The effects of attention upon contrast discrimination

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Introduction

Several studies have shown that stimuli appearing in attended locations evoke enhanced behavioral and neural responses, as if attention increased their effective contrast. However, it is not clear whether attention also alters the perceptual quality of stimuli—the way they look. In this study, the perceptual effects of attention were probed through contrast discrimination experiments in which observers judged the relative brightness of two stimuli, to one of which attention had been oriented.

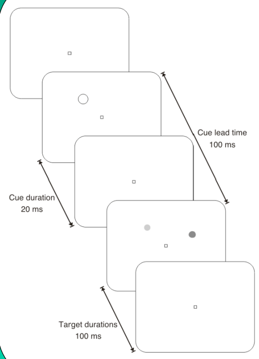
Methods

Each of ten observers participated in four separate sessions. Two types of attentional cues were used, invoking different pathways and mechanisms, and the observers performed two separate types of judgments for each cue type, to account for response biases. The cued targets were presented at seven different contrast levels, and at each level were compared to uncued targets presented at multiple contrasts. All combinations of contrast levels were randomly interleaved. Since perceived contrast varies with eccentricity, the two targets were presented at unpredictable locations within an annulus centered at 7 deg.from fixation.

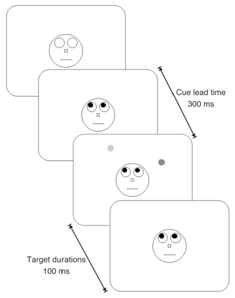
Attentional cues: *Exogenous cues* capture attention through "bottom-up" pathways, and in this study were brief rings appearing at one of the target locations. *Gaze-reflexive cues* are less directly stimulus-driven, orienting attention to one target through the gaze direction of a cartoon face. Both types of cues have been shown to automatically capture attention.

Perceptual judgments: In the *comparative judgment*, observers indicated which of the two targets appeared brighter. In the *equality judgment*, the observers indicated whether the two targets were of equal brightness. The equality judgment is less susceptible to response biases.

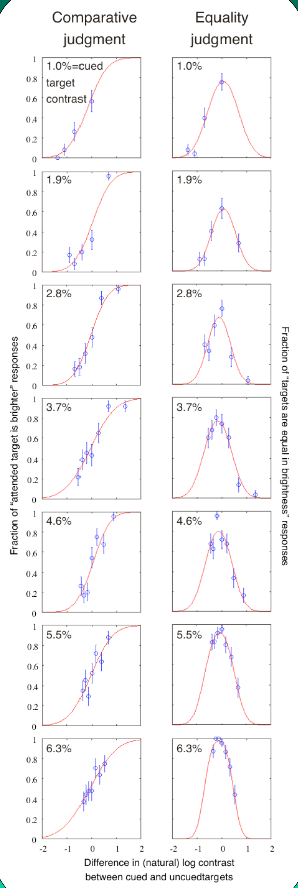
Exogenous Cue



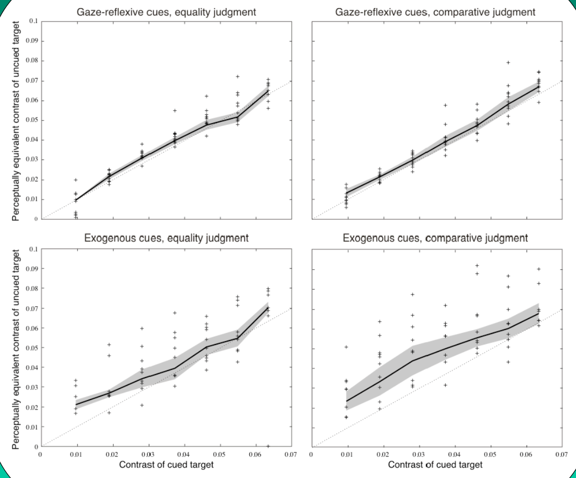
Gaze-reflexive cue



Results

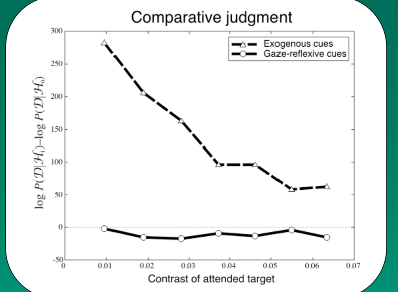


A response distribution is formed from the responses to the various contrast levels of the uncued targets for each contrast level of the cued target tested. To determine the center of each distribution, the data was fit to a cumulative normal function □(□+□logC,□) for the comparative judgment data, and □(□+□+□logC,□)–□(□–□+□logC,□) for the equality judgment data, where □logC is difference in log contrast between the cued and uncued targets, and □ is the center of the distribution. The deviation of □ from zero indicates the strength of attentional effect upon the perceived contrast. To the left are data from a typical observer for the gaze-reflexive cues.

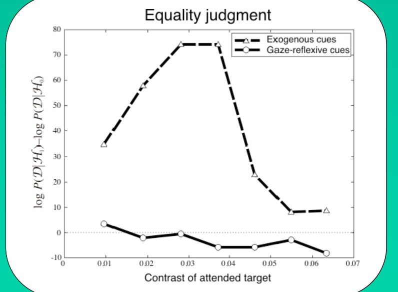


Above are the results from all ten observers for each of the four sessions. Each '+' indicates □, the center of the response distribution, for a single observer. The solid black line indicates the mean across all observers, weighted by the estimation variance of □ for each observer. The shaded regions indicate the 95% confidence range of the weighted mean. The dotted line indicates identity, along which the perceived contrast of the cued target equals that of the uncued target. Deviations from this line indicate attentional effects.

Analysis



Two hypotheses were compared. The null hypothesis $\mathcal{H}_0$ assumes □=0, that attention does not affect perceived contrast. The alternative hypothesis $\mathcal{H}_1$ posits an attentional effect, □≠0. These hypotheses were evaluated through Bayesian inference (MacKay, *Neural Computation* **4:**415–447, 1992) by directly evaluating the evidence, $P(\mathcal{D}|\mathcal{H}) = \int P(\mathcal{D}|\mathbf{w},\mathcal{H})\, P(\mathbf{w}|\mathcal{H})d\mathbf{w}$, where $\mathcal{D}$ is the experimental data and **w** is the vector of parameters for the response models fit to the data. The ratios of the evidence for each hypothesis are shown above and below for each judgment and cue type. For exogenous cues, an attentional factor is necessary to explain the results from both the comparative and equality judgments, while none is generally required to explain the gaze-reflexive results.



Conclusions

Only the bottom-up exogenous attentional cues alter the perception of contrast. It is possible that this is a result of sensory facilitation at the target location. Although more cognitive types of attentional cues can affect neural and behavioral responses, mimicking a contrast boost, perhaps the brain compensates for their effects such that contrast perception is not disturbed.