Human brain areas involved in perception of symmetrical and asymmetrical optic flow speeds across visual fields: An fMRI study

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Introduction

Locomotion of an observer in an environment is accompanied by optic flow. Optic flow pattern can be used to monitor walking speed and heading direction [1]. Although studies have implicated that the dorsal part of the medial superior temporal area (MSTd) plays an important role in the processing of optic flow stimuli (such as rotation, expansion, and contraction) [2], which brain regions in human beings are involved in the perception of change in optic flow speeds remain unknown. Additionally, asymmetric optic flow speeds across two visual fields have been reported to induce a modulation in the perception of heading direction [3]. However, the brain regions that respond to asymmetric optic flow speeds have not been reported. Accordingly, we here employ fMRI to investigate the neural correlates of the perception of symmetrical and asymmetrical changes in optic flow speeds. The aims of the study were to discover (1) brain regions involved in perception of changes in optic flow speeds; and (2) whether asymmetrical changes in optic flow speeds resulted in differential brain activity compared with symmetrical changes.

Methods

Functional MRI data were acquired from one healthy, right-handed subject with normal vision, at a 3 Tesla GE system. A simulated hallway composed of two sidewalls of white dots on a black background (Figure 1) was presented to the subject through a pair of goggles. The white dots were moving toward the subject at controlled speeds to create either symmetrical or asymmetrical optic flow stimulation across both visual fields. As shown in Figure 2, the fMRI paradigm consisted of eight 20-second constant-speed blocks, interleaved with eight 20-second alternating-speed blocks (5 min and 20 sec for each scan). In constant-speed blocks, the optic flow speed was 1 m/sec. In alternating-speed blocks, the optic flow speed alternated between 1 m/sec and 5 m/sec, every 2 seconds. In scan 1, alternating optic flow speeds were presented in both visual fields (BVF), scan 2 in the right visual field (RVF) only, and scan 3 in the left visual field (LVF) only. Subjects were instructed to look at the center of the end of the simulated hallway throughout the experimental session.

Figure 1.

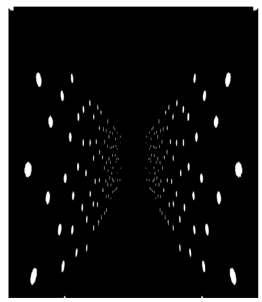
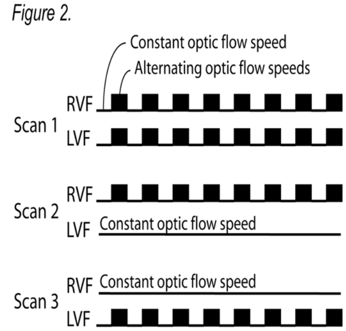


Figure 2.



Dynamic images were acquired using single-shot gradient-echo EPI with the following scan parameters: TR 2 sec, TE 35 msec, FOV 24 cm x 24 cm, matrix size 64 x 64, echo spacing time 0.592 msec, and axial-plane slice thickness 5 mm. The acquired data were processed with SPM99 software (Wellcome Department of Cognitive Neurology, London, UK). Standard image realignment, normalization, and smoothing were performed. The pre-processed images were then spatially normalized to an EPI template on the MNI305 stereotactic space. Voxels were identified as significant only if they passed a height threshold of T-score = 5.80, $p<0.001$ (corrected for multiple comparisons) and belonged to a cluster of at least 20 activated voxels.

Results

The brain regions activated during the alternating flow speeds (compared to the constant flow speed) in three different scans were summarized in Table. As shown in Figure 3a, the middle occipital gyri were activated bilaterally during symmetrical changes in optic flow speed. However, while the alternating optic flow speeds were presented in unilateral visual field, only contralateral middle occipital gyrus was activated (see Figure 3b and 3c). The contralateral activations were also observed in the postcentral gyri (see Table). Additionally, compared to the condition of symmetrical presentation, some bilateral premotor regions (such as superior, middle, and inferior frontal gyri) were significantly activated during the conditions of asymmetrical presentation (not shown in Table).

Figure 3.
(a) Speed changes in BVFs (b) Speed changes in RVF (c) Speed changes in LVF

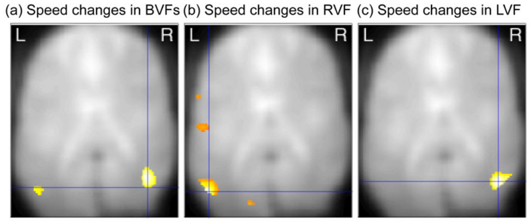


Table. Significantly activated regions (Presented in MNI Coordinates) associated with the perception of changes in optic flow speeds

Condition of presentation	Region	x	y	z	T-score
Bilateral visual fields	Right middle occipital gyrus	48	-72	6	9.05
	Left middle occipital gyrus	-56	-86	4	6.41
Right visual field	Left middle occipital gyrus	-56	-86	4	12.59
	Left postcentral gyrus	-62	-24	16	9.82
Left visual field	Right middle occipital gyrus	52	-76	4	9.29
	Right postcentral gyrus	30	-42	60	7.98

Discussion

Our study shows a distinct neural representation in bilateral middle occipital gyri (Brodmann's areas 18, 19) during perception of changes in optic flow speed across both visual fields. Furthermore, while the changes in optic flow speeds were presented in unilateral visual field, significant brain activity was only observed in the contralateral middle occipital gyrus. The results not only suggest that the middle occipital gyrus has a role in the perception of change in optic flow speeds, but also imply that information regarding the changes in flow speed may be processed contralaterally. The area MSTd was not specifically activated by the changes in flow speeds may indicate that both constant and alternating flow speeds resulted in similar degree of processing in overall optic flow information. Additionally, the increased activations in contralateral postcentral gyrus and bilateral superior, middle, and inferior frontal gyri were observed during asymmetrical presentation of changes in optic flow speed compared to the symmetrical manipulation. The findings may reflect a linking between the perception of asymmetric optic flow speeds and motor plans for heading direction.

References

[1]. Gibson, J. J. (1958). British Journal of Psychology, 49:182-194.
[2]. Morrone et al. (2000). Nature Neuroscience, 3: 1322-1328.
[3]. Dunchon et al. (2002). Psychological Science, 13: 272-278.