

Attention-Dependent Representation of a Size Illusion in Human V1

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change (increase or decrease) of the fixation point as soon as possible. The luminance changes occurred randomly with

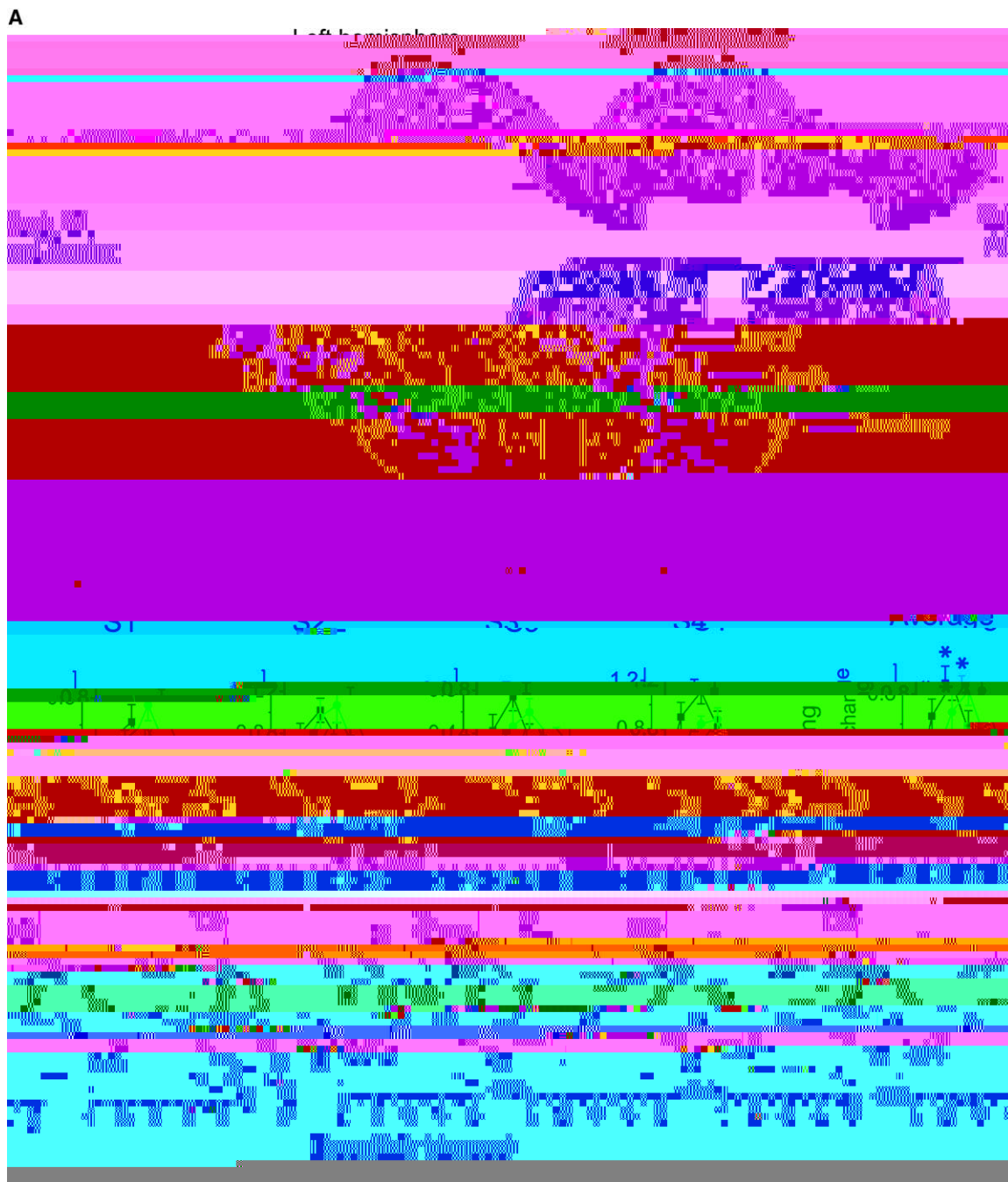


Figure 3. fMRI Results

(A) Cortical activation maps induced by the front and back flickering rings. The back view of the inflated left and right hemispheres from S1 is shown in the upper part. The regions in the yellow boxes are amplified and shown in the lower part. V1 is defined by retinotopic mapping, and its boundaries are indicated by the white dashed lines. The green and red regions were activated by the front and back flickering rings, respectively (for both, $p < 0.01$, Bonferroni corrected). The overlap between these two regions is shown in dark yellow. Compared with the red region, the green region shifts toward the foveal representation of V1.

(B) Peak fMRI signals from the six ROIs in V1 were plotted as a function of eccentricity for four individual subjects and their average. The spatial distribution of V1 activation induced by the back ring (perceptually larger) was shifted toward a more eccentric representation of the visual field in V1, whereas that induced by the front ring (perceptually smaller) was shifted toward the foveal representation. This resulted in peaks at cortical locations representing different eccentricities. The shift was significantly larger in the attend-to-ring experiment than the attend-to-fixation experiment. * $p < 0.05$. Error bars represent SEM.

feedback from higher-level visual areas that process the 3D scene. However, the evidence that the attention manipulation reduces processing of 3D scene cues in higher visual areas is only a conjecture based on the results of previously reported

attention experiments. Unfortunately, assessing the response in high-level visual areas was precluded by our high-resolution scanning sequence, which did not reliably cover the visual areas mostly likely involved in processing the 3D scene—the

lateral occipital complex (LOC) and the parahippocampal place area (PPA). To address this issue directly, we used standard imaging resolution and a simple 14 s block design to collect fMRI data from two subjects while they alternated between the two attention tasks. There was a large effect observed in the two ROIs. Specifically, activities in the LOC and PPA were significantly reduced during the attend-to-fixation task relative to the attend-to-ring task (see [Supplemental Data 2](#)), suggesting that the attention manipulation is effective at reducing activity in—and feedback from—these higher-level visual areas.

Our results in the main experiment demonstrate that removing attention from the 3D scene reduces the cortical separation of the responses to the front and back rings—a result we argue is consistent with the reduction of feedback from higher visual areas that process the 3D depth cues. However, there is a separate question about the possible role of spatial attention. Specifically, could any difference in the allocation of spatial attention be driving the basic effect of a difference between the front and back ring? For example, in the attend-to-ring condition, perhaps subjects attended more to the outer edge of the back ring and the inner edge of the front ring, thereby leading to the differences in the spatial distribution of V1 activity. Although there is no a priori reason to expect such differences in attention strategies to the front and back ring, ruling out this possibility is important. We performed a behavioral experiment that required subjects to simultaneously perform the flickering-pause detection task while also detecting a small target that could appear on either the inner or the outer edge of the ring. The target-detection performance was identical for the front and back rings at the inner and outer edges, suggesting that there are no differences in the allocation of spatial attention (see [Supplemental Data 3](#)).

Finally, to demonstrate that effects we observed in the main experiment were due to the 3D context, rather than to some other factors (e.g., different eye positions for the front and back rings), we performed a control experiment with S1 and S2 from the main experiment. The stimuli and task were the same as the attend-to-ring experiment, but the 3D background was replaced with a uniform gray background. No perceptual differences were observed between the two rings, and no

shifts of the spatial distributions of V1 activation were found (see [Supplemental Data 4](#)).

Discussion

We have demonstrated that perceived eccentricity differences are reflected by shifts in the distribution of activity across the surface of V1. The activation in response to the perceptually larger ring occurred in a more eccentric position in V1 compared to the perceptually smaller ring. We believe that it is extremely unlikely that the shifts in cortical location can be explained by local interactions between the front and back rings and the 3D scene (e.g., local contrast) because the local interaction would have increased or decreased the overall magnitude of neural activity, rather than induced the shifts.

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In fact, our results clearly show that the primary determinant of the spatial distribution of activity in V1 is the retinotopic position of the stimulus. But our results also show that this spatial pattern can be significantly modified by 3D context and is consistent with the perceptual appearance of the stimulus. Given the dynamic nature of the remapping and the fact that the 3D cues are most likely processed in higher visual areas, we suggest that V1 activity is being modified by cortical feedback. The specific neural mechanisms that support these dynamic changes in V1 maps, along with their degree of flexibility, are