Human area V5/MT+ organization changes following lesions of the primary visual cortex

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Neuroscience 2013
The visual cortex is retinotopically organized

The primary visual cortex (V1) is the major relay of visual information to the rest of the cortex

Damage of V1 leads to a loss of conscious vision in the affected region of the contralateral visual hemifield (scotoma)

Quadrantanopia

Blindsight! V1-bypassing pathways
Blindsight: activity observed in the middle temporal area (MT)

Source of visual activation:
- Superior Colliculus (SC) → Pulvinar → Extrastriate cortex (Rodman et al., 1990)
- Lateral Geniculate Nucleus (LGN) (Schmid et al., 2010)

In humans, fMRI studies of blindsight patients have reported responses in area hV5/MT+ (Goebel et al., 2001, Schoenfeld et al., 2002, Bridge et al., 2010)

It is not known how hV5/MT+ organization is affected by chronic V1 damage
Methods

- 5 patients with quadrantanopia
- fMRI measurements
- checkerboard bar stimulus
- fixation task + eyetracking

The pRF topography \((p)\) is represented by a set of weights which predicts the BOLD signal \((d)\) using the stimulus protocol \((s)\) and the HRF \((h)\):

\[
d_i = h(t) \ast (p_i^T s(t)) = Kp_i
\]

The weight vector \((p)\) is estimated by solving a linear model:

\[
J_i = \|y_i - K^+ p_i^+\|^2 + \lambda_1 \|p_i\|^2
\]

Then the appropriate model is selected by fitting a 2D-Gaussian

(Lee et al., NeuroImage, 2013)
Artificial Scotoma

- 5 control subjects

- An area of the stimulus in the upper left quadrant was obscured simulating a superior left quadrantanopia

- Only $\sim 28\%$ of voxels become unresponsive

<table>
<thead>
<tr>
<th>Area</th>
<th>V5/MT+</th>
<th>V1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>$843 \pm 275$</td>
<td>$2211 \pm 477$</td>
</tr>
<tr>
<td>AS-Controls</td>
<td>$623 \pm 280$</td>
<td>$1266 \pm 182$</td>
</tr>
</tbody>
</table>

- Displacement of pRFs under the AS condition
Artificial Scotoma

Visual Field Coverage

Right V1

Right V1 (AS)

Right V5/MT+

Right V5/MT+ (AS)

Y(AS)-Y

Elevation (deg)

-10
-5
0
5
10

Ecc(AS)-Ecc

Elevation Shift (deg)

-8
-4
0
4

Eccentricity Shift (deg)

-5
-3
-1
1

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Artificial Scotoma- Conclusions

1. Only a small number of voxels become unresponsive when an artificial scotoma is applied in the upper left quadrant.

2. The part of area hV5/MT+ corresponding to locations within the AS acquires displaced pRFs to respond to stimulus located in the surround of the AS.

3. Changes in the hV5/MT+ area of healthy controls can help us differentiate between changes that occur as a result of reorganization versus simple stimulus deprivation.
Patients

- **S12**: A patient with partial V1 lesion in the right hemisphere resulting in left quadrantanopia

- **S07**: A patient with a right superior quadrantanotic defect following a lesion of the left inferior calcarine cortex

- **S15**: A patient with a right superior quadrantanotic defect from a temporal optic radiation infarct on the left hemisphere
Does hV5/MT+ remain responsive following a V1 lesion?

<table>
<thead>
<tr>
<th>Subject ID (Lesion)</th>
<th>MT+/V1 Ratio</th>
<th>Lesioned hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>843±275</td>
<td>2211±477 0.38±0.13</td>
</tr>
<tr>
<td>AS-Control</td>
<td>623±280</td>
<td>1266±182 0.49±0.2</td>
</tr>
<tr>
<td>S12</td>
<td>163</td>
<td>1258 0.13</td>
</tr>
<tr>
<td>S07</td>
<td>135</td>
<td>157 0.86</td>
</tr>
<tr>
<td>S15</td>
<td>1895</td>
<td>2046 0.92</td>
</tr>
</tbody>
</table>

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Visual field coverage maps of hV5/MT+ overlap with the scotoma

- Areas in the scotoma covered by both coverage maps
- Areas covered in hV5/MT+ but not in V1
Does the organization of hV5/MT+ change?

S07

S15

S12 Controls: mean = -0.47, sem = 0.03

Fraction of Voxels

-6 -4 -2 0 2 4 6

LVF Seeing

UVF Scotoma

Elevation (deg)

-6 -4 -2 0 2 4 6

-2.43 ± 0.16

-0.75 ± 0.02

0.22 ± 0.1
Conclusions

1. Only a small number of voxels become unresponsive when an artificial scotoma is applied in the upper left quadrant.
   - The part of area hV5/MT+ corresponding to locations within the AS acquires displaced pRFs to respond to stimulus located in the surround of the AS.

2. The surface area of hV5/MT+ that was significantly activated in patients with quadrantanopia varies compared to the AS-controls, even though the visual field defect is the same, and depends on the type of the lesion.
   - In some cases the responsive area hV5/MT+ is larger than expected based on activation in V1, suggesting reorganization.

3. Some patients had responses in area hV5/MT+ from parts of the visual field that were not covered by the spared portion of area V1, suggesting the existence of V1-bypassing pathways.

4. The pRF center distribution was shifted to the seeing quadrant for the patients compared to controls stimulated with an artificial scotoma.
Acknowledgements

Stelios Smirnakis
Sangkyun Lee
Dorina Papageorgiou

Nikos Logothetis
Georgios Keliris
Yibin Shao

Ulrich Schiefer
Eleni Papageorgiou
Elke Krapp

Center for Opthalmology
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Eye-movements

AS-Control

S12

S07

S15