in task performance at the test phase reflected strong between-subjects agreement in the comprehension of such unstructured directions (cf. Boggia & Ristic, 2015). No additional information or clarification was provided.

**Laboratory task.** Following the socialization phase, participants completed the same experimental task as in baseline, except that they were asked to perform a target identification task by pressing the Z or

/ key in response to the “×” and “+” targets. The target type–response key assignment was counterbalanced between participants.

Figure 2 illustrates the reward schedule. For each participant, one bicolored cue was randomly assigned as the *rewarded* cue (i.e., accruing reward) and the other as the *unrewarded* cue (i.e., not accruing reward; counterbalanced between participants). Depending on which cue accrued reward (yellow-orange or green-blue), correct identification of a target congruent with the spatial location of the orange (or blue) side received positive reward, gaining 5 “points for the experimenter” for that trial (*Positive Reward*). In contrast, incorrect identification of the target congruent with the spatial location of the opposite yellow (or green) side of the same cue received negative reward, losing 5 points for that trial (*Negative Reward*). Responses for targets occurring at the two remaining locations received no reward (*Neutral*). Thus, the rewarded cue was presented on half of all trials, whereas positive and negative rewards were equally likely to occur on each trial ( $p = .125$  per target location). The number of points won was displayed to participants at the end of each trial, and a running tally of positive points was shown at the end of each block. We ran 768 trials, divided across 4 blocks.

**Test.** The test phase was run the next day using the same task as in the baseline phase. No reward was administered.

## Results

**Reward administration.** Overall, participants successfully performed the task, accruing on average 435 out of a maximum of 480 points. A repeated-measures analysis of variance (ANOVA) was conducted on accuracy data for the *rewarded* cues, with *Testing block* (1–4), *Reward* (positive, negative, neutral), and *Cue–target duration* (100, 300, 700 ms) included as variables. The learning data, plotted in Figure 3A, indicated that performance accuracy during reward administration increased as a function of *Cue–target duration* (100 ms = 89.1%; 700 ms = 92.1%),  $F(2, 46) = 8.45, p < .001, \eta_p^2 = .27$ , and *Testing block* (Block 1 = 86.2%, Block 4 = 92.2%). The steepest learning increase occurred within the first two blocks of trials (86.2%–91.7%); *Block*,  $F(3, 69) = 8.94, p < .0001, \eta_p^2 = .28$ , as is typical for reward learning (e.g., Rothkirch, Ostendorf, Sax, & Sterzer, 2013). Learning for

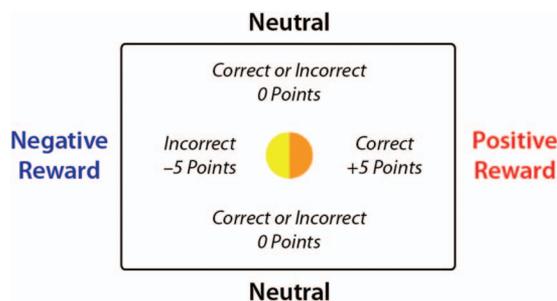


Figure 2. Reward schedule. An example reward schedule with the yellow-orange circle cue accruing reward. When the target was spatially congruent with the orange side (darker) and participants correctly discriminated the target, they accumulated 5 points. When the target was spatially congruent with the opposite yellow side (lighter) and participants incorrectly discriminated the target, they lost 5 points. No other cue–target pairings accrued reward. See the online article for the color version of this figure.

positively rewarded trials peaked earlier in Block 3 (93.4%) relative to performance for negatively rewarded trials, which peaked in Block 4 (94.8%); *Block × Reward Type*,  $F(6, 138) = 3.40, p = .004, \eta_p^2 = .13$ .

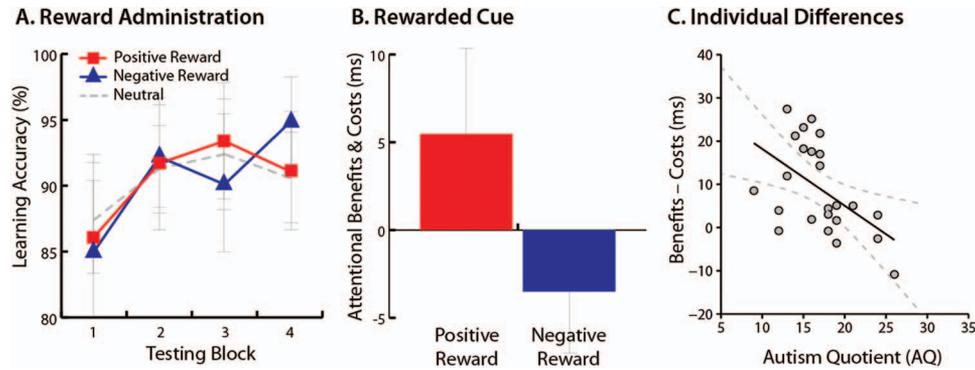
**Baseline versus test contrasts.** Response errors during baseline and test, which included anticipations (RTs < 100 ms), timed-out responses (RTs > 1,000 ms), false alarms, and incorrect key presses, were infrequent and did not differ between the two conditions (1.3% vs. 1.7%, respectively),  $t(23) = -1.71, p = .20$ . To measure attentional benefits of reward from baseline to test, we subtracted correct RTs at test from the corresponding correct RTs at baseline for each participant. Data for the *unrewarded* and *rewarded* cues were examined separately. If social reward highlights coincidental cue–target spatial associations, we expected to find attentional benefits for targets that occurred at spatial locations that received positive reward. This is exactly what our data, plotted in Figure 3B, revealed.

**Unrewarded cues.** Mean correct RTs were examined using a repeated-measures ANOVA run as a function of *Cue orientation* (left, right, up, down), *Target location* (left, right, up, down), and *Cue–target duration* (100, 300, 700 ms). No attentional biases emerged in the absence of reward, as confirmed by no reliable main effects or interactions involving target location and/or cue orientation (*Target location*; *Cue orientation × Target location*; *Cue orientation × Target location × Target duration*; all  $F_s < 1.38, p_s > .169$ , all  $\eta_p^2_s < .06$ ). An additional within-subject ANOVA with *Cue identity* (i.e., yellow-orange or green-blue) included as a variable showed no effects (all  $F_s$  involving *Cue identity* < 1.52,  $p_s > .143$ ,  $\eta_p^2_s < .06$ ). Thus, no attentional benefits were found for the unrewarded cues, consistent with the notion that nondirectional, neutral, and spatially uninformative cues do not normally elicit spatial attentional orienting.

**Rewarded cues.** We computed attentional benefits (i.e., advantage for positive reward vs. neutral) and costs (i.e., detriment for negative reward vs. neutral) by calculating difference scores between RTs for neutral targets relative to RTs for positively and negatively rewarded targets. These scores were analyzed using a repeated-measures ANOVA as a function of *Reward type* (positive, negative) and *Cue–target duration* (100, 300, 700 ms). As illustrated in Figure 3B, and supporting our main hypothesis, attentional benefits emerged for targets that received positive social reward (*Reward type*),  $F(1, 23) = 17.76, p < .001, 95\% \text{ CI } [4.57\text{ms}, 13.40\text{ms}], \eta_p^2 = .44; t(23) = 2.22, p = .037, d_z = .45^1$  (one sample, tested against 0), whereas attentional costs associated with targets that received negative social reward did not reach significance,  $t(23) = -1.96, p = .062, d_z = .40$  (one sample, tested against 0). The magnitude of the difference between attentional benefits and costs increased moderately as the time between the cue and the target lengthened (*Reward type × Cue–target duration*),  $F(2, 46) = 4.65, p = .015, \eta_p^2 = .17$ , confirming the time course of reward learning.<sup>2</sup> Once again, no effects of *Cue identity* were found (all  $F_s < 1, p_s > .41, \eta_p^2_s < .04$ ). Thus, the

<sup>1</sup> All  $d_z$ s calculated as  $t/\sqrt{N}$  (Cohen, 1988; Rosenthal, 1991).

<sup>2</sup> A separate ANOVA with cuing *Axis* (horizontal; vertical), *Reward type*, and *Cue–target duration* confirmed no changes in this data pattern as a function of the spatial position of the cue and/or target (*Axis*; *Axis × Reward Type*; *Axis × Reward Type × Cue–target Interval*, all  $F_s < 1, p_s > .413, \eta_p^2_s < .12$ ).



**Figure 3.** Experiment 1 results. Panel A: Reward administration depicts learning accuracy as a function of testing block and reward type. Positive and Negative reward conditions are denoted by solid lines; Neutral condition is denoted by a dashed line. Panel B: Rewarded cue shows the magnitude of attentional benefits (Positive Reward minus Neutral; lighter gray [red]) and costs (Negative Reward minus Neutral; darker gray [blue]) associated with the reward manipulation. Panel C: Individual differences in the magnitudes of the reward advantage (y-axis; i.e., positive reward benefit minus negative reward cost) as a function of AQ score (x-axis; lower AQ scores denote higher social function). All error bars represent 95% confidence intervals. See the online article for the color version of this figure.

results indicated the emergence of attentional benefits following the administration of complex social reward.<sup>3</sup>

**Individual differences.** Finally, we examined whether the reward advantage (i.e., the difference between attentional benefits and costs) varied with participants' level of social functioning. To do so, we first inspected the data for bivariate outliers by looking for scores whose standardized residuals fell 1 standard deviation above the mean. No outliers were found. Then, we performed Pearson correlations between participants' AQ scores and their overall magnitude of reward advantage (i.e., Positive reward benefit minus Negative reward cost). We expected that the magnitudes of reward-driven advantage would be larger for participants with higher social competence, that is, those with lower AQ scores. As shown in Figure 3C, a strong negative relationship was found (Pearson  $r = -.509$ ,  $p = .011$ , 95% CI [-.13, -.76]), with participants higher in social competence displaying larger reward-driven attentional advantages. We verified the effect magnitude of this association by applying a disattenuation procedure, which adjusts the data for measurement error while maintaining a conservative approach against overcorrecting (e.g., Spearman, 1904). Disattenuated values were calculated using the Guttman's L4 reliabilities (e.g., see Osburn, 2000), which equaled .66 for the AQ scores (see also Baron-Cohen et al., 2001) and .68 for the reward magnitude. The results supported the internal consistency of the data and the robustness of their correlations, yielding a disattenuated Pearson coefficient of  $r = -.75$ .

To probe into the influence of the facets of social function as reflected by the AQ's Communication, Social Skills, and Imagination subscales, we entered participants' scores on these subscales as predictors of their overall magnitude of reward advantage using a multiple linear regression. These social factors accounted for about 40% of the variance in the reward advantage data ( $R^2 = .392$ ),  $F(3, 23) = 4.30$ ,  $p = .017$ , Communication  $\beta = -.50$ ,  $t(20) = -2.76$ ,  $p = .012$ , 95% CI [-5.70, -.79]; Social Skills  $\beta = -.19$ ,  $t(20) = -1.01$ ,  $p = .33$ , 95% CI [-4.33, 1.51]; Imagination  $\beta = -.34$ ,  $t(20) = -1.83$ ,  $p = .08$ , 95% CI [-6.06, .40].

## Discussion

In line with our hypotheses, the results from Experiment 1 indicated that administration of positive social reward led to attentional orienting for rewarded spatial associations. The RT data showed attentional benefits at test for targets that received positive social reward. Individual differences analyses further supported this finding indicating larger magnitudes of reward-driven orienting benefits in individuals with higher social competence. The data from the learning phase indicated that the participants' reward learning was modulated by positive but also by negative reward. Although reward administration was contingent on performance accuracy and could vary between participants, due to overall high learning accuracy, fewer trials received negative (9 out of possible 96) relative to positive (86 out of 96) reward. However, typical learning curves were observed for both rewards, suggesting quick learning of negative incentives even with a reduced reward schedule. One interpretation of this finding could reflect aversion to social reward loss. Alternatively, participants may have had enough time to adjust an explicit attentional strategy rather than to continue to apply the same associative learning processes throughout the task. Future studies are needed to provide additional insights into the learning mechanisms responsible for social reward gains and losses.

Together, these data suggest that social reward exerts both general and specific effects on attention. Indicating general influence, attentional benefits following social reward were not dependent on a particular cue–target spatial arrangement, spatial location of the target, or physical identity of the cue. A specific influence of positive reward is revealed by reward-driven attentional benefits for positive reward only, because by the virtue of the design reward saliency remained equated across positive and negative

<sup>3</sup> RT comparisons between baseline and test were based on the same number of trials for each reward type condition.

reward conditions (e.g., Rothkirch et al., 2013; Watson & Platt, 2012).

Although overall these results are consistent with the idea that social reward has the power to drive novel attentional orienting behaviors, they do not indicate whether such results could also reflect participants' general motivation to accrue points (Miranda & Palmer, 2014). We tested this idea in Experiment 2 (e.g., Shomstein & Johnson, 2013). As such, the a priori power to detect this effect should be comparable to power estimates in Experiment 1.

## Experiment 2

### Method

#### Participants, apparatus, stimuli, design, and procedure.

Twenty-four new naïve undergraduate students were recruited (20 female, age = 19–29 years,  $M = 24$ ,  $SD = 3$ ). Experiment 2 was identical to Experiment 1 except that there was no socialization. Consequently, participants could only accrue “points” throughout the reward administration task.

### Results

**Reward administration.** As in Experiment 1, participants successfully learned the task, accumulating on average 427 out of a maximum of 480 points during reward administration. A repeated-measures ANOVA examined accuracy rates for the rewarded cues with *Testing block* (1–4), *Reward* (positive, negative, neutral), and *Cue–target duration* (100, 300, 700 ms) included as variables. The learning data, illustrated in Figure 4A, indicated once again that accuracy increased across *Cue–target durations* (100 ms = 86.1%; 700 ms = 90.1%),  $F(2, 46) = 12.15$ ,  $p < .001$ ,  $\eta_p^2 = .35$ , and *Testing blocks* (Block 1 = 82.8%; Block 4 = 90.5%),  $F(3, 69) = 7.74$ ,  $p < .001$ ,  $\eta_p^2 = .25$ , with the sharpest increase in learning occurring between Blocks 1 and all subsequent blocks, mirroring the results of Experiment 1. A three-way interaction between *Testing block*, *Reward type*, and *Cue–target interval* indicated that performance accuracy for negatively rewarded trials converged with the overall superior performance for positively rewarded trials only during the last block of trials,  $F(12, 276) = 1.87$ ,  $p = .038$ ,  $\eta_p^2 = .08$ .

**Baseline versus test contrasts.** Response errors were once again infrequent and did not differ between the two conditions (1.6% vs. 1.9%, respectively),  $t(23) = -.61$ ,  $p = .55$ . All analyses mirrored those conducted in Experiment 1.

**Unrewarded cues.** A repeated-measures ANOVA run as a function of *Cue orientation* (left, right, up, down), *Target location* (left, right, up, down), and *Cue–target duration* (100, 300, 700 ms) returned no main effects or interactions (all  $F_s < 1.6$ ,  $p_s > .19$ ,  $\eta_p^2_s < 0.07$ ). As before, these results did not depend on *Cue identity* (all  $F_s$  involving *Cue identity*  $< 1.44$ ,  $p_s > .17$ ,  $\eta_p^2_s < .06$ ). Thus, as in Experiment 1, no attentional benefits emerged for unrewarded cues.

**Rewarded cues.** In contrast to Experiment 1, Experiment 2 revealed no attentional benefits and costs associated with positively and negatively rewarded targets, both overall and as a function of cue–target time: *Reward Type*,  $F(1, 23) = .42$ ,  $p = .522$ , 95% CI [–3.77 ms, 7.22 ms],  $\eta_p^2 = .02$ ; *Reward type*  $\times$  *Cue–target duration*,  $F(2, 46) = 2.33$ ,  $p = .11$ ,  $\eta_p^2 = .09$  (see

Figure 4B). Once again, the data did not vary with *Cue identity* (all  $F_s$  involving *Cue identity*  $< 2.96$ ,  $p_s > .1$ ,  $\eta_p^2_s < .12$ ).<sup>4</sup> Thus, when no socialization occurred, no reward-driven attentional benefits were found. Likewise, and as shown in Figure 4C, no reliable relationship between participants' AQ and their magnitude of the reward advantage was found (Pearson  $r = .10$ ,  $p = .65$ , 95% CI [–.33, .49]). An analysis of bivariate outliers determined one deviant data point, which was excluded from the correlation analysis. As in Experiment 1, the calculation of the disattenuated correlations supported the measured effect magnitude (AQ L4 = .83; reward magnitude L4 = .53; Pearson  $r = .15$ ). No influence of the AQ social subscales were reliable in Experiment 2 ( $R^2 = .171$ ),  $F(3, 22) = 1.31$ ,  $p = .30$ , Communication  $\beta = -.30$ ,  $t(19) = -.94$ ,  $p = .36$ , 95% CI [–5.82, 2.23]; Social Skills  $\beta = .53$ ,  $t(19) = 1.61$ ,  $p = .12$ , 95% CI [–.86, 6.52]; Imagination  $\beta = -.29$ ,  $t(19) = -1.38$ ,  $p = .19$ , 95% CI [–6.32, 1.31].

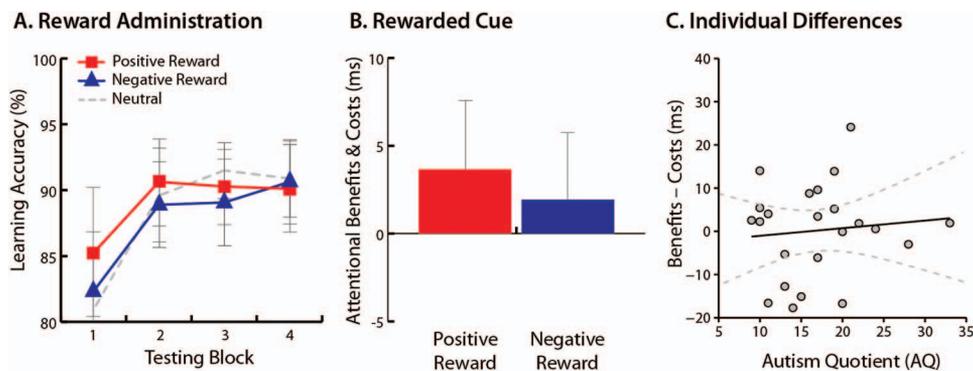
Thus, Experiment 2 found that presenting participants with an opportunity to accrue points without the manipulation of social reward did not result in subsequent attentional modulations. This finding dovetails with results of past studies that have employed similar points-based manipulations and found no effects on attentional performance (cf. Miranda & Palmer, 2014, Experiment 2; Shomstein & Johnson, 2013, Experiment 1b).

**Effect of social manipulation.** We performed three additional analyses to quantify the effect of social manipulation (see Nieuwenhuis, Forstmann, & Wagenmakers, 2011). First, we contrasted the data from the two experiments using a mixed-effects ANOVA with *Experiment* included as a between-subjects variable and *Reward type* and *Cue–target interval* included as the within-subject variables. This analysis returned an overall main effect of *Reward type*,  $F(1, 46) = 9.89$ ,  $p = .003$ ,  $\eta_p^2 = .18$  (*Positive* = 4.57 ms vs. *Negative* = –.79 ms) and two significant interactions: *Experiment*  $\times$  *Reward Type*,  $F(1, 46) = 4.55$ ,  $p = .038$ ,  $\eta_p^2 = .09$ , and *Experiment*  $\times$  *Reward type*  $\times$  *Cue–target duration*,  $F(2, 92) = 4.67$ ,  $p = .012$ ,  $\eta_p^2 = .09$  (all other  $F_s < 2.70$ ,  $p_s > .072$ ,  $\eta_p^2_s < .06$ ), both of which indicated that reward-driven benefits were larger in Experiment 1. Figures 3B and 4B suggest that this difference may reflect a performance change in the negatively rewarded condition, with reduced aversion to social loss following reduced availability of social incentives (e.g., Anderson, 2017).

Second, we compared the correlations from the two experiments using the Fisher  $r$ -to- $z$  transformation. This analysis yielded a reliable difference between the two experiments showing that the correlations between participants' AQ scores and their magnitudes of reward advantage were significantly different between the two experiments, with a larger correlation in Experiment 1 ( $z = -2.12$ ,  $p = .034$ ).

Finally, we turned to Bayesian analyses to test the apparent null effect in Experiment 2 using the prior from Experiment 1 (Dienes, 2011; Masson, 2011). To do so, we calculated the Bayes factor  $B$ , which returns the relative strength of evidence for the alternative hypothesis over the null hypothesis (i.e., zero difference), with  $B$  values below .33 providing support for the null and those above

<sup>4</sup> A separate ANOVA with cuing *Axis*, *Reward type*, and *Cue–target duration* confirmed no changes in this pattern as a function of the spatial position of the cue and/or target (*Axis*; *Axis*  $\times$  *Reward Type*; *Axis*  $\times$  *Reward Type*  $\times$  *Cue–target Interval*, all  $F_s < 1$ ,  $p_s > .378$ ,  $\eta_p^2_s < .03$ ).



*Figure 4.* Experiment 2 results. Panel A: Reward administration depicts learning accuracy as a function of testing block and reward type. Positive and Negative reward conditions are denoted by solid lines; Neutral condition is denoted by a dashed line. Panel B: Rewarded cue shows the magnitude of attentional benefits (positive reward–neutral; lighter gray [red]) and costs (negative reward–neutral; darker gray [blue]) associated with reward manipulation. Panel C: Individual differences in the magnitudes of the reward advantage (y-axis; i.e., positive reward benefit minus negative reward cost) as a function of AQ score (x-axis). The scatterplot reflects exclusion of one bivariate outlier. All error bars represent 95% confidence intervals. See the online article for the color version of this figure.

3.00 against the null, that is, for the alternative hypothesis.<sup>5</sup> The predictions of the alternative hypothesis were represented by a Gaussian distribution with a mean and standard deviation of the reward-driven effect measured in Experiment 1 ( $M = 8.985$  ms,  $SD = 10.444$ ). The resulting Bayes factor of .24 can be interpreted as moderate support for the null hypothesis in Experiment 2. This finding also held when the predictions of the alternative hypothesis were represented by a uniform prior governed by Experiment 1, varying from the lower to the upper bound of the 95% CIs [4.57 ms, 13.40 ms] of the reward-driven effect magnitudes ( $B = .13$ ). Thus, three additional lines of evidence converged onto the finding that implicates the role of social reward in the attentional effects observed in Experiment 1.

## General Discussion

In this study, we examined whether complex social motivational drives represent one of the underlying mechanisms behind spontaneous social attentional orienting that is readily observed in life and in the laboratory. To do so, we exposed participants to a real-life social interaction and later administered social reward points as a function of their trial-by-trial performance within an established attentional orienting task. Our data indicated successful reward learning and reliable attentional benefits, which emerged for cue–target pairings that received positive social reward. Moreover, this social reward–driven orienting emerged even though each cue–target spatial pairing was equiprobable and equally likely to receive positive, negative, or no reward.

Our data indicated that, similar to social attention effects elicited by more obvious social cues like faces and eyes (e.g., Bayliss & Tipper, 2005), the magnitude of the positive reward advantage, which reflected the difference between attentional benefits and costs across equally salient (i.e., positive vs. negative) reward conditions, was larger in individuals with higher social competence. No similar attentional benefits were found in Experiment 2 when social reward was not manipulated. Taken together, these data provide one of the first pieces of evidence implicating social

motivation in attentional orienting. More specifically, they show that complex social reward available in the natural environment can bias coincidental spatial associations between cues and targets and lead to spatial orienting biases. As such, these results offer three novel theoretical insights.

First, they suggest that social reward is a powerful mechanism that is capable of enhancing spatial associations between coinciding events in the environment. Extending existing knowledge about the role of motivation in attentional capture (e.g., Anderson et al., 2011; Hickey et al., 2010), our data show that in addition to modulating the perception of stimuli, motivational processes may also act to regulate the emergence of spatial orienting. Hence these results provide one of the first insights as to *why* humans follow social signals despite the fact that those signals are typically spatially uninformative and embedded within high levels of environmental noise. That is, it appears that social reward is capable of highlighting the spatial links between social cues and their corresponding targets. With repeated exposure, these associations become prioritized, automatized, and generalized to similar types of cues, leading to a wide range of social attention biases that are observed in life and in laboratory studies (e.g., isolated eyes: Hayward & Ristic, 2015; head direction: Langton & Bruce, 1999; finger pointing: Langton & Bruce, 2000).

Second, our results also suggest that social reward facilitates social attribution processes, because our reward manipulation imbued initially neutral cues with social meaning. Although social signals are typically conveyed by stimuli that are a priori socially relevant (e.g., eyes, faces), these results show that neutral and nonsocial signals may also be deemed socially relevant quickly and flexibly, depending on the nature of the accompanying social reward (i.e., positive or negative). Thus, in addition to modulating attention, social reward appears to modulate social attribution in an

<sup>5</sup> The procedure can be performed using the web-based application located at [http://www.lifesci.sussex.ac.uk/home/Zoltan\\_Dienes/inference/Bayes.htm](http://www.lifesci.sussex.ac.uk/home/Zoltan_Dienes/inference/Bayes.htm)

adaptable and ongoing manner, with the availability and utility of social incentives regulating the cue's perceived social value.

Finally, and dovetailing with the social attention literature (e.g., Bayliss & Tipper, 2005), the present data suggest important links between social function and the computation of social reward, in that individuals with reduced and/or atypical social function may be less able to ascribe social relevance to neutral cues, recognize indices of social reward in ambiguous settings, and/or derive pleasure from reward. Recent work showing that typical individuals with reduced social competence access social information from sensory cues indirectly by bootstrapping from their perceptual feature transients (Hayward & Ristic, 2017) has suggested that direct access to social information in high socially functioning individuals may facilitate the extraction of social motivational information and further reward learning. Reduced sensitivity to social reward and the misattribution of social meaning has also been proposed as a contributing factor to the core social deficit observed in autism (Chevallier et al., 2012; Dawson et al., 2004) and has been implicated in the development of maladaptive social styles like aggression in the normative population (Dodge & Frame, 1982). Although our data suggest links between social competence and social reward, they also reflect variability in a typical population and in turn may underestimate the robustness of these associations in atypical groups. As such, our novel operationalization of social rewards as real-life benefits and exchanges may be a useful future tool for studies aimed at understanding the role of social reward in typical and atypical social function, as well as for those approaches aimed at improving diagnostic and rehabilitative strategies relating to attentional bias retraining (i.e., anxiety and/or social anxiety, depression disorders; e.g., Browning, Holmes, Charles, Cowen, & Harmer, 2012).

In sum, using a manipulation of social reward that included several aspects of real-world socially rewarding experiences (e.g., praise, positive feedback, social interaction), here we show the emergence of general spatial attention orienting biases following the administration of positive social reward. These results reveal the links between complex motivational drives and core cognitive functions like attention (Ristic & Enns, 2015) and underscore the importance of studying the links between human attention and larger environmental conditions.

## References

- Anderson, B. A. (2016). Social reward shapes attentional biases. *Cognitive Neuroscience*, 7, 30–36. <http://dx.doi.org/10.1080/17588928.2015.1047823>
- Anderson, B. A. (2017). Counterintuitive effects of negative social feedback on attention. *Cognition and Emotion*, 31, 590–597. <http://dx.doi.org/10.1080/02699931.2015.1122576>
- Anderson, B. A., Kuwabara, H., Wong, D. F., Gean, E. G., Rahmim, A., Brašić, J. R., . . . Yantis, S. (2016). The role of dopamine in value-based attentional orienting. *Current Biology*, 26, 550–555. <http://dx.doi.org/10.1016/j.cub.2015.12.062>
- Anderson, B. A., Laurent, P. A., & Yantis, S. (2011). Value-driven attentional capture. *Proceedings of the National Academy of Sciences of the United States of America*, 108, 10367–10371. <http://dx.doi.org/10.1073/pnas.1104047108>
- Anderson, B. A., Laurent, P. A., & Yantis, S. (2014). Value-driven attentional priority signals in human basal ganglia and visual cortex. *Brain Research*, 1587, 88–96. <http://dx.doi.org/10.1016/j.brainres.2014.08.062>
- Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, 31, 5–17. <http://dx.doi.org/10.1023/A:1005653411471>
- Bayliss, A. P., & Tipper, S. P. (2005). Gaze and arrow cueing of attention reveals individual differences along the autism spectrum as a function of target context. *British Journal of Psychology*, 96, 95–114. <http://dx.doi.org/10.1348/000712604X15626>
- Birmingham, E., Ristic, J., & Kingstone, A. (2012). Investigating social attention: A case for increasing stimulus complexity in the laboratory. In J. A. Burack, J. T. Enns, & N. A. Fox (Eds.), *Cognitive neuroscience, development, and psychopathology* (pp. 251–276). <http://dx.doi.org/10.1093/acprof:oso/9780195315455.003.0010>
- Boggia, J., & Ristic, J. (2015). Social event segmentation. *Quarterly Journal of Experimental Psychology*, 68, 731–744. <http://dx.doi.org/10.1080/17470218.2014.964738>
- Browning, M., Holmes, E. A., Charles, M., Cowen, P. J., & Harmer, C. J. (2012). Using attentional bias modification as a cognitive vaccine against depression. *Biological Psychiatry*, 72, 572–579. <http://dx.doi.org/10.1016/j.biopsych.2012.04.014>
- Bucker, B., & Theeuwes, J. (2014). The effect of reward on orienting and reorienting in exogenous cuing. *Cognitive, Affective & Behavioral Neuroscience*, 14, 635–646. <http://dx.doi.org/10.3758/s13415-014-0278-7>
- Chelazzi, L., Eščinová, J., Calletti, R., Lo Gerfo, E., Sani, I., Della Libera, C., & Santandrea, E. (2014). Altering spatial priority maps via reward-based learning. *Journal of Neuroscience*, 34, 8594–8604. <http://dx.doi.org/10.1523/JNEUROSCI.0277-14.2014>
- Chevallier, C., Kohls, G., Troiani, V., Brodtkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in Cognitive Sciences*, 16, 231–239. <http://dx.doi.org/10.1016/j.tics.2012.02.007>
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
- Dawson, G., Meltzoff, A. N., Osterling, J., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. *Journal of Autism and Developmental Disorders*, 28, 479–485. <http://dx.doi.org/10.1023/A:1026043926488>
- Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: Social orienting, joint attention, and attention to distress. *Developmental Psychology*, 40, 271–283. <http://dx.doi.org/10.1037/0012-1649.40.2.271>
- Dienes, Z. (2011). Bayesian versus orthodox statistics: Which side are you on? *Perspectives on Psychological Science*, 6, 274–290. <http://dx.doi.org/10.1177/1745691611406920>
- Dodge, K. A., & Frame, C. L. (1982). Social cognitive biases and deficits in aggressive boys. *Child Development*, 53, 620–635. <http://dx.doi.org/10.2307/1129373>
- Engelmann, J. B., & Pessoa, L. (2007). Motivation sharpens exogenous spatial attention. *Emotion*, 7, 668–674. <http://dx.doi.org/10.1037/1528-3542.7.3.668>
- Failing, M. F., & Theeuwes, J. (2014). Exogenous visual orienting by reward. *Journal of Vision*, 14, 6. <http://dx.doi.org/10.1167/14.5.6>
- Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences of the United States of America*, 99, 9602–9605. <http://dx.doi.org/10.1073/pnas.152159999>
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G\*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39, 175–191. <http://dx.doi.org/10.3758/BF03193146>
- Foulkes, L., Viding, E., McCrory, E., & Neumann, C. S. (2014). Social Reward Questionnaire (SRQ): Development and validation. *Frontiers in Psychology*, 5, 201.

- Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, 5, 490–495. <http://dx.doi.org/10.3758/BF03208827>
- Friesen, C. K., Ristic, J., & Kingstone, A. (2004). Attentional effects of counterpredictive gaze and arrow cues. *Journal of Experimental Psychology: Human Perception and Performance*, 30, 319–329. <http://dx.doi.org/10.1037/0096-1523.30.2.319>
- Gallup, A. C., Hale, J. J., Sumpster, D. J. T., Garnier, S., Kacelnik, A., Krebs, J. R., & Couzin, I. D. (2012). Visual attention and the acquisition of information in human crowds. *Proceedings of the National Academy of Sciences of the United States of America*, 109, 7245–7250. <http://dx.doi.org/10.1073/pnas.1116141109>
- Hayward, D. A., & Ristic, J. (2015). Exposing the cuing task: The case of gaze and arrow cues. *Attention, Perception, & Psychophysics*, 77, 1088–1104. <http://dx.doi.org/10.3758/s13414-015-0877-6>
- Hayward, D. A., & Ristic, J. (2017). Feature and motion-based gaze cuing is linked with reduced social competence. *Scientific Reports*, 7, 44221. <http://dx.doi.org/10.1038/srep44221>
- Hayward, D. A., Voorhies, W., Morris, J. L., Capozzi, F., & Ristic, J. (in press). Staring reality in the face: A comparison of social attention across laboratory and real world measures suggests little common ground. *Canadian Journal of Experimental Psychology*.
- Hickey, C., Chelazzi, L., & Theeuwes, J. (2010). Reward changes salience in human vision via the anterior cingulate. *Journal of Neuroscience*, 30, 11096–11103. <http://dx.doi.org/10.1523/JNEUROSCI.1026-10.2010>
- Hickey, C., & Peelen, M. V. (2015). Neural mechanisms of incentive salience in naturalistic human vision. *Neuron*, 85, 512–518. <http://dx.doi.org/10.1016/j.neuron.2014.12.049>
- Hopf, J.-M., Schoenfeld, M. A., Buschschulte, A., Rautzenberg, A., Krebs, R. M., & Boehler, C. N. (2015). The modulatory impact of reward and attention on global feature selection in human visual cortex. *Visual Cognition*, 23, 229–248. <http://dx.doi.org/10.1080/13506285.2015.1011252>
- Hurst, R. M., Mitchell, J. T., Kimbrel, N. A., Kwapil, T. K., & Nelson-Gray, R. O. (2007). Examination of the reliability and factor structure of the Autism Spectrum Quotient (AQ) in a non-clinical sample. *Personality and Individual Differences*, 43, 1938–1949. <http://dx.doi.org/10.1016/j.paid.2007.06.012>
- Kennedy, D. P., & Adolphs, R. (2012). The social brain in psychiatric and neurological disorders. *Trends in Cognitive Sciences*, 16, 559–572. <http://dx.doi.org/10.1016/j.tics.2012.09.006>
- Langton, S. R. H., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition*, 6, 541–567. <http://dx.doi.org/10.1080/135062899394939>
- Langton, S. R. H., & Bruce, V. (2000). You must see the point: Automatic processing of cues to the direction of social attention. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 747–757. <http://dx.doi.org/10.1037/0096-1523.26.2.747>
- Le Pelley, M. E., Pearson, D., Griffiths, O., & Beesley, T. (2015). When goals conflict with values: Counterproductive attentional and oculomotor capture by reward-related stimuli. *Journal of Experimental Psychology: General*, 144, 158–171. <http://dx.doi.org/10.1037/xge0000037>
- MacLean, M. H., & Giesbrecht, B. (2015). Neural evidence reveals the rapid effects of reward history on selective attention. *Brain Research*, 1606, 86–94. <http://dx.doi.org/10.1016/j.brainres.2015.02.016>
- Masson, M. E. J. (2011). A tutorial on a practical Bayesian alternative to null-hypothesis significance testing. *Behavior Research Methods*, 43, 679–690. <http://dx.doi.org/10.3758/s13428-010-0049-5>
- Miranda, A. T., & Palmer, E. M. (2014). Intrinsic motivation and attentional capture from gamelike features in a visual search task. *Behavior Research Methods*, 46, 159–172. <http://dx.doi.org/10.3758/s13428-013-0357-7>
- Nieuwenhuis, S., Forstmann, B. U., & Wagenmakers, E.-J. (2011). Erroneous analyses of interactions in neuroscience: A problem of significance. *Nature Neuroscience*, 14, 1105–1107. <http://dx.doi.org/10.1038/nn.2886>
- Osburn, H. G. (2000). Coefficient alpha and related internal consistency reliability coefficients. *Psychological Methods*, 5, 343–355. <http://dx.doi.org/10.1037/1082-989X.5.3.343>
- Pool, E., Brosch, T., Delplanque, S., & Sander, D. (2014). Where is the chocolate? Rapid spatial orienting toward stimuli associated with primary rewards. *Cognition*, 130, 348–359. <http://dx.doi.org/10.1016/j.cognition.2013.12.002>
- Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3–25. <http://dx.doi.org/10.1080/00335558008248231>
- Ristic, J., & Enns, J. T. (2015). The changing face of attentional development. *Current Directions in Psychological Science*, 24, 24–31. <http://dx.doi.org/10.1177/0963721414551165>
- Rosenthal, R. (1991). *Meta-analytic procedures for social research*. Atlanta, GA: Sage.
- Rothkirch, M., Ostendorf, F., Sax, A. L., & Sterzer, P. (2013). The influence of motivational salience on saccade latencies. *Experimental Brain Research*, 224, 35–47. <http://dx.doi.org/10.1007/s00221-012-3284-4>
- San Martín, R., Appelbaum, L. G., Huettel, S. A., & Woldorff, M. G. (2016). Cortical brain activity reflecting attentional biasing toward reward-predicting cues covaries with economic decision-making performance. *Cerebral Cortex*, 26, 1–11. <https://doi.org/10.1093/cercor/bhu160>
- Sha, L. Z., & Jiang, Y. V. (2016). Components of reward-driven attentional capture. *Attention, Perception, & Psychophysics*, 78, 403–414. <http://dx.doi.org/10.3758/s13414-015-1038-7>
- Shomstein, S., & Johnson, J. (2013). Shaping attention with reward: Effects of reward on space- and object-based selection. *Psychological Science*, 24, 2369–2378. <http://dx.doi.org/10.1177/0956797613490743>
- Spearman, C. (1904). The proof and measurement of association between two things. *American Journal of Psychology*, 15, 72–101. <http://dx.doi.org/10.2307/1412159>
- Watson, K. K., & Platt, M. L. (2012). Social signals in primate orbitofrontal cortex. *Current Biology*, 22, 2268–2273. <http://dx.doi.org/10.1016/j.cub.2012.10.016>

Received January 6, 2017

Revision received May 14, 2017

Accepted May 16, 2017 ■