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Ocular Dominance and Fmri Activation in Response to Various Stimuli

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ABSTRACT

The aim of the study was to determine whether functional magnetic resonance imaging (FMRI) activation in response to various types of stimulation is dependent on ocular dominance. Our sample included 20 eyes of 10 healthy subjects (8 female with the mean age of 50.25 and 2 male with the mean age of 59). None of the subjects had ocular or neurological diseases. All subjects were tested for sighting and sensory ocular dominance. All the control subjects underwent a functional magnetic resonance imaging examination with the stimulation of both eyes together and each eye separately using a black-and-white checkerboards with two different sizes - 25.8x16.2 (larger field-LF) and 2x2 (small field-SF). All subjects showed different interocular FMRI activity. Larger differences were observed during small field activation. Sighting and sensory eye dominance did not correlate with the activity FMRI. We did not even observe hemispheric laterality after the separate stimulation of the dominant eye when using a larger field or small field activation.

Introduction

In our recent work we examined possible dependencies between ocular dominance and functional magnetic resonance imaging (FMRI) activity. But, unlike other authors, we have not demonstrated any dependence. In this study, we tried to determine whether the dependence could not be demonstrated using a small field stimulation. We therefore compared the results from both FMRI examinations. In addition, we examined lateralization after the separate stimulation of each eye with the stimulation field of two different sizes.

Material and Methods

Our sample included 20 eyes of 10 healthy subjects (8 female with the mean age of 50.25 and 2 male with the mean age of 59). The visual acuity (determined on ETDRS charts) of all subjects was 1.5 with correction where needed (**Table 1**). All subjects were right-handed and had no ocular or neurological diseases. All subjects were tested for sighting ocular dominance (hole in hand and pointing-a-finger test) and sensory ocular dominance (Worth's lights with red-green glasses and fogging test-blurred test)[1]. Table 2 provides a summary of the examinations performed.

All subjects were monitored for FMRI activity and hemispheric laterality after stimulation of each eye separately.

The study protocol was approved by the local Ethics Committee and the study was performed in accordance with Good Clinical practice and the Declaration of Helsinki.

Functional MRI

Functional MRI examinations were carried out on the Philips Achieva 3T TX MR system(Philips Healthcare, Eidhoven, Netherlands) operating with a magnetic field strength of 3 Tesla using the BOLD method. A standard 32-channel SENSE head RF coil was used forscanning. For measuring the FMRI with the blood oxygenation level dependent (BOLD) technique, the gradient-echo EPI sequencewas used with the following parameters: TE = 30 ms, TR = 3 s, flip angle of 90 °. Themeasured volume contained 39 continuous 2mm-thick slices. The voxel size measured was 2x 2 x 2 mm (FOV = 208 x 208 mm, matrix 104 x 104, SENSE factor 1.8).

Optical stimulation was provided by a black/white checkerboard alternated with its negative image, with a frequency of 2 Hz. The size of the black and white checkerboard was 25.8x16.2 degrees (larger field-LF) and 2x2 degrees (small field-SF). The measurements consisted of a sequence of five 30-second active phaseperiods and five resting periods of the same length (10 dynamic scans). During the resting phase of each FMRI scan, a static crosshair, situated in the center of the visible field, was projected. In total, every measurement included 100 dynamics and took 5 minutes.

The obtained data was processed using SPM8 software and general linear model (GLM).

During the pre-process, the data was motion corrected (realignment) and corrected for time shifts of individual slices (slice timing) and then smoothed with a Gaussian filter with FWHM 6 x 6 x 6 mm and finally standardized into the MNI_152 space. For statistics on the level of individual subjects, the GLM with canonical HRF (hemodynamic response function) applied to the block scheme of stimulation, was used. Statistical maps were thresholded at p = 0.05 with FWE correction.

Lateralization index (LI) was calculated using LI-toolbox for SPM8 and the bootstrap thresholdingmethod[2]. As an inclusive mask, the occipital lobe was selected and all other parameters were used in default settings. For the final statistic, the weighted mean LI, as a result of the calculation, was utilized. A strong advantage of this approach is the independence of the subjective choice of the statistical threshold and also the ability to equalize differences in the strength of the BOLD effect in individual cases.

Results

Visual acuity (VA) in all examined subjects was 1.5. Table 1 summarizes the refraction of the examined eyes.

No.	RE	LE
1.	0	0
2.	0	0
3.	-0.75	-1.25
4.	-1.5	-1.5
5.	-0.5	-0.5
6.	-3.75	-3.75
7.	+2	+2
8.	+3.5	+3
9.	-0.5	-0.5
10.	-3.25	-2.75

Table 1: Refractive errors with achieved visual acuity of 1.5 after correction. RE- right eye, LE-left eye.

All subjects in our sample showed a sighting dominance of the right eye. Three subjects (2, 4, 5) had right eye sensory dominance; the sensory dominance could not be demonstrated in the seven subjects. FMRI activity after larger field stimulation of the right eye correlated with sensory dominance of the right eye in two out of three cases (4,5). Where sensory dominance could not be demonstrated, the FMRI activity was higher after stimulation of the right eye in five cases (6-10) and after stimulation of the left eye in two cases (1,3). FMRI activity after small field stimulation did not correlate with sensory dominance of the right eye in either case. Where sensory dominance could not be demonstrated, FMRI activity was higher after the stimulation ofthe right eye in four cases (3, 6 , 8, 9) and after stimulation of the left eye in three cases (1, 7, 10). FMRI activity [in voxels] after larger field stimulation showed values to the order of 1 000. Exact numbers are shown in our most recent work1. Because FMRI activity in voxels, after small field stimulation, approached 0, we chose a percentage ratio between the right and left eye for comparison. Higher valueswere assigned 100 %, lower values were then assigned corresponding percentage ratio. Table 2

Individual values for each hemisphere, when stimulating RE and LE, are shown in Table 2. Negative values indicate directional laterality of the right hemisphere, positive values indicate directional laterality of the left hemisphere.

FMRI hemispheric activity (laterality) after the stimulation of each eye is shown in Table 3.

No.	Sex/Age	dominance		fMRIlarger field (%)		fMRI small field (%)		weighted Mean LI LF		weighted Mean LI SF	
		sighting	sensory	RE	LE	RE	LE	RE	LE	RE	LE
1.	F/45	RE	RE/LE	83	100	87	100	-0,048	0,012	-0,330	-0,580
2.	F/48	RE	RE	72	100	34	100	-0,320	-0,090	-0,250	-0,300
3.	F/50	RE	RE/LE	56	100	100	53	-0,420	0,070	-0,610	-0,470
4.	F/50	RE	RE	100	99	89	100	0,280	0,085	0,430	0,054
5.	F/50	RE	RE	100	69	56	100	0,400	0,240	0,200	-0,310
6.	F/50	RE	RE/LE	100	64	100	12	0,064	-0,180	-0,300	-0,340
7.	F/60	RE	RE/LE	100	79	44	100	-0,059	-0,100	-0,640	-0,320
8.	F/65	RE	RE/LE	100	95	100	19	0,310	0,500	-0,150	0,180
9.	M/58	RE	RE/LE	100	83	100	62	0,200	0,100	-0,170	-0,310
10.	M/60	RE	RE/LE	100	64	29	100	-0,510	-0,270	-0,150	0,086

Table 2: Summary of performed examinations. RE/LE sensory dominance means that dominance has not been demonstrated. FMRI values in % are explained in the text.

	weighted Mean LI BF		weighted Mean LI SF	
No.	RE	LE	RE	LE
1	re/le	re/le	re	re
2	re	re	re	re
3	re	le	re	re
4	le	le	le	le
5	le	le	le	re
6	re/le	re	re	re
7	re/le	re	re	re
8	le	le	re	le
9	le	le	re	re
10	re	re	re	le

Table 3: Laterality dominance in this table was evaluated by means of thresholding the LI at a level of 0.07. LI lower than -0.07 is signed as re, LI higher than 0.07 means le and LI between -0.07 and 0.07 is related to the absence of dominance (re/le).

Discussion

The first records of FMRI and eye dominance were provided by Romboutset al.[3]. This study used the near-far alignment test for the examination of ocular dominance in 26 healthy subjects. Visual stimulation was done with goggles, with two LED matrices (red light, 8 Hz); each in front of one eye. In each subject, the left and right eye were stimulated separately and together, in a randomly alternating order. Authors found differences between activated areas when the left or the right eye was stimulated separately. Twenty-two subjects showed activation, of whom eight subjects had a dominant left eye and 14, a dominant right eye. In general, the size of the activated area was bigger upon stimulation of the dominant eye. The difference with the area upon stimulation of the non-dominant eye was statistically significant in the right eye dominant group. These results indicate that the dominant eye actually activated a larger area of the primary visual cortex than the non-dominant eye.

Our results confirm these findings. The only difference was in the methodology of ocular dominance assessment and also in the type of stimulation during the FMRI examination. Rombouts et al. compared sighting dominance (differs from sensory dominance) and used diffuse light for stimulation[3].

Mendola and Connerfound that a percent change in FMRI BOLD signal was stronger for the dominant eye as defined by the acuity method, and this effect was significant for areas located in the ventral occipital territory. In contrast, assigning dominance based on sighting produced no significant interocular BOLD differences. They concluded that interocular BOLD differences in normal subjects exist, and may be predicted by acuity measures[4].

Also our results showed a difference in FMRI activity after a separate stimulation of the right and left eye. But this difference was not statistically significant and did not correlate with either a sighting or sensory ocular dominance. Even after small field stimulation, we did not demonstrate a relationship between the extent of activation and the dominance of each eye. We did not find any correlation even after a separate stimulation of the same eyes with different-sized stimuli.

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Menon et al., Toosy et al., Algazeet al. observed differences in FMRI activity after the separate stimulation of each eye5-7.

Algaze et al. found interocular differences of 4.82% ± 0.74% in 6 controls7. Our 10controlsshowed the average interocular difference of 2.2%, and this difference was not statistically significant (P = 0.85).

Miki et al.found that eye dominance was observed in the contralateral anterior visual cortex. However, eye dominance in the visual cortex was found not only in the most anterior area, corresponding to the monocular temporal crescent but also in the more posterior area, presumably showing a greater sensitivity of the temporal visual field (nasal retina) as compared with the nasal visual field (temporal retina) in the peripheral visual field (peripheral retina)[8].

Toosyet al. demonstrated asymmetric activation patterns in the visual cortices of normal humans who have undergone functional MRI with monocular photic stimulation. The contralateral hemisphere was activated more strongly and to a greater spatial extent than the ipsilateral hemisphere when either eye was stimulated[6].

Our results,comparing the laterality of activity in individual hemispheres after separate stimulation of each eye, did not globally confirm this finding. Laterality in the contralateral occipital lobe,described by the authors,was not demonstrated during our study.

Conclusion

We did not demonstrate a dependence of FMRI activity on sighting or sensory ocular dominance after the separate examination of each eye using various types of stimulation. Other mechanisms will most likely be involved in FMRI activity after visual stimulation. We did not even demonstrate hemispheric laterality after a separate stimulation of the dominant eye with either larger field or small field stimuli.

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