REWARD MODULATES VISUAL PERCEPTION INDEPENDENTLY OF CONSCIOUSNESS

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BACKGROUND

Rewards influence behaviour: we might order cake rather than salad because it tastes nicer, or swipe right on a dating app for an attractive individual. Rewards also influence cognition prior to overt choice: e.g., reward cues receive attentional priority for further cognitive processing (Anderson 2016; Le Pelley et al 2016).

Here, we investigate whether the effect of reward can be observed even earlier in the stream of visual information processing, through modulating early perceptual processes.

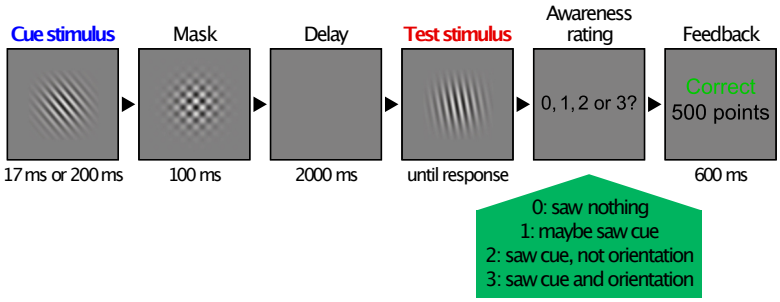
The possibility that reward exerts an early influence on visual perception is suggested by studies showing that reward modulates neural gain in early visual areas (e.g., V1) that encode low-level features (Serences 2008; Shuler & Bear 2006; Stănişor et al 2013).

This raises the intriguing possibility that perceptual encoding of visual stimuli might be modulated by their reward status: establishing a stimulus as a signal of high reward might enhance the speed and accuracy of encoding that stimulus relative to a signal of low reward.

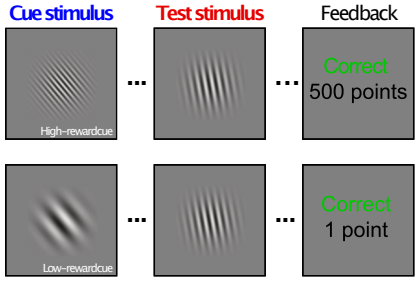
THE TASK

- **Testing perception of a brief, masked grating**
- **Cue stimulus** presented for either
  - 17ms **(short cue condition)** or
  - 200ms **(long cue condition)**

  and immediately masked
- **Test stimulus** appears after delay
- **Orientation response:** Has orientation rotated clockwise/counterclockwise relative to cue?
- **Awarenesstest:** Were you aware of seeing the cue stimulus?

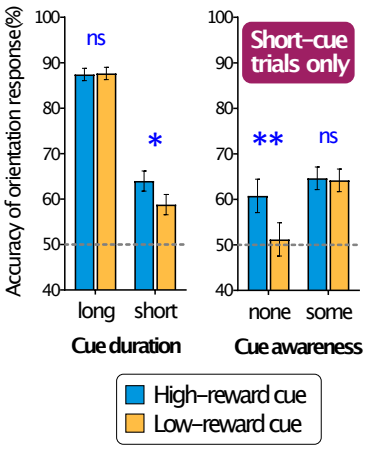


EXPERIMENT 1 (n = 30)



- Spatial frequency (SF) of **cue stimulus** signals whether correct orientation response will receive high reward or low reward
- **Test stimulus** has constant, medium SF on every trial

Note: The relationship between SF and reward was counterbalanced across participants
For half of participants: high SF → high reward and low SF → low reward
For half of participants: low SF → high reward and high SF → low reward



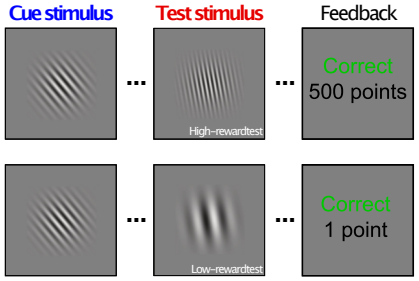
Left panel: For long-cue (200ms) condition, orientation-response accuracy is high regardless of reward status of cue ($p = .87$). For short-cue (17ms) condition, accuracy is higher when cue signals high reward ($p = .012$).

Right panel: Accuracy on short cue trials in which participants reported no awareness of the cue (rating = 0) versus some awareness (rating = 1, 2 or 3). Accuracy was greater for high-reward than low-reward cues when participants were unaware of the cue ($p = .007$).

- Reward-related benefit under the most challenging conditions: when cue was very brief, and participants reported no awareness of the cue.
- Enhanced **perceptual encoding** of high-reward vs low-reward cues?
- Or similar encoding for both cue types, but greater **motivation to retrieve** info about the high-reward cue when presented with the test stimulus, since a larger reward is available for a correct response?

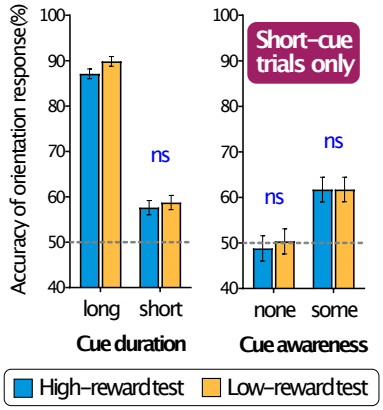
Experiment 2 probed this idea, by testing for an influence of reward on motivated retrieval of cue information.

EXPERIMENT 2 (n = 29)



- **Cue stimulus** has constant, medium SF on every trial
- SF of **test stimulus** signals whether correct orientation response will receive high reward or low reward

- If the reward benefit for the short-cue condition seen in Exp 1 reflected greater **motivation to retrieve** the cue when high reward was at stake, we should see a similar effect in Exp 2. Or a larger effect, since reward info was more visible in Exp 2: the test stimulus (which signalled reward) was presented until response.
- If results of Exp 1 reflected effect of reward on **encoding** of cue stimulus, we should see no corresponding effect in Exp 2 since here encoding of the cue stimulus occurred before any reward info was provided.



Left panel: In contrast to Exp 1, there was no effect of reward on accuracy in the short-cue condition ($p = .77$, $BF_{01} = 7.70$).

Right panel: Accuracy did not differ for high- vs low-reward short-cue trials, regardless of whether participants reported awareness or not ($ps > .50$, $BF_{01} > 7.50$). Accuracy was not above chance when there was no awareness ($ps > .45$).

Exp 1 found an effect of reward on accuracy when **cue stimulus** signals reward, i.e. when reward info present at time of **encoding**.

Exp 2 found NO effect of reward when **test stimulus** signals reward, i.e. when reward info present at time of **retrieval**.

CONCLUSIONS

Together, these findings suggest reward influences perceptual encoding: the visual system becomes more sharply 'tuned' to high-reward than low-reward information, so high-reward stimuli undergo rapid neural encoding with higher fidelity.

Effect of reward on perception operates very rapidly, and prior to consciousness. In the long-cue condition of Exp 1, there was plenty of time to encode the cue and so reward modulation of encoding would have little effect.

Our findings indicate that early perceptual processes are malleable, and can be shaped by knowledge of reward. These results highlight the cognitive penetrability of perception by showing that beliefs and desires implicated in reward knowledge can influence early, rapid & unconscious aspects of perception.

REFERENCES **Anderson(2016).** The attention habit: How reward learning shapes attentional selection. AnnNY AcadSci, 1369, 24–39. **Le Pelley, Mitchell, Beesley, George&Will (2016).** Attention and associative learning in humans: An integrative review. Psychol Bull, 142, 1111–1140. **Serences (2008).** Value-based modulations in human visual cortex. Neuron, 60, 1169–1181. **Shuler &Bear (2006).** Reward timing in the primary visual cortex. Science, 311, 1606–1609. **Stănişor, van der Togt, Pennartz & Roelfsema(2013).** A unified selection signal for attention and reward in primary visual cortex. PNAS, 110, 9136–9141.