Retinotopic to spatiotopic mapping in a blind patient implanted with a visual cortical neurostimulator

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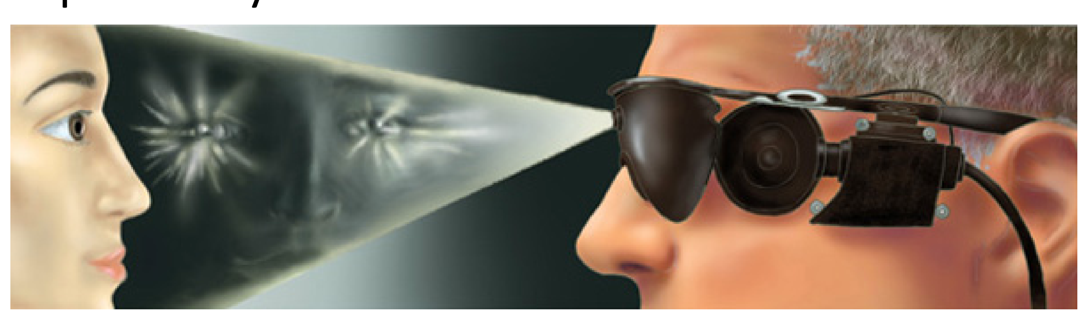
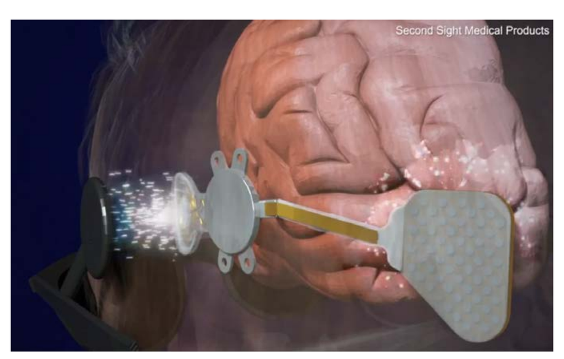
Background

- Current and future *retinal prostheses* can treat only blindness that is caused by limited retinal degeneration syndromes.
- Stimulation at higher locations in the visual pathway, e.g. in the visual cortex, would bypass the eye and the optic nerve and allow broader treatment of blindness.
- A *visual cortical prosthesis device* would electrically stimulate targeted visual areas according to an image captured by a head-mounted camera.

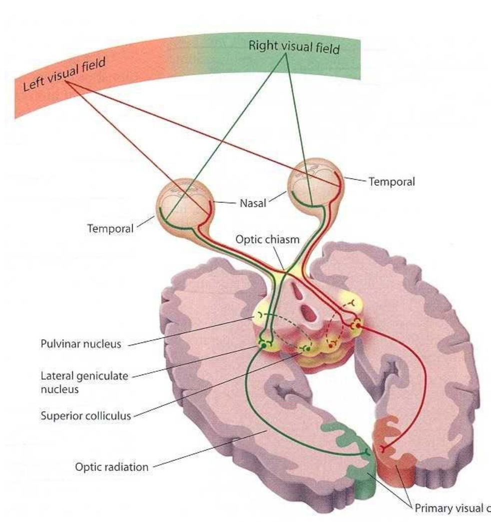




- An essential requirement for an *artificial visual sensory system* is that the electrical stimulation should convey to the brain patterned visual information that is mapped to the applicable spatial locations in the world.
- In natural vision, visual information is acquired at retinotopic (eye-centered) coordinates it is mapped to spatiotopic (world-centered) according to the position of the head and eyes.

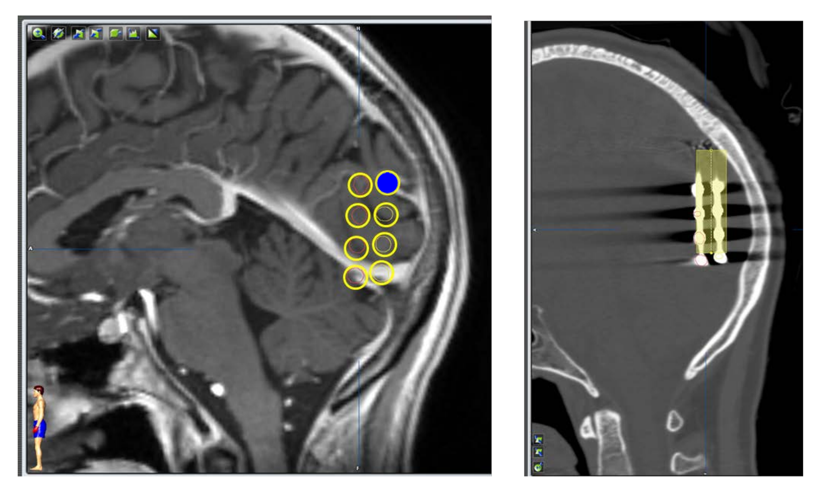
Purpose

To test if a visual percept created by electrical stimulation of the occipital lobe is converted from retinotopic (retina-centered) spatiotopic (world-centered) coordinates, i.e. the effect of eye movements on the perceived location.



Patient and the neurostimulator

- The RNS neurostimulator (NeuroPace, Mountain View, CA) contains two parallel strips of four electrodes each was implanted over the right medial occipital lobe.
- A 30-year-old volunteer, female, with an 8-year history of bare light perception secondary to Vogt-Koyanagi-Harada Syndrome participated in the study.



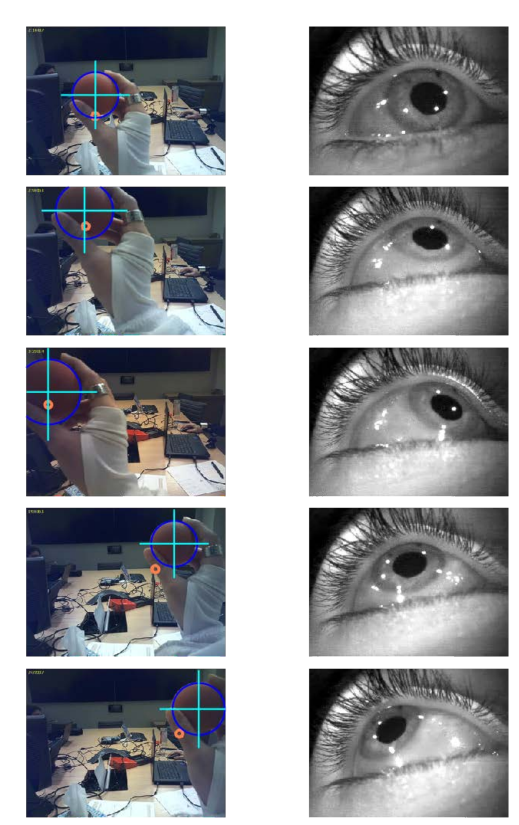
Pre-operative MRI with an overlay of the estimated electrode locations (left panel) based on comparison with the post-operative CT scan (right panel).

Each electrode has a diameter of 3 mm and the distance between neighboring electrodes on the stripe is 10 mm.

The electrode that was tested in this experiment is marked by a blue symbol.

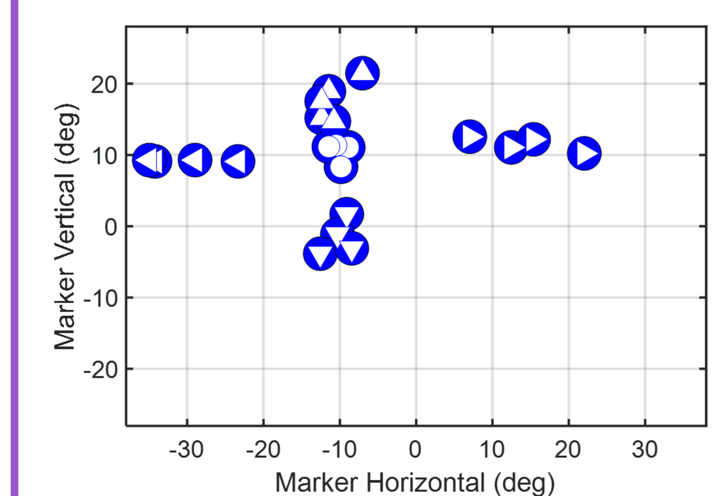
Experimental procedure

- In each trial, a single electrode was directly stimulated and the patient was instructed to place a red racquetball (57-mm diameter), at the location of the “light.”
- Eye positions were recorded with time stamp synchronized with the onset of stimulation using the SMI ETG 2.0 eye-tracker glasses (SensoMotoric Instruments, Teltow, Germany) in a self-calibrating mode.
- The location of the handheld marker was recorded using the forward-facing scene camera mounted onto the eye-tracker glasses.



Snapshots from the scene camera that were used to track the marker location in head-centered coordinates (left column). Pupil position (right column) at the onset of the stimulation that triggered the percept.

Results



Percept’s location of a single electrode at 5 gaze directions.

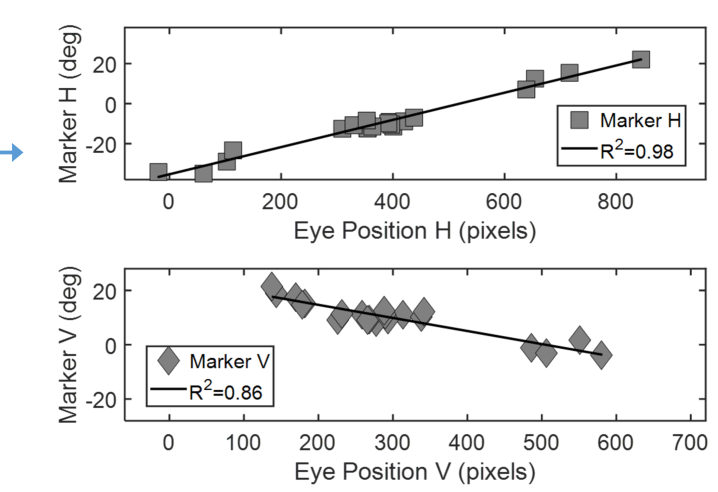
The blue symbols indicate the location of the percept created by electrical stimulation of the same electrode in different trials.

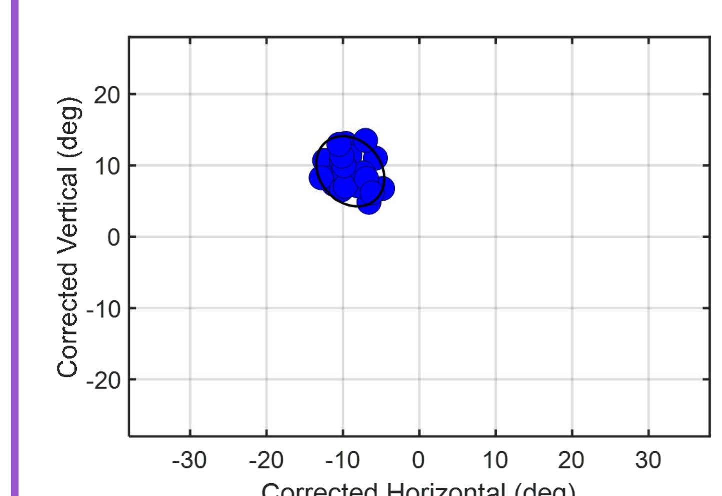
The white arrows represent the direction in which the patient was instructed to shift the gaze at each trial.

The shifts in location of the percept, as indicated by the handheld marker, match the gaze direction at each trial.

Correlations between percept’s location and eye’s position.

The circles show the location of the percept as a function of the self-calibrated eye’s position in the horizontal and the vertical dimensions along with regression lines.





Remapped percepts of a single electrode at 5 gaze directions.

The fitted line was used to remap the responses from world-centered to retina-centered coordinates that are independent of eye position.

The location of a generated by occipital lobe stimulation is consistent with retinal location.

Conclusions

- The brain of a blind individual preserves the necessary functionality to map visual information based on eye movements.
- A future visual cortical prosthesis will be able to utilize eye movements for visual scanning.