



## Social reward shapes attentional biases

Brian A. Anderson

To cite this article: Brian A. Anderson (2016) Social reward shapes attentional biases, Cognitive Neuroscience, 7:1-4, 30-36, DOI: [10.1080/17588928.2015.1047823](https://doi.org/10.1080/17588928.2015.1047823)

To link to this article: <http://dx.doi.org/10.1080/17588928.2015.1047823>



Accepted author version posted online: 05 May 2015.  
Published online: 21 May 2015.



Submit your article to this journal [↗](#)



Article views: 157



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 3 View citing articles [↗](#)

## Social reward shapes attentional biases

Brian A. Anderson

Psychological & Brain Sciences, Johns Hopkins University, Baltimore, USA

Paying attention to stimuli that predict a reward outcome is important for an organism to survive and thrive. When visual stimuli are associated with tangible, extrinsic rewards such as money or food, these stimuli acquire high attentional priority and come to automatically capture attention. In humans and other primates, however, many behaviors are not motivated directly by such extrinsic rewards, but rather by the social feedback that results from performing those behaviors. In the present study, I examine whether positive social feedback can similarly influence attentional bias. The results show that stimuli previously associated with a high probability of positive social feedback elicit value-driven attentional capture, much like stimuli associated with extrinsic rewards. Unlike with extrinsic rewards, however, such stimuli also influence task-specific motivation. My findings offer a potential mechanism by which social reward shapes the information that we prioritize when perceiving the world around us.

**Keywords:** Selective attention; Social feedback; Reward learning.

Limitations in the brain's capacity to represent perceptual input create conditions under which stimuli compete for representation at later, capacity-limited stages of cognition, such as memory storage and decision-making. Attention serves as the mechanism by which the brain selects which, among multiple, stimuli receive such representation (Desimone & Duncan, 1995). In order for an organism to survive and thrive, attention must select stimuli that provide information useful for guiding behavior toward reward outcomes.

Although theories of attentional selection have historically emphasized the interplay between the goals of the observer (e.g., Folk, Remington, & Johnston, 1992; Wolf, Cave, & Franzel, 1989) and the physical salience (i.e., feature contrast) of the stimulus (e.g., Theeuwes, 1992; Yantis & Jonides, 1984), there is growing consensus that the reward history tied to stimuli also plays a role in guiding selection. The receipt of a reward has an immediate impact upon the

subsequent selection of a target stimulus (e.g., Della Libera & Chelazzi, 2006; Hickey, Chelazzi, & Theeuwes, 2010). Selection of a stimulus is facilitated once it has been learned to reliably predict a reward (e.g., Della Libera & Chelazzi, 2009; Kiss, Driver, & Eimer, 2009; Raymond & O'Brien, 2009), and such previously reward-associated stimuli automatically capture attention even when task-irrelevant and physically nonsalient (e.g., Anderson, Laurent, & Yantis, 2011b, 2014). These latter findings provide strong evidence that reward history biases attention in a manner that is not reducible to the well-known goal-directed and salience-driven mechanisms, supporting a distinctly value-driven mechanism of selection (Anderson, 2013).

For humans and other primates who exist in the context of complex social networks, social standing reflects a valuable resource. Gaining and maintaining the approval or favor of another can improve mating opportunities, create allies, and generally promote

---

Correspondence should be addressed to: Brian A. Anderson, 3400 N. Charles St, Baltimore, MD 21218-2686, USA.  
E-mail: [bander33@jhu.edu](mailto:bander33@jhu.edu)

The author is grateful to M. DiBartolo and M. Chiu for assistance with data collection, and to M. Chiu for assistance with generating the experimental stimuli.

No potential conflict of interest was reported by the author.

This work was supported by the National Institutes of Health [grant number R01-DA013165].

favorable treatment from others. There is ample evidence that social information is incorporated into the guidance of attention. For example, the eye gaze of another can bias the orienting of attention in its direction (e.g., Frischen, Bayliss, & Tipper, 2007), and stimuli associated with the self (such as one's own name) have high attentional priority (e.g., Harris, Pashler, & Coburn, 2004; Moray, 1959; Sui, Chechlacz, & Humphreys, 2012; Sui, He, & Humphreys, 2012). How strongly monetary rewards bias attention is modulated by knowledge concerning the relative earnings of other participants (Jiao, Du, He, & Zhang, *in press*). The role of social reward, or positive social feedback, in shaping the guidance of attention, however, remains unexplored. In the present study, I examine whether social reward can bias attention toward the stimuli that predict such reward, mirroring the value-driven attentional capture observed for stimuli previously associated with tangible, extrinsic rewards such as money (e.g., Anderson et al., 2011b; Anderson, Laurent, et al., 2014) and food (Pool, Brosch, Delplanque, & Sander, 2014).

## METHODS

### Participants

Twenty-six participants were recruited from the Johns Hopkins University community. All reported normal or corrected-to-normal visual acuity and normal color vision. The data for one participant were replaced due

to poor performance on the task (accuracy < 70%). Participants were compensated with \$10 (US Dollars). All experimental procedures were approved by the Johns Hopkins University Institutional Review Board.

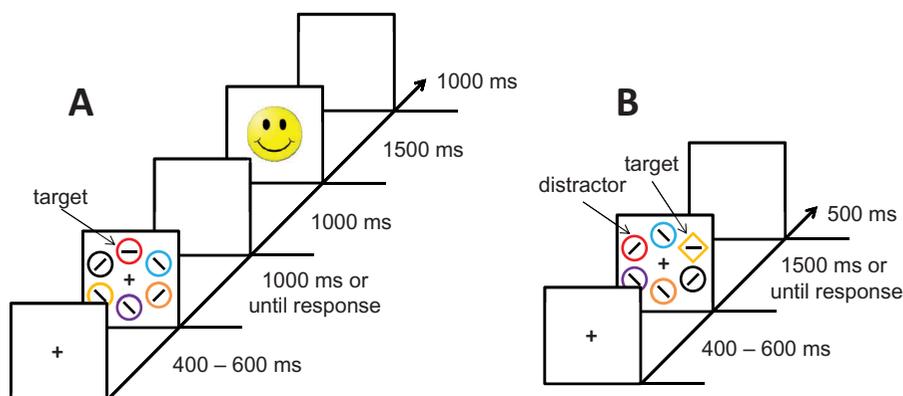
### Apparatus

A Mac Mini equipped with Matlab software and Psychophysics Toolbox extensions (Brainard, 1997) was used to present the stimuli on an Asus VE247 monitor. The participants viewed the monitor from a distance of approximately 70 cm in a dimly-lit room. Manual responses were entered using a standard keyboard.

### Training phase

#### Stimuli

Each trial consisted of a fixation display, a search array, and a social feedback display (Figure 1A). The fixation display contained a white fixation cross ( $0.5^\circ \times 0.5^\circ$  visual angle) presented in the center of the screen against a black background, and the search array consisted of the fixation cross surrounded by six colored circles (each  $2.3^\circ \times 2.3^\circ$ ) placed at equal intervals on an imaginary circle with a radius of  $5^\circ$ . The target was defined as the red or green circle, exactly one of which was presented on each trial; the color of each nontarget circle was drawn from the set {blue, cyan, pink, orange, yellow, white}



**Figure 1.** Sequence and time course of trial events. **(A)** Training phase. Participants reported the orientation of the bar within the color-defined (red or green) target with a keypress. Independent of whether the response was correct or not, the target display was followed by feedback consisting of the presentation of a face. One target color was associated with a greater probability of a happy face vs a neutral face, while for the other target color this mapping was reversed. Note that in the actual experiment, the faces used were images of real people taken from the AR face database. **(B)** Test phase. Participants searched for a shape singleton target (diamond among circles or circle among diamonds) and reported the orientation of the bar within the target as vertical or horizontal. On a subset of trials, one of the nontargets was rendered in the color of a former target from the training phase.

without replacement. Inside the target circle, a white bar was oriented either vertically or horizontally, and inside each of the nontargets, a white bar was tilted at 45° to the left or to the right (randomly determined for each nontarget). The feedback display consisted of a picture of a face exhibiting either a smile or a neutral expression. The faces were those of 20 male and 20 female models taken from the AR face database (Martinez & Benavente, 1998).

### *Design*

One of the two color targets (counterbalanced across participants) was followed by a face exhibiting a smile on 80% of trials and a face exhibiting a neutral expression on the remaining 20% (high-reward target); for the other color target, these percentages were reversed (low-reward target). Each model face was presented a total of three times in each of the two expressions for each participant, with each instance paired pseudorandomly with a color target based on the proportion of smiling versus neutral expressions assigned to each color. Each color target appeared in each of the six possible stimulus locations equally often, and trials were presented in a random order.

### *Procedure*

The training phase consisted of 240 trials, which were preceded by 40 practice trials. Each trial began with the presentation of the fixation display for a randomly varying interval of 400, 500, or 600 ms. The search array then appeared and remained on screen until a response was made or 1000 ms had elapsed, after which the trial timed out. The search array was followed by a blank screen for 1000 ms, the social feedback display for 1500 ms, and a blank 1000-ms inter-trial interval (ITI).

Participants made a forced-choice target identification by pressing the “z” and the “m” keys for the vertically- and horizontally-orientated bars within the targets, respectively. They were instructed to respond both quickly and accurately. The content of the social feedback following each search array was independent of the participant’s actual behavior; that is, it was not affected by the speed or accuracy of the response on that (or any) trial. Participants were only informed that the faces would “react to what happened on each trial.” Participants were not explicitly informed that these reactions were related to the color of the target, which could only be learned through experience in the task. If the trial timed out, the computer emitted a 500-ms 1000 Hz tone. A

mandatory 30-second break period was provided every 60 trials.

## **Test phase**

### *Stimuli*

Each trial consisted of a fixation display, a search array, and (in the event of an incorrect response) a feedback display (Figure 1B). The six shapes now consisted of either a diamond among circles or a circle among diamonds, and the target was defined as the unique shape. On a subset of the trials, one of the nontarget shapes was rendered in the color of a former target from the training phase (referred to as the *distractor*); the target was never red or green. The feedback display only informed participants if their prior response was incorrect.

### *Design*

Target identity, target location, distractor identity, and distractor location were fully crossed and counterbalanced, and trials were presented in a random order. Distractors were presented on 50% of the trials, half of which were high-value distractors and half of which were low-value distractors (high- and low-reward color from the training phase, respectively).

### *Procedure*

Participants were instructed to ignore the color of the shapes and to focus on identifying the unique shape both quickly and accurately, using the same orientation-to-response mapping. The test phase consisted of 240 trials, which were preceded by 32 practice (distractor absent) trials. In the event of an incorrect response, the search array was followed immediately by the word “Incorrect” centrally presented for 1000 ms (feedback was omitted following a correct response); no faces were shown during the test phase. Each trial ended with a 500-ms ITI. Trials timed out after 1500 ms. As in the training phase, if the trial timed out, the computer emitted a 500-ms 1000 Hz tone. A mandatory 30-second break period was provided every 60 trials.

## **Data analysis**

Only correct responses were included in all analyses of response time (RT), and RTs more than 2.5 SDs

(standard deviations) above or below the mean of their respective condition for each participant were trimmed.

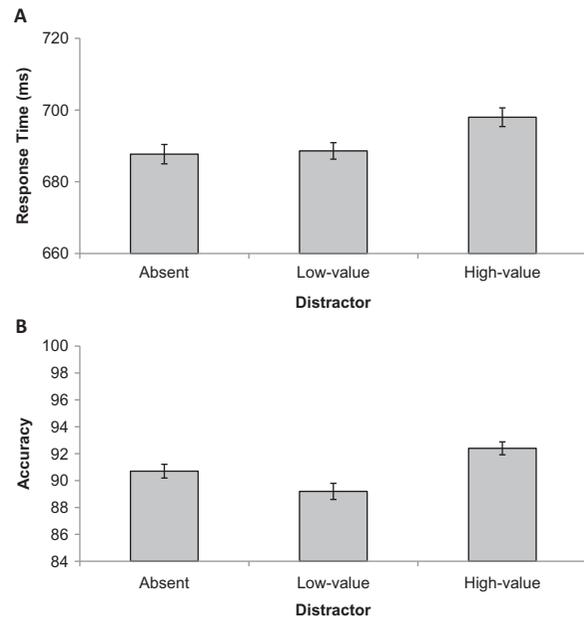
## RESULTS

### Training phase

Participants were neither significantly faster,  $t(25) = 0.40$ ,  $p = .690$ , nor more accurate,  $t(25) = 1.13$ ,  $p = .271$ , to report a high-reward target (mean RT = 607 ms, mean accuracy = 90.2%) than a low-reward target (mean RT = 610 ms, mean accuracy = 89.0%). The performance benefit associated with the high-reward target also did not differ between the first and second half of the training phase for either RT,  $t(25) = 0.18$ ,  $p = .856$ , or accuracy,  $t(25) = 1.76$ ,  $p = .090$  (first half: 4 ms, 0%; second half: 5 ms, 2.4%). This suggests that participants searched for each target color with roughly equal priority, as is commonly observed in this paradigm using monetary rewards (e.g., Anderson, Faulkner, Rilee, Yantis, & Marvel, 2013; Anderson, Laurent, & Yantis, 2011a; Anderson, Leal, Hall, Yassa, & Yantis, 2014; Roper, Vecera, & Vaidya, 2014). Of primary interest was how the experience of these stimulus–outcome associations would influence attention in the test phase, when the same color stimuli were presented as task-irrelevant distractors, thereby providing a sensitive measure of involuntary attentional bias.

### Test phase

A repeated-measures analysis of variance (ANOVA) on mean RT with distractor condition (absent, low-value, high-value) as a factor revealed a main effect,  $F(2, 50) = 3.35$ ,  $p = .043$ ,  $\eta_p^2 = .118$  (see Figure 2A). Participants were slower to report the target on high-value distractor trials compared to both low-value distractor,  $t(25) = 2.28$ ,  $p = .032$ ,  $d = 0.45$ , and distractor-absent trials,  $t(25) = 2.16$ ,  $p = .040$ ,  $d = 0.42$ ; the latter two conditions did not significantly differ,  $t(25) = 0.22$ ,  $p = .831$ . This decrement in RT on high-value distractor trials mirrors the pattern indicative of value-driven attentional capture (e.g., Anderson et al., 2011b), only in this case following social rather than monetary rewards. The difference between the high- and low-value distractor conditions can only be explained in terms of the probability of each color



**Figure 2.** Behavioral performance. Mean response time (A) and accuracy (B) by distractor condition in the test phase. Error bars reflect the within-subjects SEM.

being followed by a smile during training, as that is all that differed between them.

The ANOVA on accuracy also revealed a significant main effect of distractor condition,  $F(2, 50) = 6.28$ ,  $p = .004$ ,  $\eta_p^2 = .201$  (see Figure 2B). In prior studies of value-driven attentional capture, there has been either no differences in accuracy (e.g., Anderson et al., 2011a, 2011b) or accuracy was lower on high-value distractor trials (Anderson & Yantis, 2012; Laurent, Hall, Anderson, & Yantis, 2015), mirroring the decrement observed in RT. In the present study, in contrast, accuracy was significantly higher on high-value distractor trials compared to both low-value distractor,  $t(25) = 3.43$ ,  $p = .002$ ,  $d = 0.67$ , and distractor-absent trials,  $t(25) = 2.15$ ,  $p = .042$ ,  $d = 0.42$ ; the latter two conditions did not significantly differ,  $t(25) = -1.56$ ,  $p = .132$ . Possible interpretations of the observed differences in accuracy are addressed in the Discussion.

It is important to note that the slowing of RT observed on high-value distractor trials cannot be explained by a strategic choice to respond more conservatively (slower but more accurate) on those trials. Given the mixed-trial design, it was impossible to anticipate whether an upcoming trial would contain a high-value distractor. Therefore, any deliberate shift in the conservativeness of the response criterion on high-value distractor trials would imply that the

distractor was attended despite being task-irrelevant, which would support the central hypothesis. Furthermore, if the observed differences in RT and accuracy between high- and low-value distractor trials reflected only a shift in the speed–accuracy tradeoff function without any underlying mean differences, we would expect the two to be positively correlated across participants—that is, the slower the RT on high-value compared to low-value distractor trials, the larger the improvement in accuracy should be and vice versa. However, there was no hint of such a positive correlation in the data,  $r = -.100$ ,  $p = .627$ .

Comparing performance across the first and second halves of the test phase, the difference in RT between high- and low-value distractor trials showed no evidence of extinction during the timeframe tested, being numerically identical across the two halves,  $t(25) = -0.04$ ,  $p = .967$ , which is consistent with prior studies using monetary reward (e.g., Anderson et al., 2011b; Anderson & Yantis, 2012, 2013). In contrast, the difference in accuracy between these two conditions did show evidence of extinction, decreasing significantly from the first to the second half (5.5% vs 1.1%),  $t(25) = 2.15$ ,  $p = .041$ .

## DISCUSSION

Social feedback provides a teaching signal that can powerfully modulate behavior. The processing of social feedback conforms to basic reinforcement learning principles (Klucharev, Hytönen, Rijkema, Smidts, & Fernández, 2009) and promotes rapid learning (e.g., Goldstein & Schwade, 2008). Both social and monetary rewards are represented by overlapping neural populations (Izuma, Saito, & Sadato, 2008). In the present study, I examined whether social reward can influence the attentional priority of visual stimuli via simple association.

The present study provides evidence that social rewards bias attention toward stimuli that have been learned to predict those rewards. When arbitrary stimuli co-occur with positive social feedback, that feedback changes how the attention system prioritizes those stimuli. This effect of social reward mirrors the effects of monetary reward (e.g., Anderson, 2013) and food reward (Pool et al., 2014) on the attention system, demonstrating that the principle of value-driven attention extends to learning that is shaped by the quality of observed social responses.

In the present study, the presence of a high-value distractor was associated with improved accuracy in reporting the target. This finding was unexpected, and contrasts with the results from studies investigating

the effects of monetary reward on attention. In these prior studies, if there is a significant difference in accuracy tied to the high-value distractor, it is in the opposite direction, with performance in target detection being impaired by the presence of a high-value distractor (Anderson & Yantis, 2012; Laurent et al., 2015). The improved accuracy in the present study suggests that stimuli associated with positive social feedback elicit heightened motivation. By preferentially attending to stimuli associated with positive social feedback, organisms will be drawn toward opportunities to interact with their world in ways that can improve and maintain social standing. Once the distractor is selected, the processing of this stimulus associated with social reward might then trigger greater recruitment of goal-directed cognitive control mechanisms. Given that social reactions are often tied to the quality of our own behavior and to performance, such a modulation of motivational processes could be adaptive. Future research should further investigate this potential link between associative learning via social rewards and motivational processes.

The slowing of RT caused by the high-value distractor is consistent with involuntary attentional capture and cannot be explained by a strategic choice to respond more conservatively (slower but more accurate) on those trials. In the case of the latter, improvements in accuracy would have been correlated with slower RTs on high-value distractor trials across participants, but there was no hint of such a relationship in the data. The dissociation in the extinction rate between the slowing of RT and the increase in accuracy associated with the high-value distractor is also consistent with two distinct influences of reward learning on performance. Furthermore, for the distractor to elicit a more conservative strategy or any other change in motivated cognition, participants would need to represent the presence of the distractor, which would imply that the distractor was selectively attended despite being task-irrelevant and physically nonsalient.

The effect size for the attentional bias measured in the present study was smaller and less statistically robust than that measured in similar studies using this paradigm, particularly studies involving training with monetary reward (e.g., Anderson et al., 2011b; Anderson, Laurent, et al., 2014). Thus, it is possible that social reward is not as powerful a determinant of attentional priority as compared to the receipt (or promise) of tangible resources. However, social reward was manipulated using pictures of faces in the present study, and richer (e.g., with accompanying verbal feedback) or more naturalistic

social feedback might have stronger effects on the attention system. It would also be useful for future research to examine whether factors mediating the personal relevance of the social feedback, such as the relationship between the observer and the individual providing the feedback, influence how that feedback biases subsequent attention. There is evidence that certain colors, such as red, green, and pink, convey affective information (e.g., Elliot & Maier, 2007; Kaya & Epps, 2004) and can influence the processing of social stimuli (e.g., Elliot & Niesta, 2008; Gil & Le Bigot, 2014). Such colors, which were used to define the stimuli of interest in the present study, might be more readily associated with positive social feedback than other colors and features. Although the findings of the present study make it clear that positive social feedback can modulate attentional biases for an associated stimulus feature, it would be useful for future research to explore a broader range of stimuli when examining the influence of social feedback on attention.

The present study provides the first evidence that social feedback can shape attentional biases through associative learning. Here, positive social feedback was used to modulate involuntary attentional processing. It would be interesting to examine whether negative social feedback has a similar effect on attention. Stimuli associated with aversive outcomes such as monetary loss and electric shock (Schmidt, Belopolsky, & Theeuwes, 2015; Wang, Yu, & Zhou, 2013) are known to preferentially capture attention, suggesting that negative social expressions such as anger might produce a pattern of performance similar to that observed in the present study.

Future research should also investigate the neural mechanisms by which social reward modulates attentional priority. Studies involving tangible extrinsic rewards have implicated the visual corticostriatal loop in the value-driven orienting of attention (Anderson, Laurent, et al., 2014; Hikosaka, Yamamoto, Yasuda, & Kim, 2013). The approach used in the present study would permit an opportunity to investigate whether different forms of reward influence attention via the same brain systems, consistent with a domain-general value signal to which social feedback contributes (Izuma et al., 2008). Given the improved accuracy associated with the presence of a high-value distractor, another interesting possibility is that stimuli associated with positive social feedback activate the brain systems by which reward prospect enhances goal-directed cognition (e.g., Pessoa, 2015; Pessoa & Engelmann, 2010), reflecting synergy between voluntary and automatic modes of value-modulated information

processing. The dissociation in the extinction rate between these two influences of reward learning on performance suggests two distinct underlying mechanisms.

The magnitude of attentional bias arising from learned associations between visual stimuli and monetary reward has been linked to psychopathology. Specifically, hypersensitive value-driven attentional capture has been associated with addiction (Anderson et al., 2013) and hyposensitive value-driven attentional capture with depression (Anderson, Leal, et al., 2014). Abnormal sensitivity to attentional biases driven by social feedback might similarly be associated with psychopathologies that have a strong social component, such as severe social anxiety (hypersensitivity) and autism spectrum disorders (hyposensitivity).

Original manuscript received 29 November 2014

Revised manuscript received 27 April 2015

First published online 28 May 2015

## REFERENCES

- Anderson, B. A. (2013). A value-driven mechanism of attentional selection. *Journal of Vision*, 13(3), 7. doi:10.1167/13.3.7
- Anderson, B. A., Faulkner, M. L., Rilee, J. J., Yantis, S., & Marvel, C. L. (2013). Attentional bias for non-drug reward is magnified in addiction. *Experimental and Clinical Psychopharmacology*, 21, 499–506. doi:10.1037/a0034575
- Anderson, B. A., Laurent, P. A., & Yantis, S. (2011a). Learned value magnifies salience-based attentional capture. *PLoS ONE*, 6(11), e27926.
- Anderson, B. A., Laurent, P. A., & Yantis, S. (2011b). Value-driven attentional capture. *Proceedings of the National Academy of Sciences, USA*, 108, 10367–10371. doi: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. doi:10.1016/j.brainres.2014.08.062
- Anderson, B. A., Leal, S. L., Hall, M. G., Yassa, M. A., & Yantis, S. (2014). The attribution of value-based attentional priority in individuals with depressive symptoms. *Cognitive, Affective, & Behavioral Neuroscience*, 14, 1221–1227. doi:10.3758/s13415-014-0301-z
- Anderson, B. A., & Yantis, S. (2012). Value-driven attentional and oculomotor capture during goal-directed, unconstrained viewing. *Attention, Perception, & Psychophysics*, 74, 1644–1653. doi:10.3758/s13414-012-0348-2
- Anderson, B. A., & Yantis, S. (2013). Persistence of value-driven attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*, 39, 6–9.

- Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision*, 10, 433–436. doi:10.1163/156856897X00357
- Della Libera, C., & Chelazzi, L. (2006). Visual selective attention and the effects of monetary rewards. *Psychological Science*, 17, 222–227. doi:10.1111/j.1467-9280.2006.01689.x
- Della Libera, C., & Chelazzi, L. (2009). Learning to attend and to ignore is a matter of gains and losses. *Psychological Science*, 20, 778–784. doi:10.1111/psci.2009.20.issue-6
- Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, 18, 193–222. doi:10.1146/annurev.ne.18.030195.001205
- Elliot, A. J., & Maier, M. (2007). Color and psychological functioning. *Current Directions in Psychological Science*, 16, 250–254. doi:10.1111/cdir.2007.16.issue-5
- Elliot, A. J., & Niesta, D. (2008). Romantic red: Red enhances men's attraction to women. *Journal of Personality and Social Psychology*, 95, 1150–1164. doi:10.1037/0022-3514.95.5.1150
- Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, 18, 1030–1044.
- Frischen, A., Bayliss, A., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, 133, 694–724. doi:10.1037/0033-2909.133.4.694
- Gil, S., & Le Bigot, L. (2014). Seeing life through positive-tinted glasses: Color-meaning associations. *PLoS ONE*, 9(8), e104291.
- Goldstein, M. H., & Schwade, J. A. (2008). Social feedback to infants babbling facilitates rapid phonological learning. *Psychological Science*, 19, 515–523. doi:10.1111/j.1467-9280.2008.02117.x
- Harris, C. R., Pashler, H. E., & Coburn, P. (2004). Moray revisited: High-priority affective stimuli and visual search. *The Quarterly Journal of Experimental Psychology Section A*, 57, 1–31. doi:10.1080/02724980343000107
- Hickey, C., Chelazzi, L., & Theeuwes, J. (2010). Reward changes salience in human vision via the anterior cingulate. *Journal of Neuroscience*, 30, 11096–11103. doi:10.1523/JNEUROSCI.1026-10.2010
- Hikosaka, O., Yamamoto, S., Yasuda, M., & Kim, H. F. (2013). Why skill matters. *Trends in Cognitive Sciences*, 17, 434–441. doi:10.1016/j.tics.2013.07.001
- Izuma, K., Saito, D. N., & Sadato, N. (2008). Processing of social and monetary rewards in the human striatum. *Neuron*, 58, 284–294. doi:10.1016/j.neuron.2008.03.020
- Jiao, J., Du, F., He, X., & Zhang, K. (in press). Social comparison modulates reward-driven attentional capture. *Psychonomic Bulletin and Review*.
- Kaya, N., & Epps, H. H. (2004). Relationship between color and emotion: A study of college students. *College Student Journal*, 38, 396–405.
- Kiss, M., Driver, J., & Eimer, M. (2009). Reward priority of visual target singletons modulates event-related potential signatures of attentional selection. *Psychological Science*, 20, 245–251. doi:10.1111/psci.2009.20.issue-2
- Klucharev, V., Hytönen, K., Rijpkema, M., Smidts, A., & Fernández, G. (2009). Reinforcement learning signal predicts social conformity. *Neuron*, 61, 140–151. doi:10.1016/j.neuron.2008.11.027
- Laurent, P. A., Hall, M. G., Anderson, B. A., & Yantis, S. (2015). Valuable orientations capture attention. *Visual Cognition*, 23, 133–146.
- Martinez, A. M., & Benavente, R. (1998). *The AR face database (CVC Technical Report #24)*.
- Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology*, 11, 56–60. doi:10.1080/17470215908416289
- Pessoa, L. (2015). Multiple influences of reward on perception and attention. *Visual Cognition*, 23, 272–290.
- Pessoa, L., & Engelmann, J. B. (2010). Embedding reward signals into perception and cognition. *Frontiers in Neuroscience*, 4, 17. doi:10.3389/fnins.2010.00017
- 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. doi:10.1016/j.cognition.2013.12.002
- Raymond, J. E., & O'Brien, J. L. (2009). Selective visual attention and motivation: The consequences of value learning in an attentional blink task. *Psychological Science*, 20, 981–988. doi:10.1111/psci.2009.20.issue-8
- Roper, Z. J. J., Vecera, S. P., & Vaidya, J. G. (2014). Value-driven attentional capture in adolescence. *Psychological Science*, 25, 1987–1993. doi:10.1177/0956797614545654
- Schmidt, L. J., Belopolsky, A. V., & Theeuwes, J. (2015). Attentional capture by signals of threat. *Cognition and Emotion*, 29, 687–694.
- Sui, J., Chechlacz, M., & Humphreys, G. W. (2012). Dividing the self: Distinct neural substrates of task-based and automatic self-prioritization after brain damage. *Cognition*, 122, 150–162. doi:10.1016/j.cognition.2011.10.008
- Sui, J., He, X., & Humphreys, G. W. (2012). Perceptual effects of social salience: Evidence from self-prioritization effects on perceptual matching. *Journal of Experimental Psychology: Human Perception and Performance*, 38, 1105–1117.
- Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception and Psychophysics*, 51, 599–606.
- Wang, L., Yu, H., & Zhou, X. (2013). Interaction between value and perceptual salience in value-driven attentional capture. *Journal of Vision*, 13(3), 5.
- Wolfe, J. M., Cave, K. R., & Franzel, S. L. (1989). Guided search: An alternative to the feature integration model for visual search. *Journal of Experimental Psychology: Human Perception and Performance*, 15, 419–433.
- Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance*, 10, 350–374.