Changes in saccade rate over time in simulated thalamic visual prostheses

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Abstract

Due to the millions of people at risk for vision loss, building a visual prosthesis is crucial to restore at least crude vision. We have previously found from simulations of artificial vision in humans and non-human primates that both can perform well above chance to recognize letters using discrete visual phosphene patterns (Bourkiza et al. 2013, Killian et al., under review). However, we wanted to explore the techniques the animals developed over time to be able to perform at levels comparable to humans. After exploring the strategies the animals developed over time in regard to saccadic activity, we found that an increasing number of saccades along with an increase in saccade rate over time lead to better performance in the visual task across all phosphene

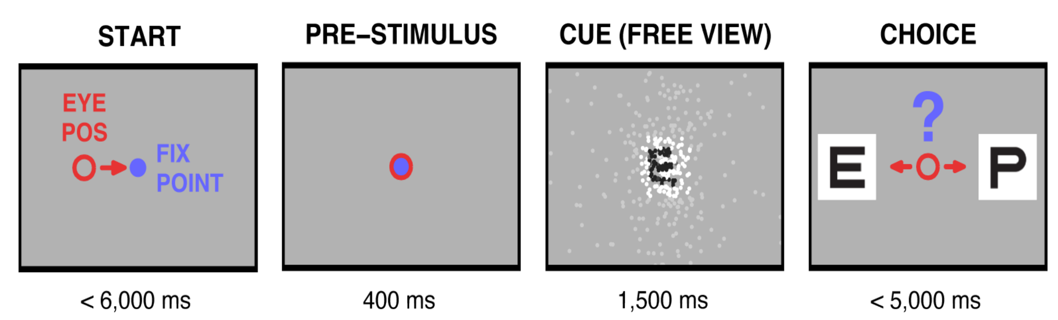
Introduction

Virtual reality artificial vision experiments use simulations of artificial vision to help determine the best design for visual prostheses. We used a two-alternative forced choice letter recognition task that was previously used in humans (Vurro et al. 2014) with non-human primates (*Macaca mulatta*). The task involves a simulation of artificial vision that involves an array of phosphenes (artificial points of light) stabilized on the retina. The animals have been able to perform to levels comparable to humans, even though training them on the task has taken a much longer time than for humans. The visual system can quickly adapt to the environment and thus, constant input can lead to perceptual fading during neural adaptation (Riggs & Ratli 1952). To compensate, the eye constantly makes movements to "refresh" the image onto the fovea. Saccades or eye movements in a visual prosthesis are thought to be extremely necessary since they allow greater visual acuity with a lower number of phosphenes or pixel arrays (Caspi & Zivotofsky 2015). We wanted to explore the strategies the animals (N = 3) have adapted in the task.. Most prostheses do not compensate for eye movements and any visual prosthesis that can use the natural eye movements to better achieve visual perception is expected to be incredibly beneficial to the millions of

Methods

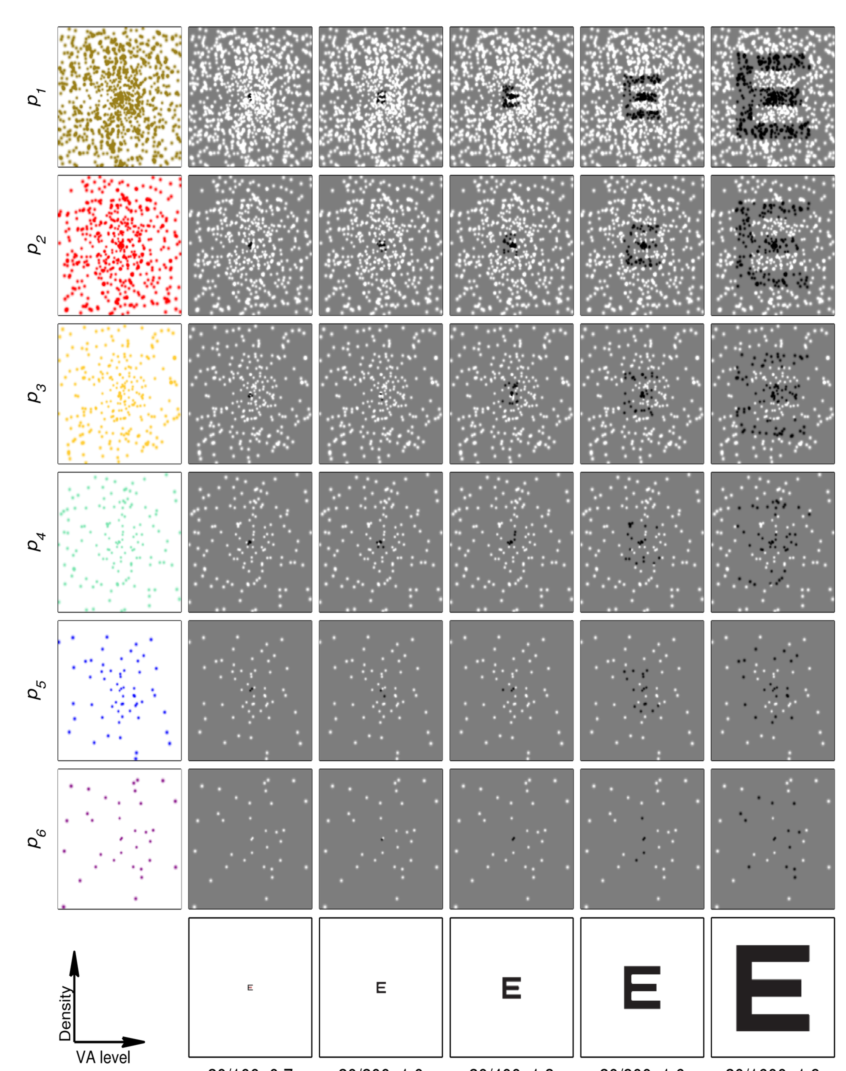
Animals were shown a sample letter cue on a computer screen followed by two alternative letter targets (one matching the cue and the other a distractor). Each cue was either presented under simulated artificial vision or as *clear view* text with no phosphine vision simulation (letters appeared on the screen as they would normally) and each target was presented as clear view. Each letter was presented in a region that covered 10 degrees of visual angle on each side.

Two-alternative forced choice letter recognition task



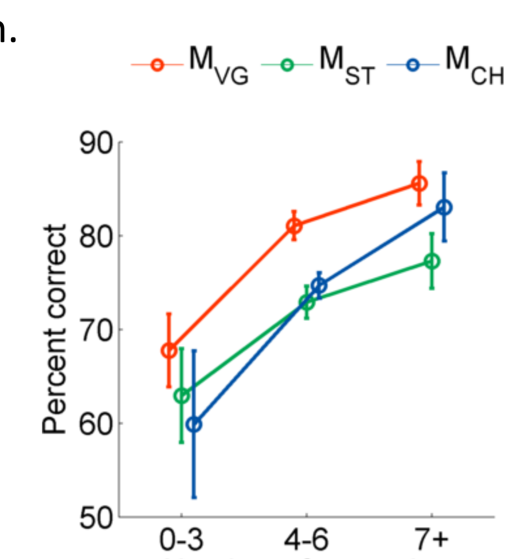
Simulated phosphenes

Letters of the Roman alphabet were shown in 5 different font sizes (Visual Acuity) and 6 different phosphene patterns (*p1-p6*) and a clear viewing condition. Phosphene patterns were centrally weighted in the visual field and took into account the current gaze position to stabilize the position on the retina.



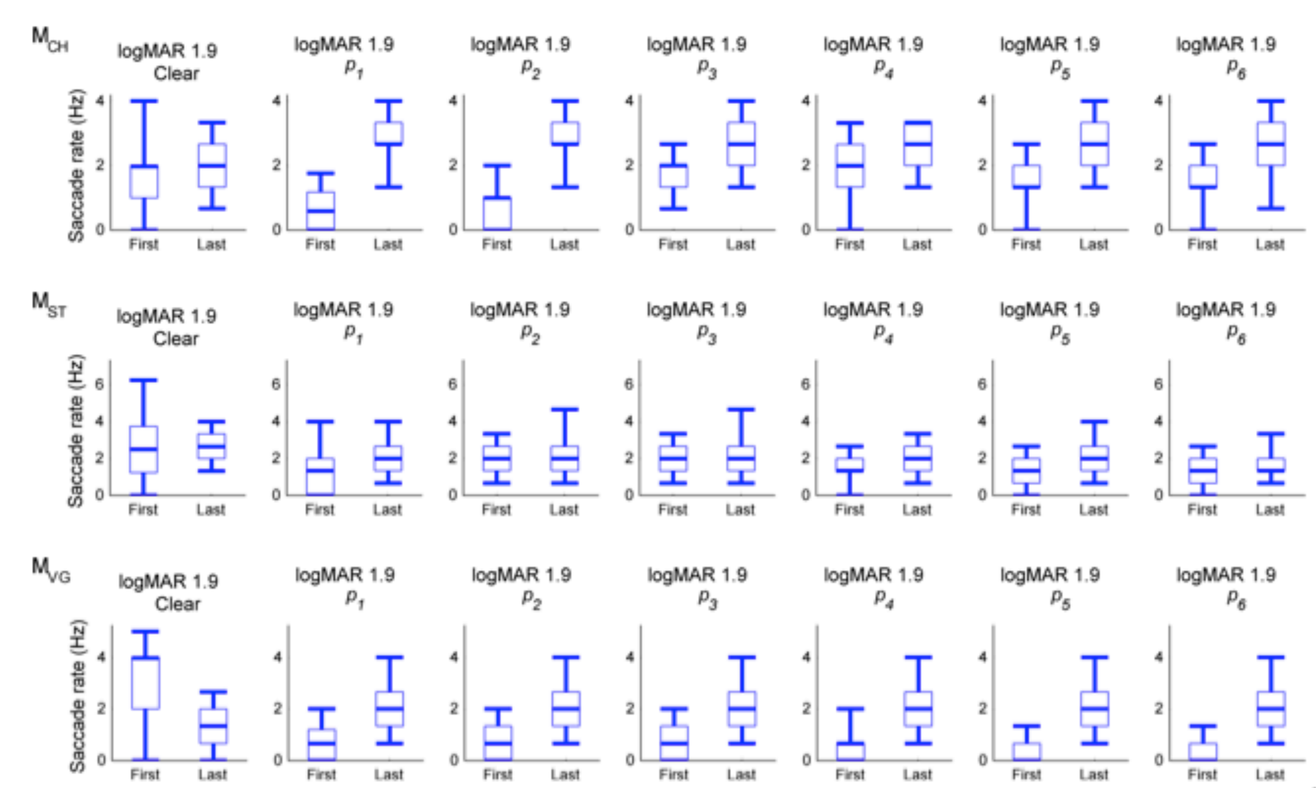
Performance with number of saccades.

Each animal showed performance improvements with a concomitant increasing number of saccades during the cue period when pooling over all trials with different visual acuity and phosphene patterns. Each symbol represents the mean with error bars and standard deviation.

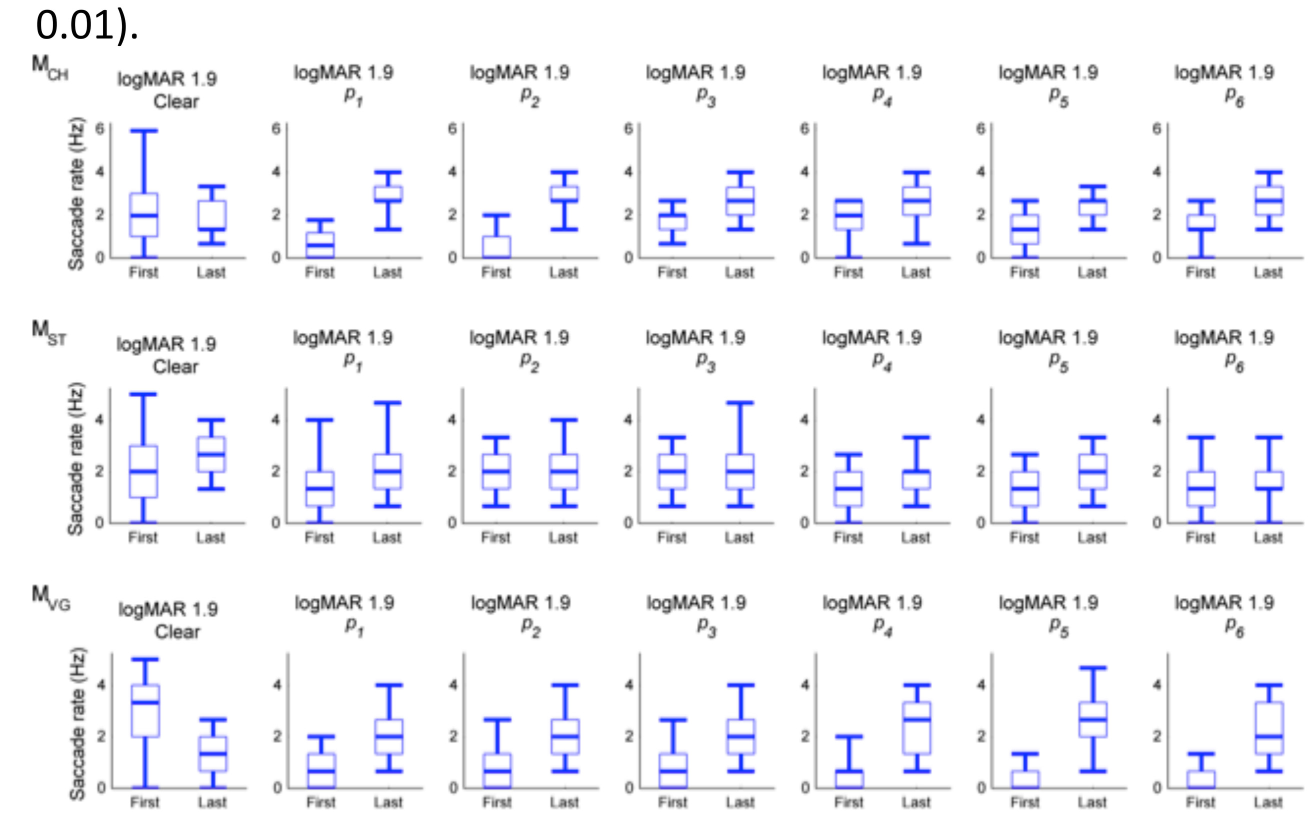


Initial vs. final saccade rate.

For only the largest letter font (logMAR 1.9) with all the phosphene patterns (p_1 to p_6) and the clear view condition for all three animals for initial saccade rate versus the saccade rate for the latest trials. 'First' and 'Last' trials are bins of 200 trials. The saccade rate for correct and incorrect trial bins shows a general trend for increasing saccade rate in all phosphene patterns (p_1 to p_6) for M_{CH}, M_{VG} and M_{ST} (p-value < 0.01). For animal M_{CH} and M_{ST}, no statistical significance of decrease (p-value > 0.05) in the clear condition. There is a decrease in saccade rate for the clear view condition for M_{VG} (p-value < 0.01).

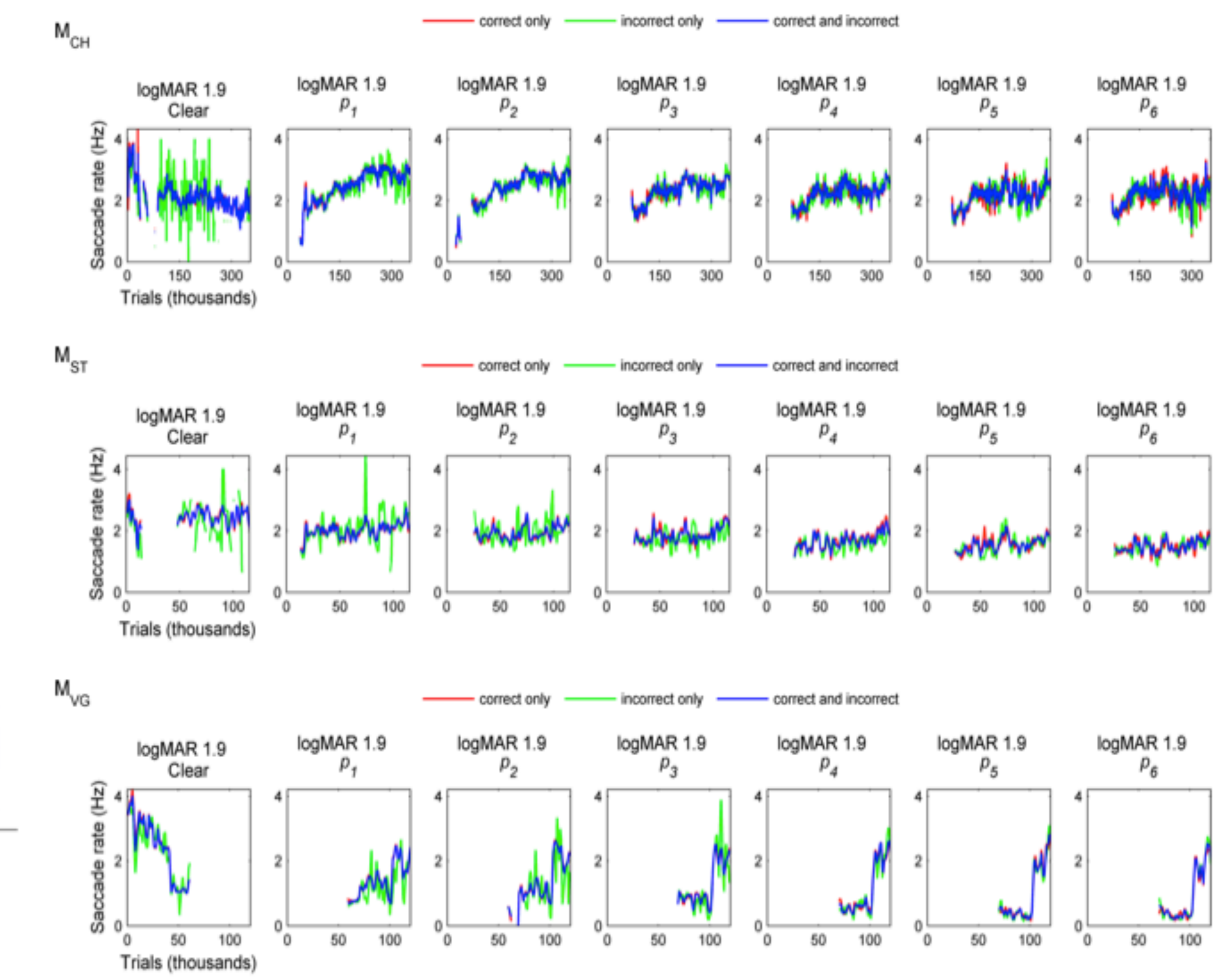


Looking at only the correct trials, M_{CH} and M_{ST} have increases in saccade rate for all phosphene patterns ($p < 0.01$) but no change for the clear view condition ($p > 0.05$). M_{VG} has increases in all phosphene patterns and a decrease in the clear view condition ($p < 0.01$).

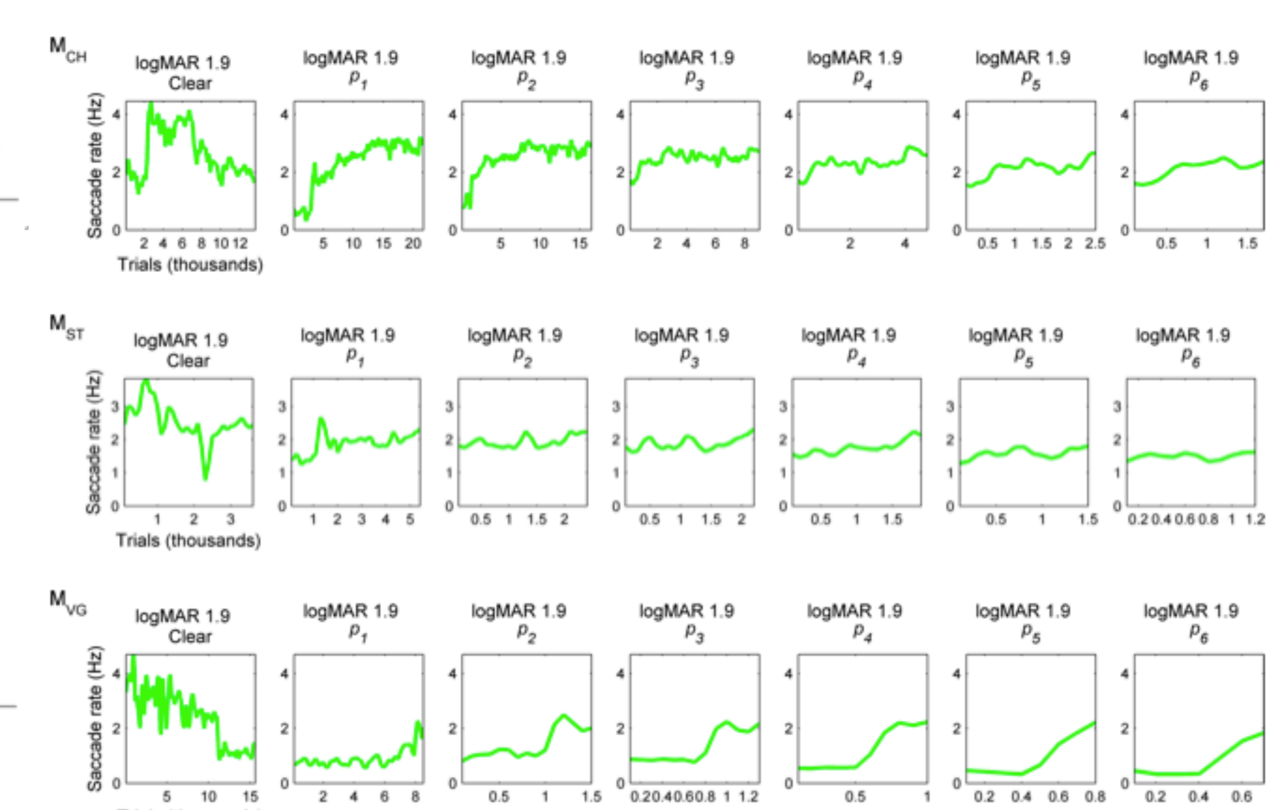


Saccade rate over time.

Examining all trials, both correct and incorrect, saccade rate (the number of saccades per second) shows an overall increase for the largest font size (logMAR 1.9) for each animal over the six phosphene patterns, and a general decrease in the clear view condition over time.



Saccade rate over time for the correct trials only shows a similar trend as the correct and incorrect together. There is an increase in saccades over variable time for each animal.



Conclusion & Future Direction

- Increasing amount of saccades lead to better performance in a visual task
- Increase in saccade rate over time for almost all viewing conditions with phosphenes and decrease in saccade rate over time the clear viewing condition
- Anticipate implant of a 128-electrode prosthesis in an animal model
- The data from the animal model will help guide the way for initial tests in human volunteers

References

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