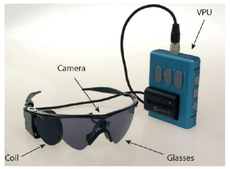
Neuroimaging in the Blind with Retinal Prostheses: Does Sensory Reorganization During Blindness Limit Visual Restoration?

Noelle R. B. Stiles[1], Jeiran Choupan[2], Negin Nadvar[3], Hossein Ameri[1], James D. Weiland[3, 4], Vivek R. Patel[1], Yonggang Shi[2]

[1]Department of Ophthalmology, University of Southern California; [2]Stevens Neuroimaging and Informatics Institute, Department of Neurology, University of Southern California; [3]Department of Biomedical Engineering, University of Michigan; [4]Department of Ophthalmology and Visual Sciences, University of Michigan

Background

- Retinal prostheses restore vision to the blind by stimulating surviving retinal ganglion cells within the retina of the eye
- The prosthesis includes a camera mounted on a pair of glasses that transmits a live video feed to an electrical microstimulator array proximity coupled to the retina
- Nearly 400 Argus II retinal prostheses have been implanted worldwide to date



Argus II Retinal Prosthesis External Components

- All Argus II patients are late blind and therefore previously had vision
- Blindness can generate plastic changes in early visual regions, including the processing of tactile and auditory stimuli within visual cortex
- However, the brain may be able to adapt to the new Argus input and reverse previous changes that occurred during blindness

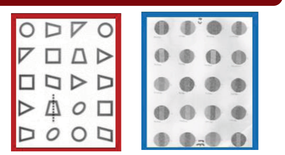
Key Questions:

- **Do the changes during blindness limit the restoration of vision?**
- **Does the brain readapt to vision by reversing the crossmodal reorganization from blindness?**

Experimental Setup

Argus II fMRI Tasks

1. **Shape Tactile Task** – Evaluate the symmetry of raised shapes on paper (Active *vs.* Rest Block Design)
2. **Sandpaper Tactile Task** – Evaluate the roughness of sandpaper patch stimuli (Active *vs.* Rest Block Design)



Tactile Stimuli (shape on left and sandpaper on right)

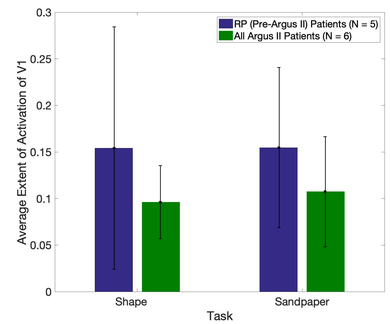
- Two patient groups: Argus II patients post-implantation, and blind control patients
- The Argus II device is MRI conditional, and is approved for scanning when the external equipment (glasses and VPU) are removed, and the device is OFF
- Primary visual cortex was defined in the patients by the Benson Template
- Extent of activation was measured as the fraction of voxels in V1 with a *zstat* score of 2.3 or greater

Behavioral Task: Performed outside the scanner with the Argus II device turned on. Behavioral task detailed further in results section (middle column, bottom)

Results

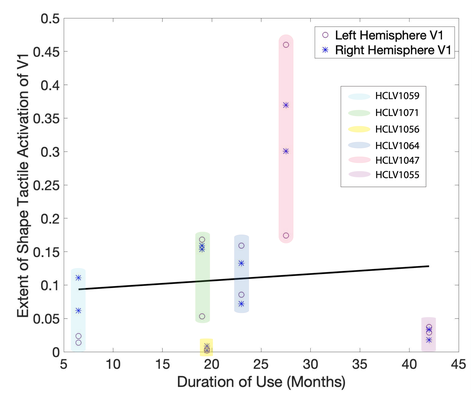
Do Argus II Patients Have Crossmodal Activation of V1?

- Tactile driven activation in primary visual cortex for Argus II patients (N = 6) in comparison to blind control patients with Retinitis Pigmentosa (RP) (N = 5)
- Patients performed the two tactile tasks twice, one fMRI scanned anterior to posterior (AP) and one *vice versa*. The two task scans as well as the left and right hemispheres were averaged to generate one combined extent of activation during the task metric
- Argus II patients were not significantly different from the RP patients tested in the extent of activation during the task
- Argus II patients have a significant number of voxels (extent) with tactile-driven activation in early visual cortex
- **Argus II patients still have tactile processing in early visual cortex after vision restoration**



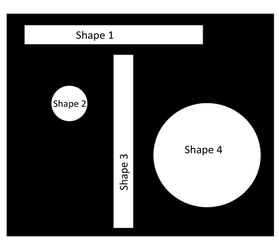
Is Crossmodal Reorganization Reduced with Visual Restoration?

- Does the brain readapt to vision by reversing the crossmodal reorganization from blindness?
- Extent of early visual activation (V1) during a tactile task *did not* correlate with the duration of prosthesis use (N = 6)
- **There does not seem to be a significant effect on tactile capture of V1 with device use**



Does Crossmodal Reorganization Limit Visual Restoration?

- **Hypothesis:** Patients with greater tactile repurposing of visual cortex (*before* implantation) will experience ***diminished*** visual restoration capabilities *after* implantation of the retinal prosthesis
- Perform correlation between visual activation during tactile tasks and Argus II visual performance. Argus II performance must be measured with a behavioral task outside the fMRI scanner.



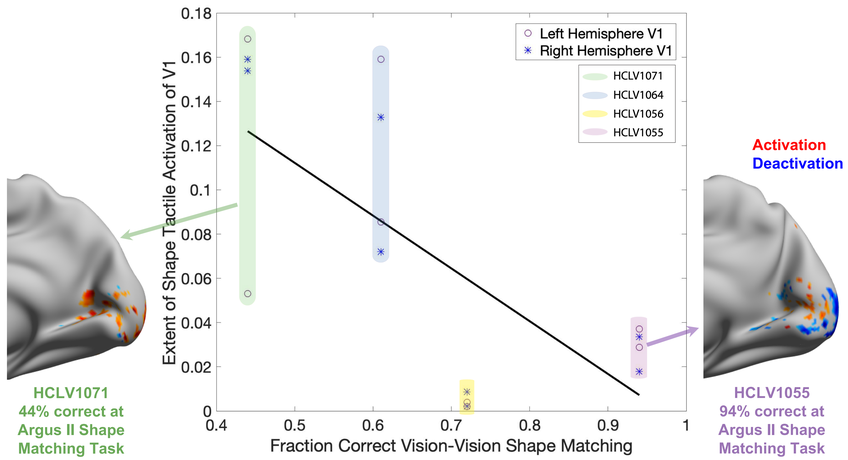
Visual Stimuli

Behavioral Task Experimental Design

- **Shape Matching Task:** Determine whether two shapes are the same or different. The shapes are "different" if they have different orientations, sizes, or shapes (geometry)
- Patients view each of the two shapes one at a time with the Argus II device. Then the patients report whether the two shapes (of four possible shapes) are the same or different.

Does Crossmodal Reorganization Limit Visual Restoration? (Cont.)

- Tactile shape symmetry task (Shape Tactile Task) was performed *within* the fMRI scanner, and the Shape Matching Task was performed *outside* the fMRI scanner
- Argus II patients (N = 4) show a significant *anti-correlation* between their *visual* shape matching performance and the amount of *tactile* repurposing of visual cortex
- **The patients that are the *most functional* with the Argus II visual prosthesis had the *least* amount of tactile reorganization of visual cortex**



Conclusions

- Argus II patients retain tactile activation of V1 following partial visual restoration
  - No significant change in tactile capture is apparent with duration of device use
- Argus II patients with the least amount of tactile processing in V1 have the greatest visual functionality at a comparable task with the Argus II device
- Crossmodal repurposing of visual cortex may be maladaptive to visual restoration. If this is supported by further testing, the next steps are:
  - *Patient pre-selection* based on neural plasticity
  - Research on therapies and methods that *prevent or reduce plasticity* during blindness

Acknowledgments

- Arnold O. Beckman Postdoctoral Fellowship
- The National Institutes of Health (NIH), National Eye Institute (NEI)
- The Philanthropic Educational Organization (PEO) Scholar Award Program
- The Ginsburg Institute for Biomedical Therapeutics