BLINDSIGHT IS COLOR-BLIND TO S-CONE ISOLATING STIMULI: AN fMRI STUDY

Sandra E. Leh[1,2], Alain Ptito[1], Marc Schönwiesner[3], Mallar M. Chakravarty[4], Kathy T. Mullen[5]

[1]Cognitive Neuroscience Unit, Montreal Neurological Institute and Hospital, McGill University, Montreal, Canada; [2]Toronto Western Hospital, University Toronto, Toronto, Canada; [3]International Laboratory for Brain Music and Sound Research (BRAMS), Université de Montréal, Montreal, Canada; [4]Pathophysiological and Experimental Tomography Center and Center for Functionally Integrated Neuroscience, Aarhus University Hospitals, Aarhus Denmark; [5]Vision Research Department of Ophthalmology, McGill University, Montreal, Canada

INTRODUCTION

Blindsight is the ability to respond to visual stimuli in the blind field without consciously experiencing them. A previous behavioural study in hemispherectomized (HS) subjects with blindsight demonstrated a Spatial Summation Effect to achromatic but not to S-Cone isolating stimuli (Ref. 1).

Since primate data have shown that the Superior Colliculi (SC) lack S-Cone sensitive neurons, the most prominent hypothesis postulates that blindsight is mediated by the SC.

To date, however, there are no studies on the S-Cone sensitivity of the SC in humans.

In this study we designed an fMRI paradigm using sinewave checkerboard stimuli to investigate and compare the role of achromatic contrast and S-cone contrast in blindsight in hemispherectomized subjects.

METHODS

*Subjects

- 1 control subject
- 1 HS with blindsight
- 1 HS without blindsight

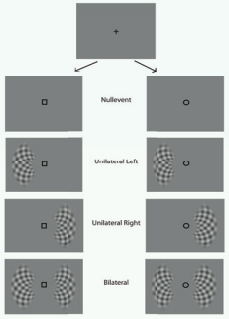
*Stimuli:

Stimuli were presented binocularly at 8° in the right, left, or in both visual fields. We used sinwave checkerboard stimuli that were:

1. achromatic (SC-visible, Pulvinar visible)
2. S-cone isolating (SC-invisible, Pulvinar visible)

with the following parameters:

- 0.5cpd,
- spatial envelope σ= 1.5cycle,
- temporal envelope σ=250ms



For further details see Ref. 2

DATA ACQUISITION and PREPROCESSING

fMRI data was acquired on a 3 Tesla MRI TIM Trio scanner using echo-planar imaging (EPI) with an eight channel head coil.

Cardiac gating (Ref. 3) was used to minimize motion artifacts in the brainstem signal resulting from pulsation of the basilar artery.

The functional images were triggered 300 ms after the R-wave in the electrocardiogram, when the cardiac cycle is in its diastolic phase.

*Parameters

- Anatomical MRI scan 1x1x1 mm voxel size
- fMRI scan: TR 2540ms, TE 30ms, FA 90 deg., 30 slices, total of 822 acquisitions were collected in three runs from each participant

RESULTS STUDY 1:
Is the human SC color-blind to S-Cone isolating (Blue/yellow) stimuli?

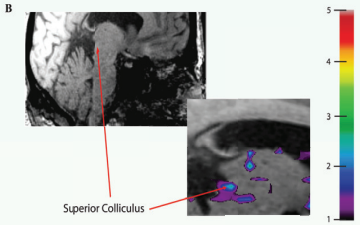
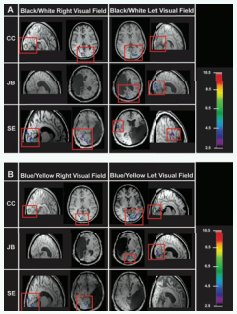


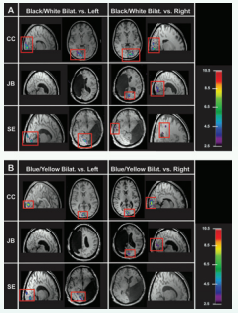
Figure illustrates an example (HS subject SE) of a t-map within the left superior colliculi for the contrast achromatic (black/white) minus S-cone isolating stimuli (BW-BY).

RESULTS STUDY 2:
Cortical activation pattern to unilaterally presented stimuli



- T-maps for unilateral achromatic (black/white) (A) and S-cone isolating (B) stimuli are displayed for all subjects (CC, JB, SE).
- Examples of activation patterns to stimuli presented to the right visual field can be seen in the left column and to the left visual field in the right column.
- All subjects showed contralateral activation in visual cortical areas to stimuli presented in their healthy visual field.
- JB did not show any activation pattern when stimuli were presented in the blind visual field (right visual field).
- SE showed activation in V5 and FEF if achromatic (black/white) stimuli were presented to his blind visual field, but not to S-cone isolating stimuli.

RESULTS STUDY 3:
Does presentation of an additional stimulus enhance the cortical activation pattern?



- Examples of enhanced activation pattern to two stimuli compared to a single stimulus in the right (left column) and left visual field (right column) are displayed as t-maps for all subjects (CC, JB, SE).
- Results for achromatic black/white stimuli are displayed in A and for S-cone isolating stimuli in B.
- Whereas subject CC showed an enhancement to two achromatic black/white and to two S-cone isolating stimuli compared to single conditions, JB did not show this enhancement when a second stimulus was presented in his blind visual field (see JB left column).
- In contrast, SE showed enhanced activation patterns to two stimuli compared to a single stimulus if stimuli presented were achromatic black/white but not to S-cone isolating stimuli (see SE column right).

SUBJECTS		Achromatic Stimuli		S-Cone Isolating Stimuli	
		Right visual field presentation	Left visual field presentation	Right visual field presentation	Left visual field presentation
Healthy Subject CC	V1	5, -90, 2	5, -90, 2	2, -93, 1	-2, -93, 2
	V2	11, -90, 6	-11, -90, 6	2, -90, 1	-6, -90, 1
	FEF	no activation	no activation	no activation	no activation
	V5	no activation	no activation	no activation	no activation
HS Subject with blindsight SE	V1	no activation	-1, -86, 4.1	no activation	-6, -90, 1
	V2	no activation	-33, -90, 4.1	no activation	-6, -90, 6
	FEF	-30, 3.1 127	no activation	no activation	no activation
	V5	-47, -71, 9	no activation	no activation	no activation
HS Subject without blindsight JB	V1	-2, -90, 2	no activation	-2, -90, 1	no activation
	V2	-17, -91, 1.3	no activation	2, -91, 12	no activation
	FEF	no activation	no activation	no activation	no activation
	V5	no activation	no activation	no activation	no activation

CONCLUSIONS

We confirmed the existence of blindsight to superior colliculus visible (achromatic) stimuli.

Our results also strongly suggest that the human superior colliculus is color-blind to S-cone isolating stimuli and that hemispherectomized subjects show blindsight only to stimuli visible to the superior colliculi, hereby supporting our previous behavioural results (Leh et al., 2007).

Stimuli invisible to the superior colliculi such as S-cone isolating stimuli do not mediate blindsight.

Further studies are necessary to examine the neuronal correlates of blindsight in subjects other than hemispherectomized patients.

Acknowledgments

We thank the subjects for their time. This study was supported by a doctoral scholarship from CRIR to SEL, a doctoral and postdoctoral scholarship from FRSQ to SEL, an NSERC research grant to AP (RGPIN 37354-02) and a CIHR grant to KTM (MOP-10819).

References

(1) Leh et al., EJN 2007

(2) Leh et al., JOCN 2009 in press

(3) Guimaraes et al., Human Brain Mapp 1989