Population receptive field mapping in human subjects with lesions of the visual cortex

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Introduction

- Primary Visual Cortex (V1): major gateway for the transfer of visual information from subcortical centers to the rest of extrastriate visual cortical areas.

- Damage to V1: Cortical Blindness.

- Small amount of residual sensitivity: “Blindsight”

- Alternate pathways transmit information from the retina to cortex and appear to effectively bypass V1 in transmitting visual information directly to extrastriate visual areas.
Controversy about the reorganization of V1 in subjects suffering from macular degeneration and other retinal lesions (Caldford et al., 1999; Chino et al., 1992; Gilbert & Wiesel, 1992; Kaas et al., 1990; Schmid et al., 1996; Dilks et al., 2009, DeAngelis et al., 1995; Smirnakis et al., 2005; Sunness et al., 2004; Wandell & Smirnakis, review 2009; Baseler et al., 2011).

Little is known about the ability of the visual cortex to reorganize following V1 lesions.

Visual training after V1 lesions seems to provide evidence for perceptual plasticity both in monkeys (Cowey & Weiskrantz, 1963; Mohler & Wurtz, 1977) and in humans (Huxlin, 2009).

Areas V2/V3 and V5/MT+ can be visually modulated following V1 lesions (Schmid, 2009; Baseler, 1999; Goebel, 2001; Zeki, 1998; Blythe, 1987; Weiskrantz, 1991).
pRF mapping - Methods

- 6 Patients screened at the center for Ophthalmology, Tuebingen. Normal subjects were used as controls.

- fMRI measurements were obtained during the presentation of a moving bar stimulus.
  (size: 1 deg., step: 0.5 deg every TR= 2sec., 8 different directions)

- Behavioral task to ensure fixation. An infrared eye tracker recorded eye movements.

- Control: an area of the stimulus was obscured creating a so-called “artificial scotoma”.
Population Receptive Field (pRF) method to measure the aggregate receptive field properties of neuronal populations voxel by voxel in the visual cortex. VistaSoft software. (Dumoulin and Wandell, *Neuroimage* 2008)
Control Subjects

Angular Map

Eccentricity map

Receptive field size map

Eccentricity - Prf size

Eccentricity (degrees)

0 2 4 6 8 10 12

pRF size (sigma) (degrees)

0 1 2 3 4 5 6 7
Patients with cortical lesions

- Difficulty in characterizing the properties of the visual pathways.
- Unique cases. Differences in the extend and location of the lesion.
- Chronic lesions.

Solution:

- Comparison to a population of control subjects.
### PRF Size Range - 10 Control Subjects

<table>
<thead>
<tr>
<th></th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>MT+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope ±std</td>
<td>0.17 ±0.05</td>
<td>0.24 ±0.04</td>
<td>0.34 ±0.08</td>
<td>0.73 ±0.12</td>
</tr>
<tr>
<td>pRF size at 7 deg ±std</td>
<td>2.08 ±0.5</td>
<td>2.42 ±0.4</td>
<td>3.31 ±0.5</td>
<td>6.82 ±0.86</td>
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</tbody>
</table>
**PRF Size Voxel Distribution**

**V1**
- **pRF size voxel distribution - Area V1 Control Subjects**
- Peak = 1.25 deg
- Half width: 1.86 deg

**V2**
- **pRF size voxel distribution - Area V2 Control Subjects**
- Peak = 1.35 deg
- Half width: 2 deg

**V3**
- **pRF size voxel distribution - Area V3 Control Subjects**
- Peak = 1.55 deg
- Half width: 2.5 deg

**V5/MT+**
- **pRF size voxel distribution - Area V5/MT+ Control Subjects**
- Peak = 1.75 deg
- Half width: 1.75 deg

**Peak**
- V1: 1.25 deg
- V2: 1.35 deg
- V3: 1.55 deg
- V5/MT+: 1.75 deg

**Half width**
- V1: 1.86 deg
- V2: 2 deg
- V3: 2.5 deg
- V5/MT+: 1.75 deg
Artificial Scotoma at the upper left quadrant

Angular Map

Eccentricity Map

Visual field coverage - Artificial Scotoma

Right V1
Artificial Scotoma at the upper left quadrant

pRF size range- Area V1 Controls with AS

Eccentricity (deg)
pRF size (sigma, deg)

Mean
Max
Min

pRF size range- Area hV5/MT+ Controls with AS

Eccentricity (deg)
pRF size (sigma, deg)

Mean
Max
Min

pRF size voxel distribution- Area V1 Controls with AS

V1 RH (AS)
Mean (Controls without AS)
Std

# of voxels (normalized)

prf size (sigma)

pRF size voxel distribution- Area V5/MT+ Controls with AS

V5/MT+ RH (AS)
Mean (Controls without AS)
Std

# of voxels (normalized)

prf size (sigma)
Reflection of the healthy hemisphere to cover the lesion of the other hemisphere.
Patient S12

Octopus 90°

S12 pRF size against Eccentricity

- Right V1
- Right MT
- Right V2d
- Right V3d

Eccentricity (deg)

pRF size (sigma, deg)

V3v

Eccentricity (degrees)

0 2 4 6 8 10 12
Patient S12

Right Hemisphere

pRF size voxel distribution - Area V1

- S12 V1 RH (lesioned)
- Mean
- Std

Right Hemisphere - Controls with AS

- V1 RH
- Mean
- Std

V1 RH: Right Hemisphere

V3v: V3v
V3a/b: V3a/b
V3d: V3d
V2d: V2d
V5/MT+: V5/MT+

Lesion: Lesion

pRF size (sigma) (degrees)

0 1 2 3 4 5 6 7
Patient S12

Right Hemisphere

Wilcoxon signed rank test

p = 0.0004
p = 0.0005

Left Hemisphere

Wilcoxon signed rank test

p = 0.0004
p = 0.0007

S12 V5/MT+ RH

Mean
Std

S12 V5/MT+ LH

Mean
Std

pRF size voxel distribution - Area V5/MT+

pRF size (sigma)

# of voxels (normalized)
Patient S29

V1 Prf size against eccentricity
Left Hemisphere

Octopus 90°
Patient S29

**Patient S29- Area V2**

- **Eccentricity (deg)**
- **pRF size (sigma, deg)**

**Patient S29- Area V3**

- **Eccentricity (deg)**
- **pRF size (sigma, deg)**

**pRF size voxel distribution- Area V2**

- **S29 V2 LH**
- **Mean (Controls)**
- **Std**

**pRF size voxel distribution- Area V3**

- **S29 V3 LH**
- **Mean (Controls)**
- **Std**
Patients - pRF size of the spared areas

pRF size Vs Eccentricity - Patients Area V1

Eccentricity (degrees)
pRF size (sigma)

pRF size Vs Eccentricity - Patients Area V2d

Eccentricity (deg)
pRF size (sigma, deg)

pRF size Vs Eccentricity - Patients Area V3d

Eccentricity (deg)
pRF size (sigma, deg)

pRF size Vs Eccentricity - Patients Area V5/MT+

Eccentricity (deg)
pRF size (sigma, deg)
Conclusions

- Retinotopic maps in the patients’ spared early visual cortex appear to be consistent with retinotopic maps obtained in control subjects.

- The organization of higher level visual areas, such as V5/MT+ show preliminary some differences compared to those of normal subjects.

- Population receptive field size of some of the patients' spared visual areas show deviations from the normal range of population receptive field sizes derived from the control subjects.