

# Thalamic Visual Prosthesis Project

**John S. Pezaris, Ph.D.**

**Visual Prosthesis Laboratory  
Department of Neurosurgery  
Massachusetts General Hospital  
Harvard Medical School**

# Collaborators and Disclosures

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- **HMS**  
Clay Reid
- **MGH**  
Emad Eskandar  
Nathan Killian  
Milena Vurro  
Bechir Bourkiza  
Margee Kyada  
Sarah Keith  
Ailsa Jeffries  
Anne Marie Crowell
- **Disclosures**  
No financial conflicts  
Speculative use of therapies not approved by FDA

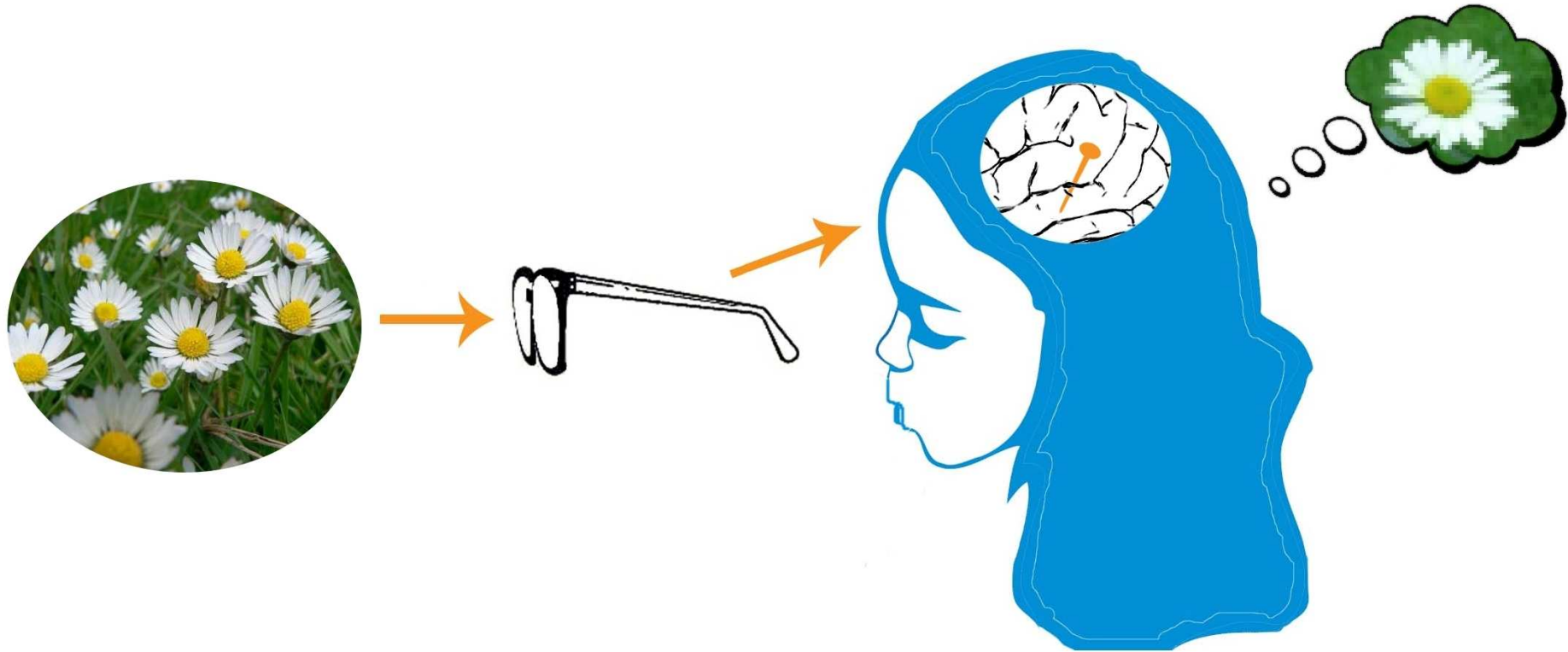
# The Problem: Blindness

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- **Blindness in Developed Countries**
  - millions affected
  - eyes no longer sensitive to light
    - glaucoma
    - macular degeneration
    - retinitis pigmentosa
    - trauma (military personnel, civilians, children)
    - surgical removal
    - (congenital?)
  - rest of visual brain intact
  - is system repairable?

# A Solution: Visual Prosthesis

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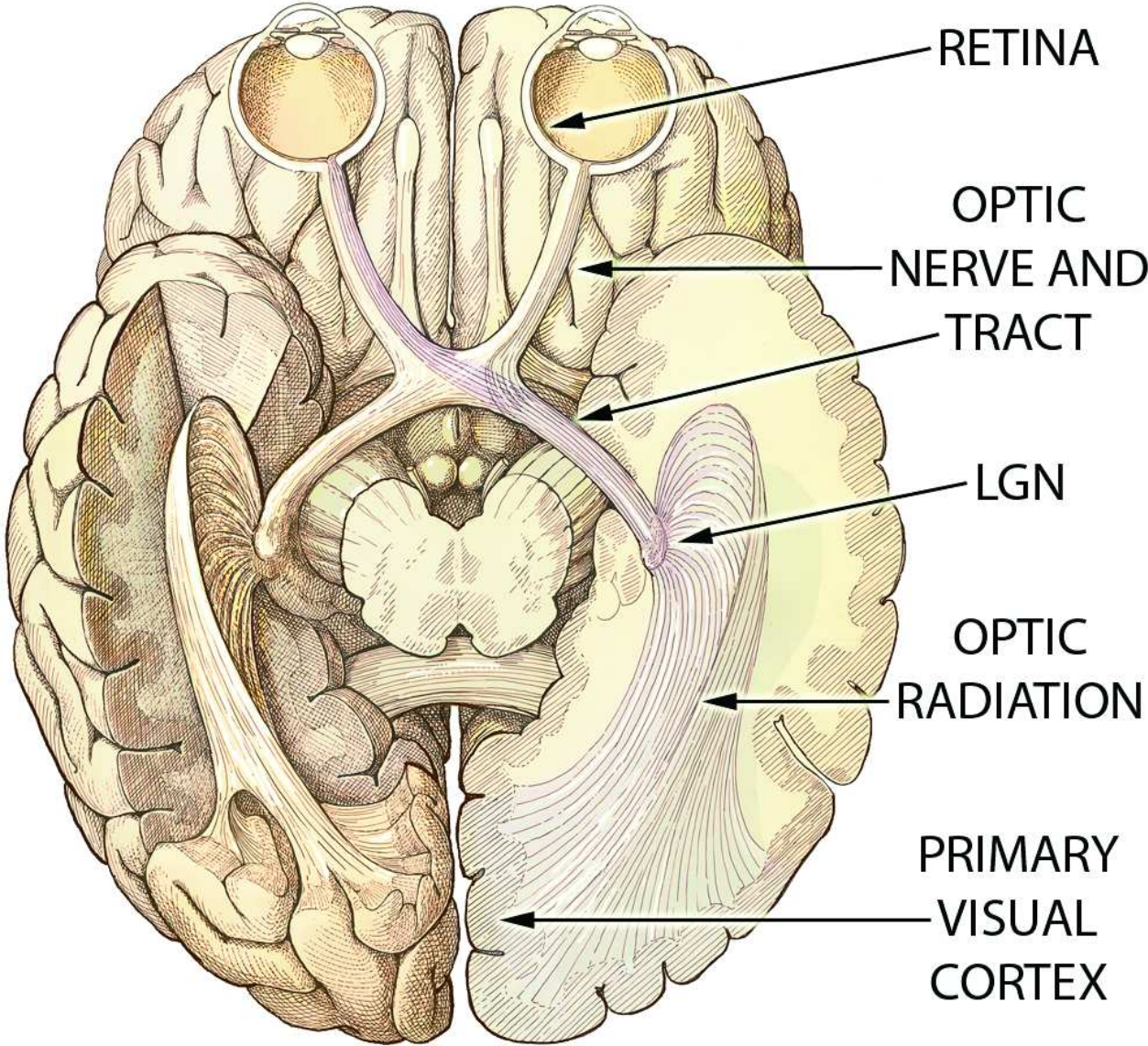


Digital Camera  
Eyeglasses + Wireless Electrode  
Implant in Brain = **Sight for  
the Blind**



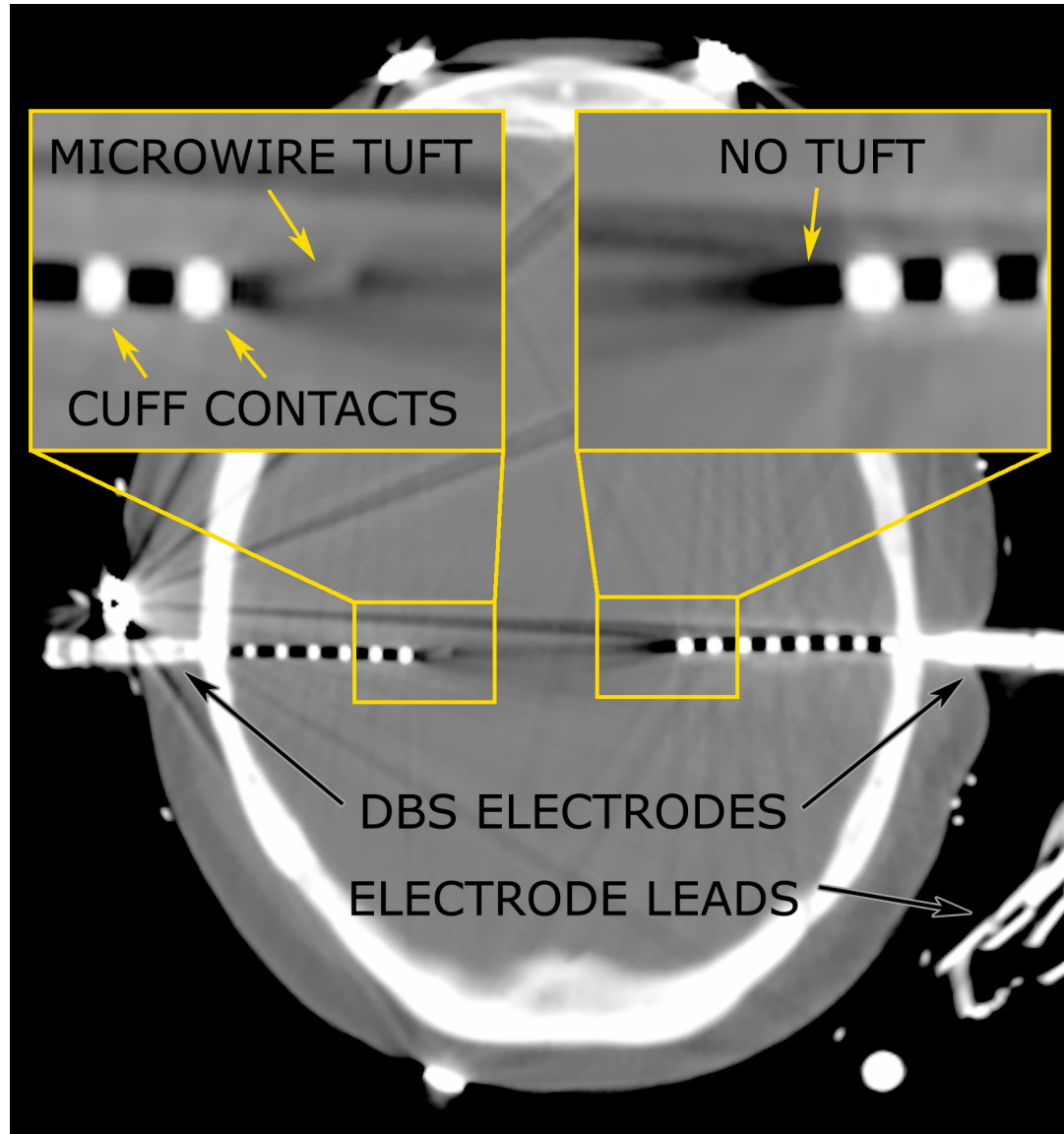
# Early Visual Pathway

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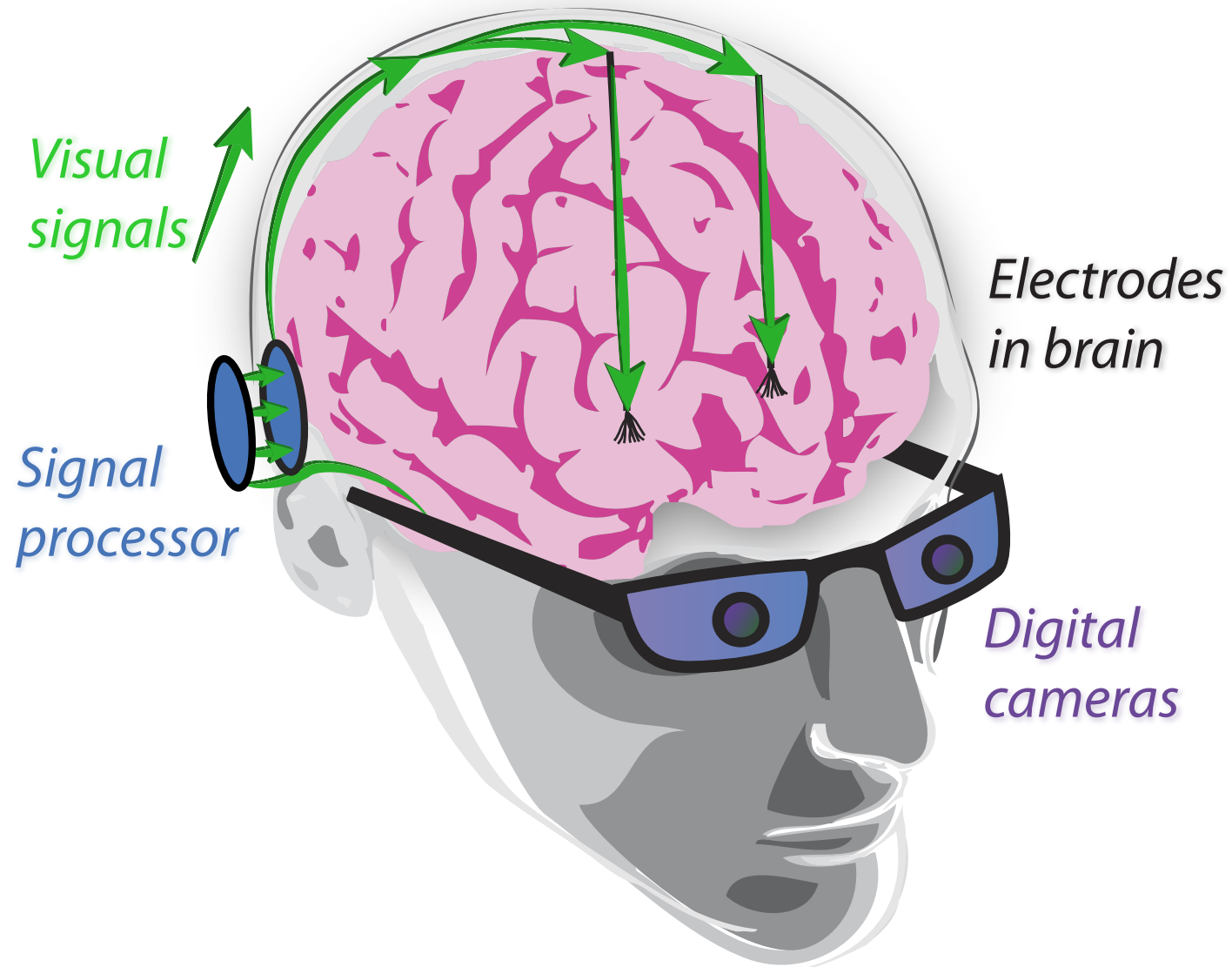
# DBS / Depth Electrodes in the Clinic

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# Prosthesis through Microstimulation in LGN

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# Thalamic Visual Prosthesis Project

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- **Expt. 1: Proof of Concept**
- **Expt. 2: Engineering Validation**
- **Expt. 3: Human Acuity**
- **Expt. 4: Human Reading**
- **Expt. 5: Monkey Acuity**
- **Expt. 6: Monkey Prosthetic Vision**
- **Expt. 7: Human Prosthetic Vision**

# Experiment 1: Proof of Concept

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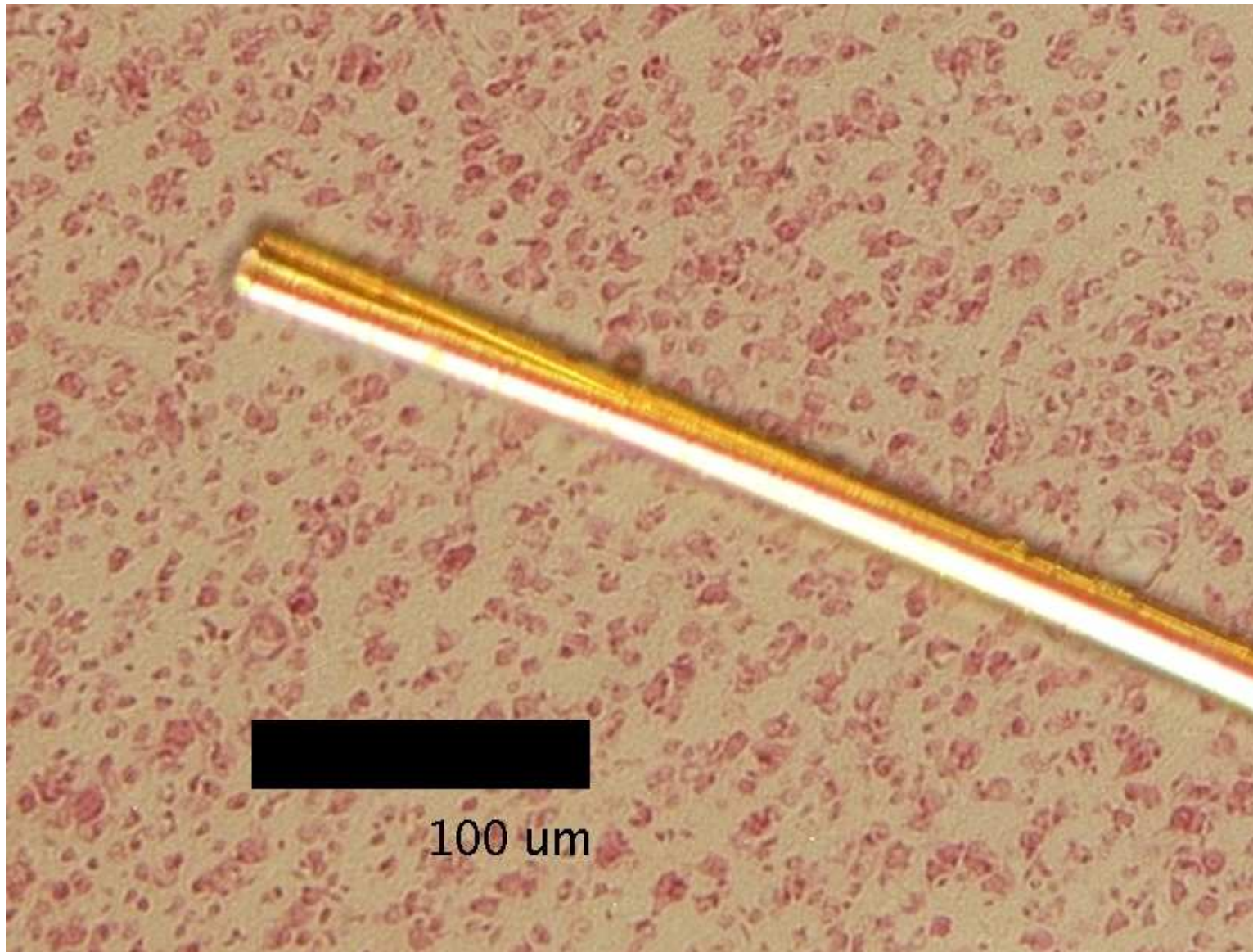
**Q: Does LGN microstimulation elicit predictable visual percepts?**

**(Electrical stimulation in monkeys with behavioral report.)**

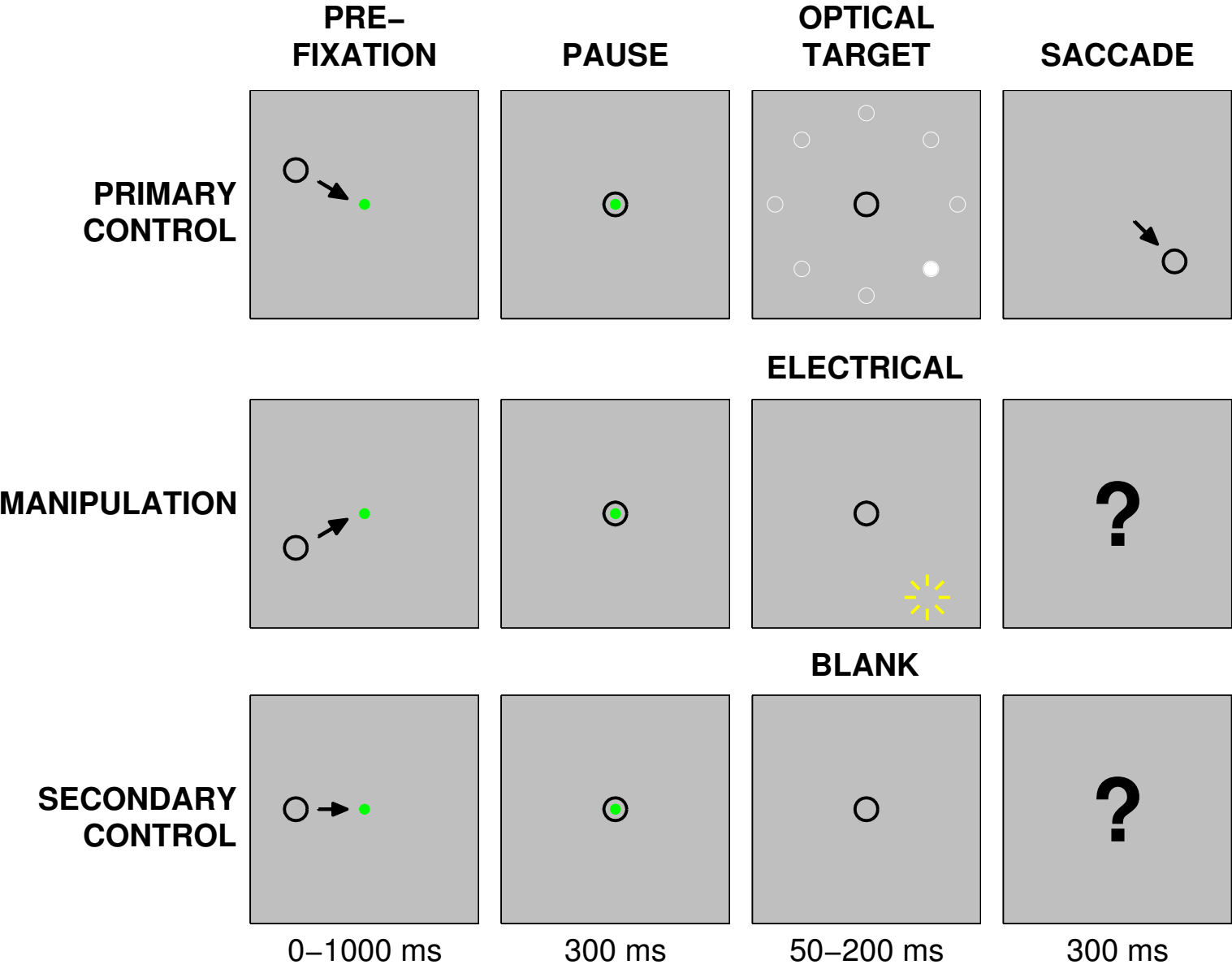


# Experiment 1: Methods

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# Experiment 1: Methods



# Experiment 1: Results

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`vid/pezaris-reid-2007-pnas-movie-sh`

**Movie of monkey saccading from central optically presented point to peripheral points presented both optically and electrically.**



## Expt 2: How Many Electrodes Fit in LGN?

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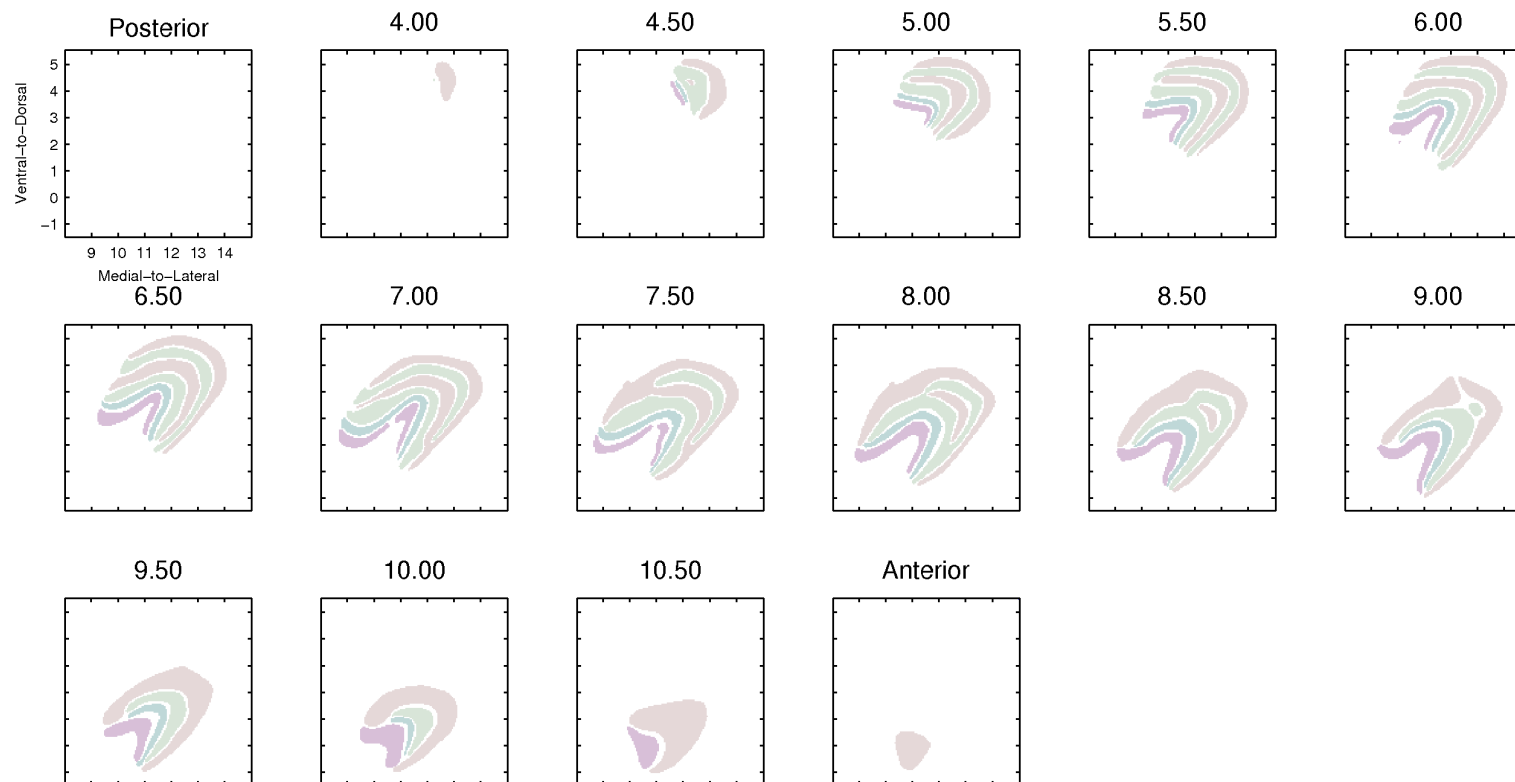
**Q: How many microwires fit comfortably in LGN?**

**(Computer stimulation.)**

# Experiment 2: Methods

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- electrode contacts evenly spaced in 3D
- how many fit in LGN?
- what does it look like?



## Experiment 2: Results

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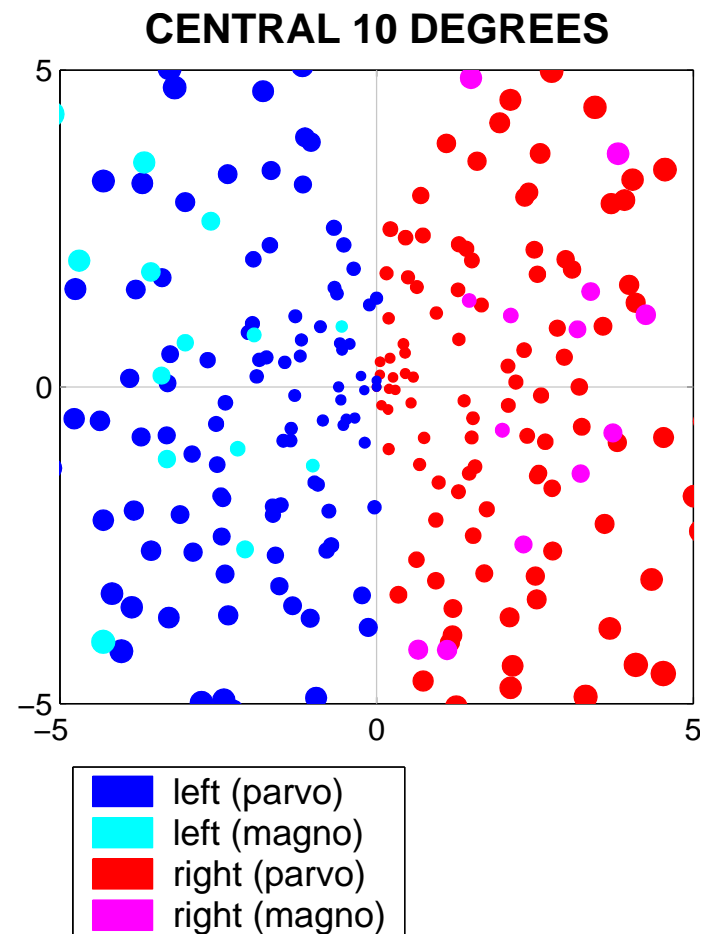
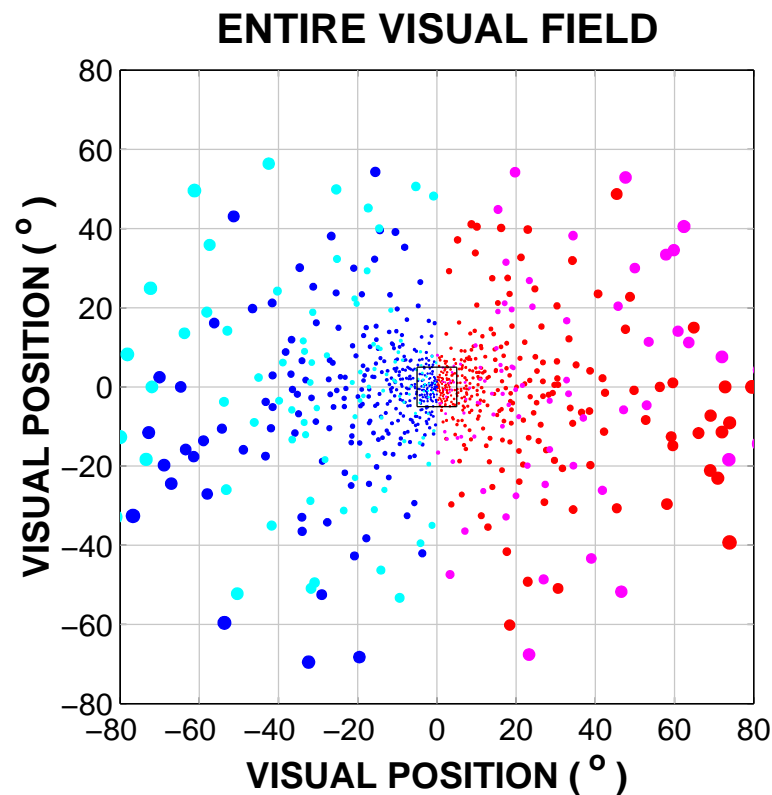
$\lambda$ ( $\mu m$ )	<i>Total Points</i>	<i>Within <math>10^\circ</math></i>	<i>Magno</i>	<i>Parvo</i>
<b>1000</b>	<b>110<math>\pm</math> 4</b>	<b>24<math>\pm</math> 2</b>	<b>12<math>\pm</math> 3</b>	<b>43<math>\pm</math> 3</b>
<b>800</b>	<b>217<math>\pm</math> 4</b>	<b>48<math>\pm</math> 3</b>	<b>23<math>\pm</math> 3</b>	<b>87<math>\pm</math> 4</b>
$\Rightarrow$ <b>600</b>	<b>522<math>\pm</math> 8</b>	<b>124<math>\pm</math> 6</b>	<b>52<math>\pm</math> 5</b>	<b>211<math>\pm</math> 7</b>
<b>400</b>	<b>1707<math>\pm</math>13</b>	<b>372<math>\pm</math> 7</b>	<b>180<math>\pm</math> 8</b>	<b>686<math>\pm</math>11</b>

TABLE 1. *LGN Electrode Tip Count for Isotropic Placement Matrix.* The number of electrode tips landing in LGN were counted for varying mean densities based on Cartesian electrode spacing ( $\lambda$ ). The total count of electrode tips falling bilaterally in LGN is given, along with the number of these which fell within the central 10 degrees of visual space, and the breakdown for those in magnocellular and parvocellular layers.

Adapted from Pezaris, Reid, 2009, IEEE-TR-BME

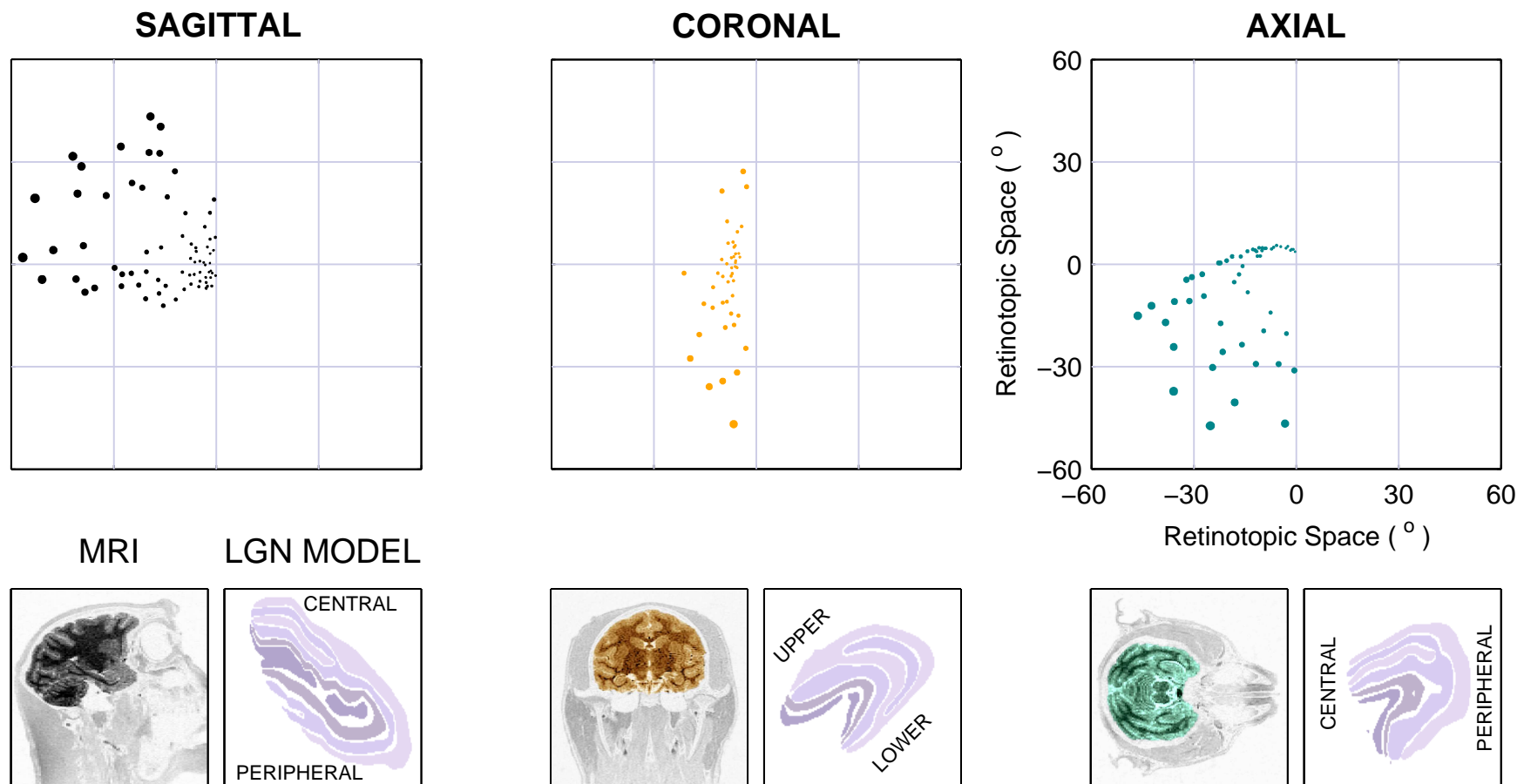
# Experiment 2: Results

- 500 total electrodes / 250 per hemisphere
- 110 total within 10 degrees



# Experiment 2: Results

- Assessment of Surgical Approach (50 contacts)



# Experiment 2: Simulated Artificial Vision

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vid/pezaris-simulated-prosthetic-vision.flv

**Movie of simulated artificial vision.**

# Experiment 3: Acuity vs Electrode Count

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**Q: What acuity with reasonable electrode counts?**

**(Virtual Reality simulation in sighted humans.)**

# Experiment 3: Background

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Snellen Chart for Visual Acuity



# Experiment 3: Methods

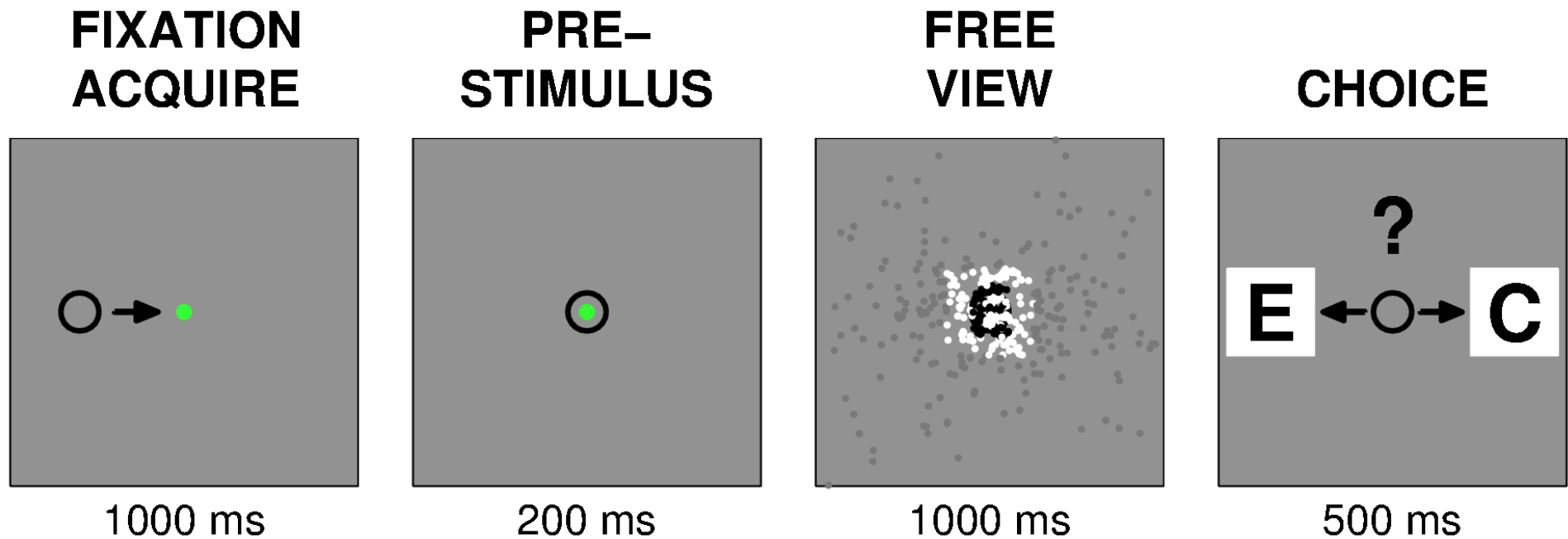
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Bourkiza, Vurro, Jeffries, Pezaris, 2013, PLoS ONE

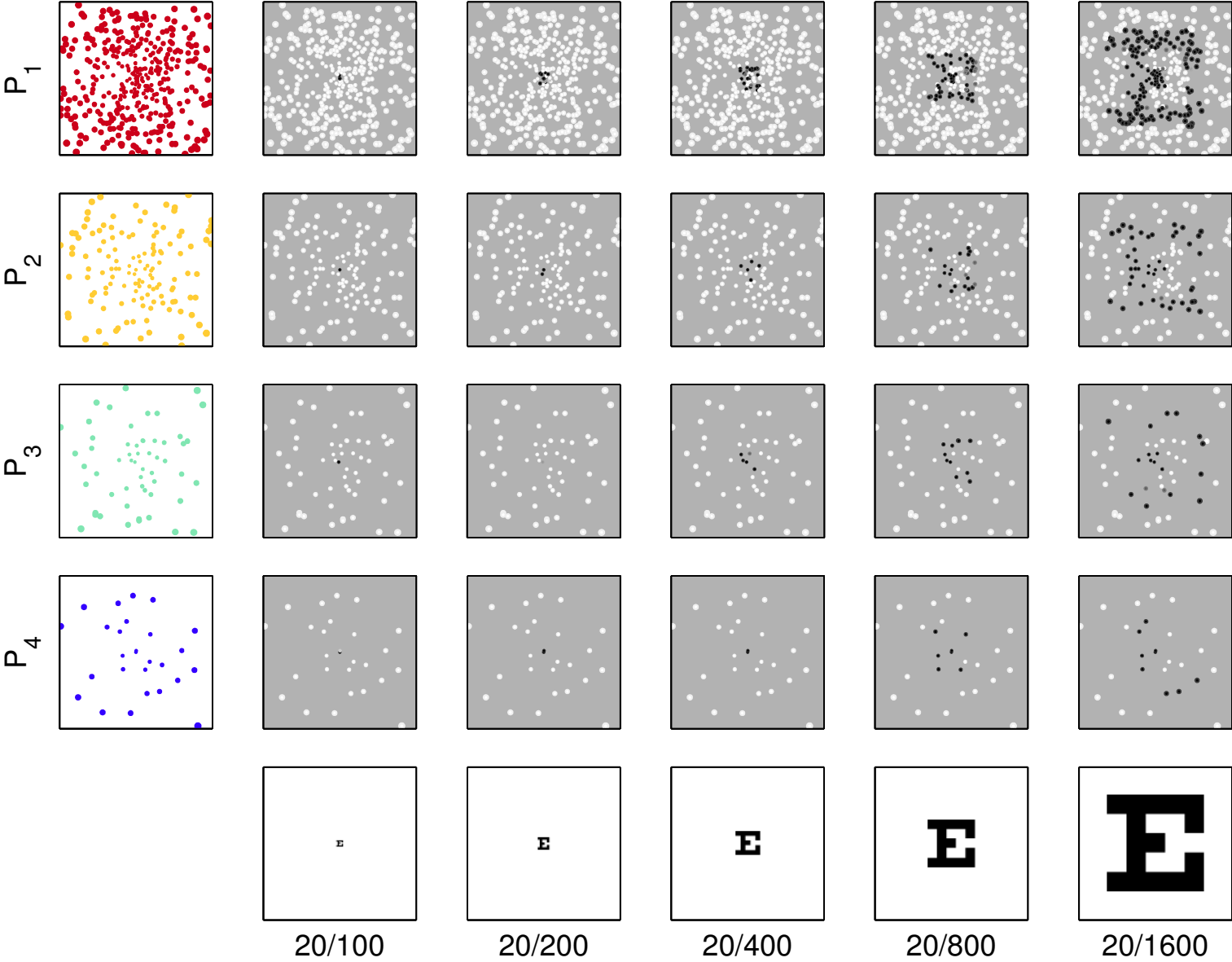
# Experiment 3: Methods

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2AFC Letter Recognition Task

# Experiment 3: Methods



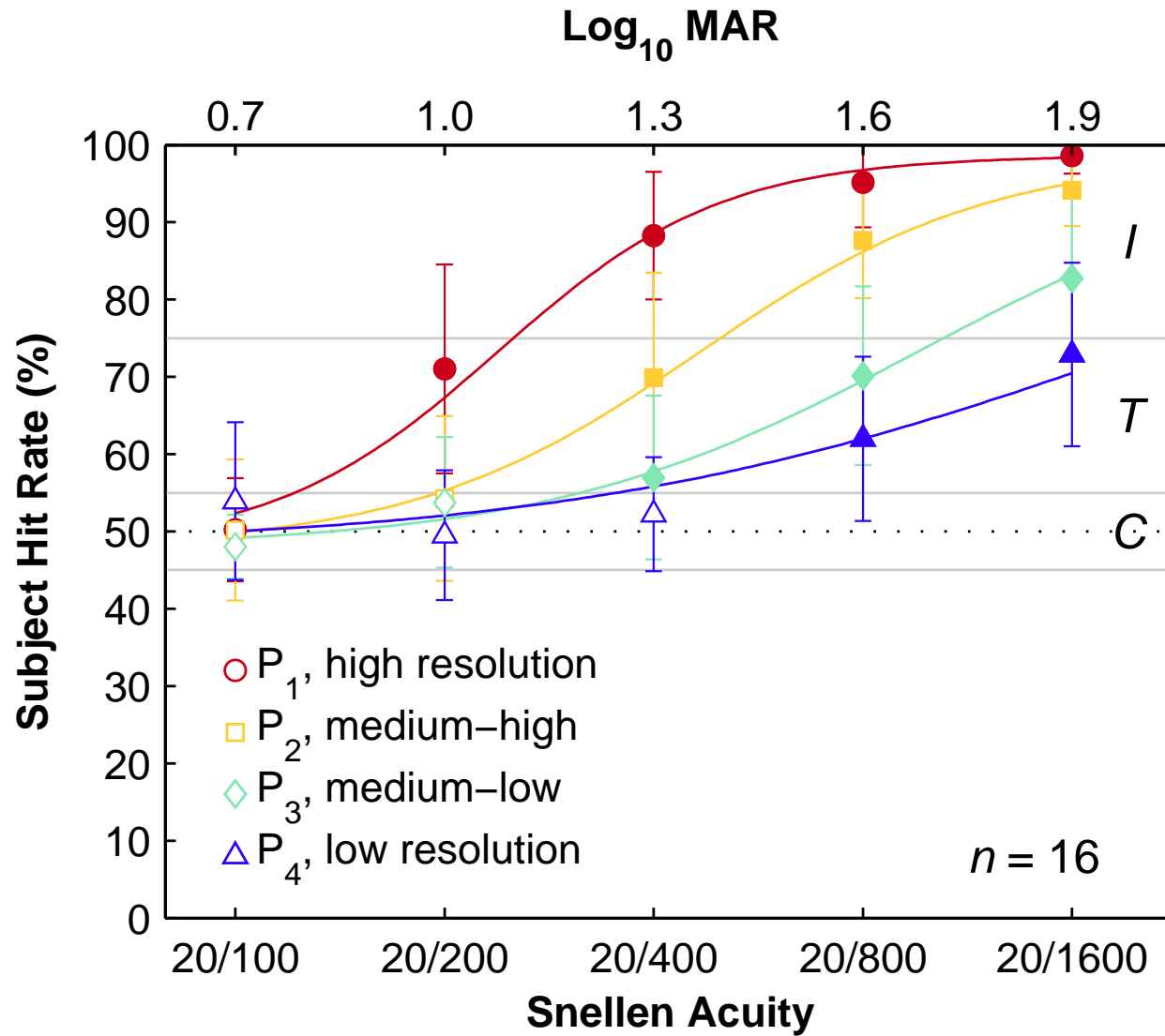
# Experiment 3: Movie

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`vid/pezaris-letter-recognition-movi`

**Movie of human letter recognition task.**

# Experiment 3: Results



# Experiment 4: Human Simulations, Reading

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**Q: Can LGN phosphene patterns be used to read?**

**(Virtual Reality simulation in sighted humans.)**

# Experiment 4: Background

Lighthouse Enterprises  
Professional Products Division  
111 East 58th Street  
New York, NY 10022  
800-433-6923  
Cat. No. C940

**MNREAD™ LOW-VISION READING ACUITY CHART 1**

M size	Snellen for 40cm (16 inches)	logMAR
8.0	20/400	1.3
6.3	20/320	1.2
5.0	20/250	1.1

My father takes me to school every day in his big green car

Everyone wanted to go outside when the rain finally stopped

They were not able to finish playing the game before dinner

© Copyright 1996, Regents of the University of Minnesota. MNREAD™ 3.2.1 300

**MNREAD™ LOW-VISION READING ACUITY CHART 1**

M size	Snellen for 40cm (16 inches)	logMAR
4.0	20/200	1.0
3.2	20/160	0.9
2.5	20/125	0.8
2.0	20/100	0.7
1.6	20/80	0.6
1.3	20/63	0.5
1.0	20/50	0.4
0.8	20/40	0.3
0.6	20/32	0.2
0.5	20/25	0.1
0.4	20/20	0.0

My father asked me to help the two men carry the box inside

Three of my friends had never been to a circus before today

My grandfather has a large garden with fruit and vegetables

He told a long story about ducks before his son went to bed

My mother loves to hear the young girls sing in the morning

The young boy held his hand high to ask questions in school

My brother wanted a glass of milk which his mother refused to give him

I do not understand why my aunt has invited me to the party

The man behind the counter asked me for the money

The teacher asked me to read the story

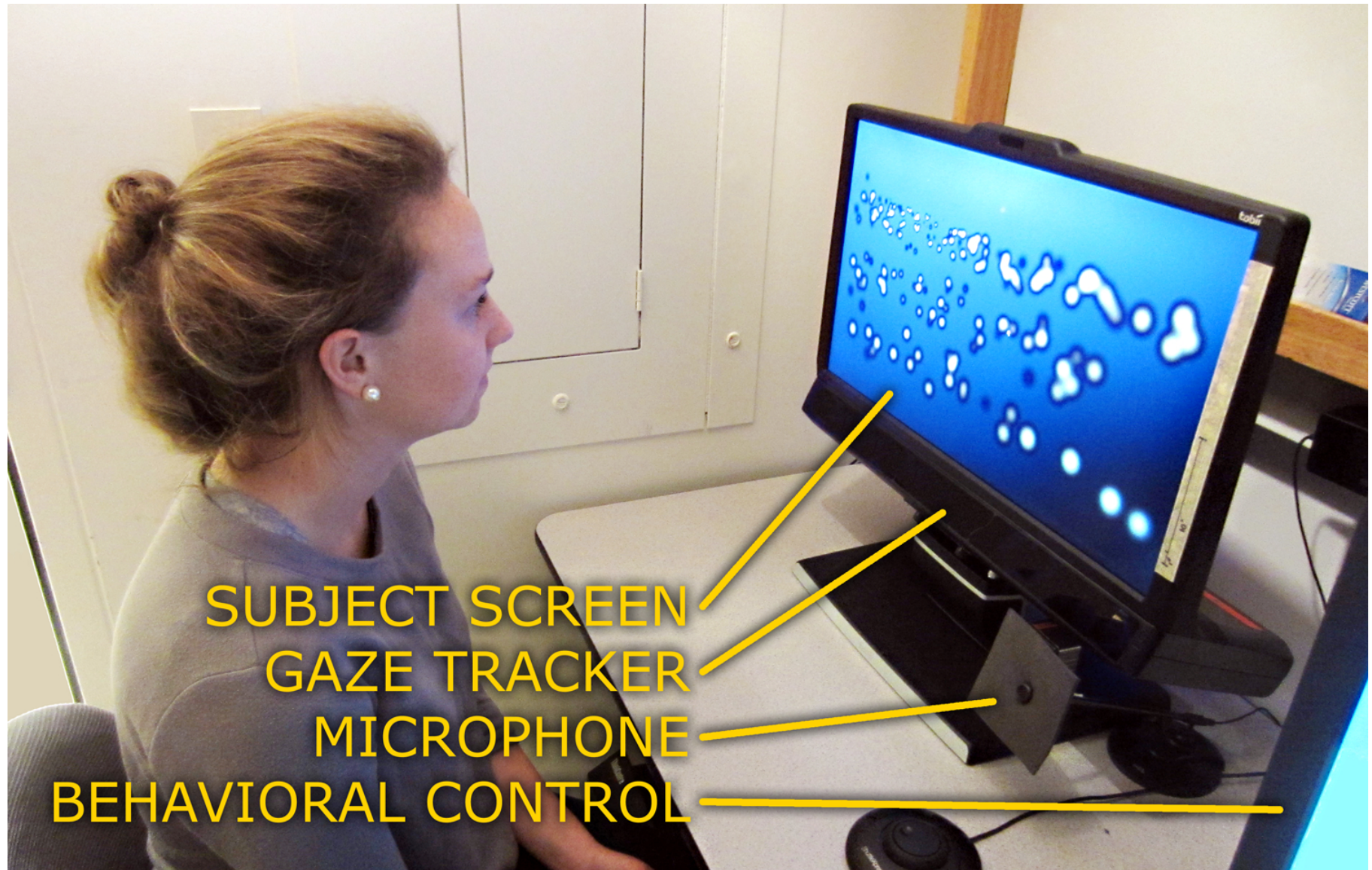
© Copyright 1996, Regents of the University of Minnesota. MNREAD™ 3.2.1 300

## Minnesota Reading Task (MNREAD)



# Experiment 4: Methods

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Vurro, Crowell, Pezaris, 2014, Front. Human Neurosci.



# Experiment 4: Movie (1800 phosphenes)

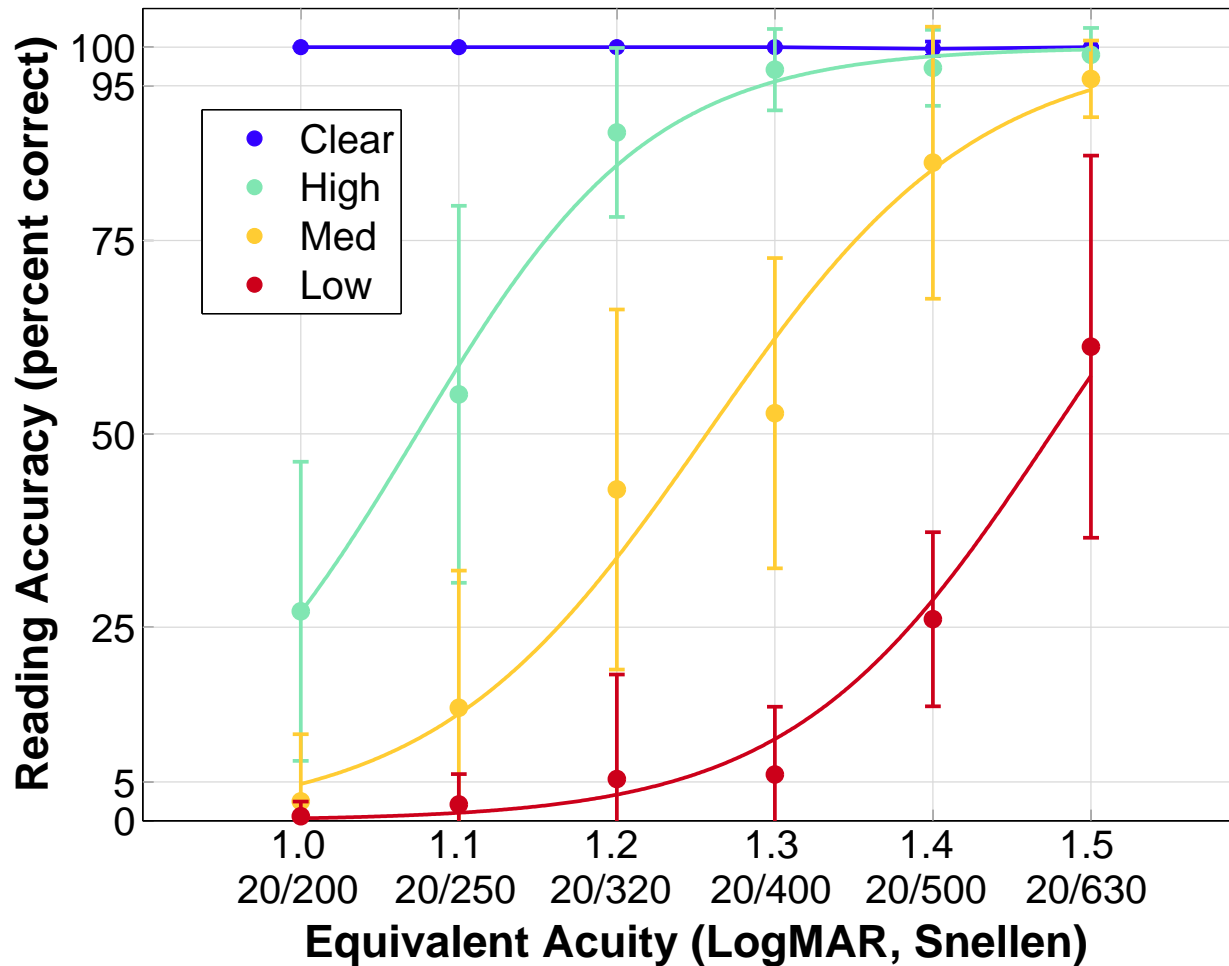
---

vid/reading-h-flowers.flv

**Ten different kinds / of flowers grow by / the side of the road.**

# Experiment 4: Results

**READING ACCURACY vs. NUMBER OF PHOSPHENES**



H,M,L: 1800(370), 1000(230), 500(124)

Vurro, Crowell, Pezaris, 2014, Front Hum Neurosci

# Experiment 5: Monkey Acuity

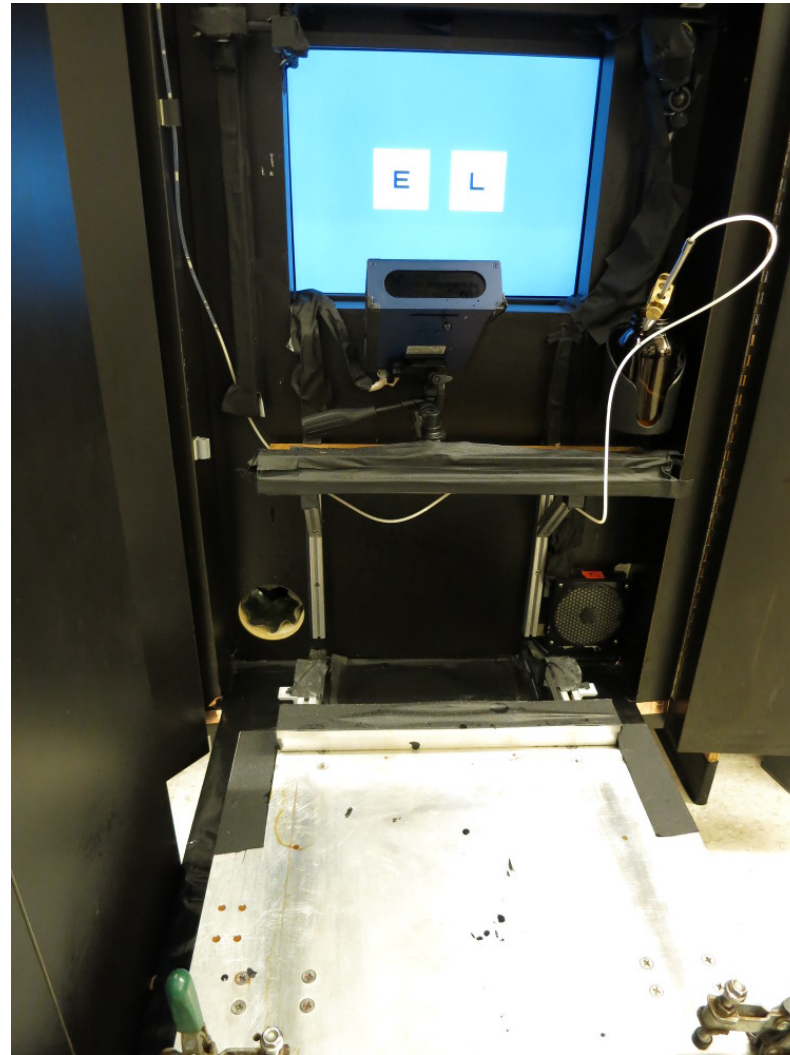
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**Q: What is acuity available for reasonable electrode counts?**

**(Virtual reality simulation in sighted monkeys.)**

# Experiment 5: Methods

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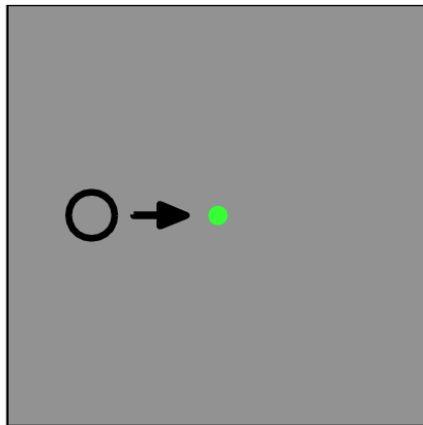


**Monkey version of human psychophysics setup**

# Experiment 5: Task

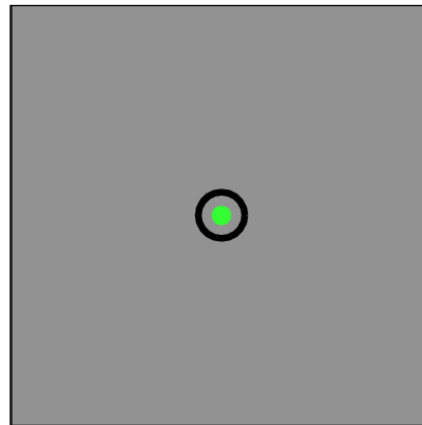
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**FIXATION  
ACQUIRE**



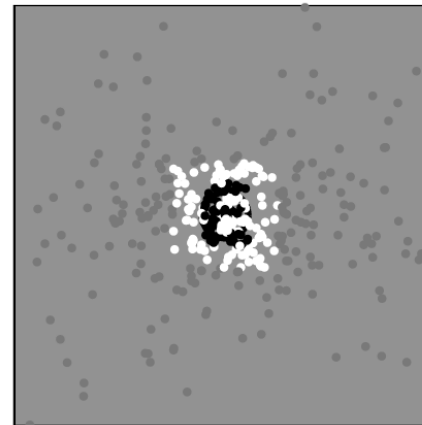
1000 ms

**PRE-  
STIMULUS**



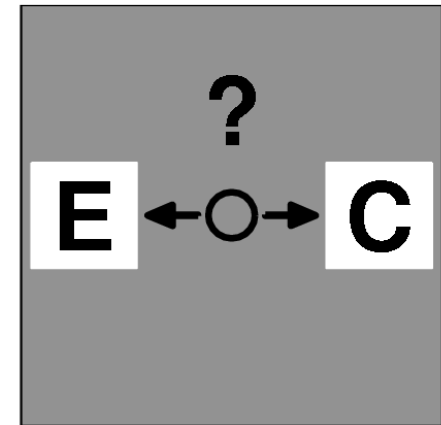
200 ms

**FREE  
VIEW**



1000 ms

**CHOICE**



500 ms

Same as human task, except . . .

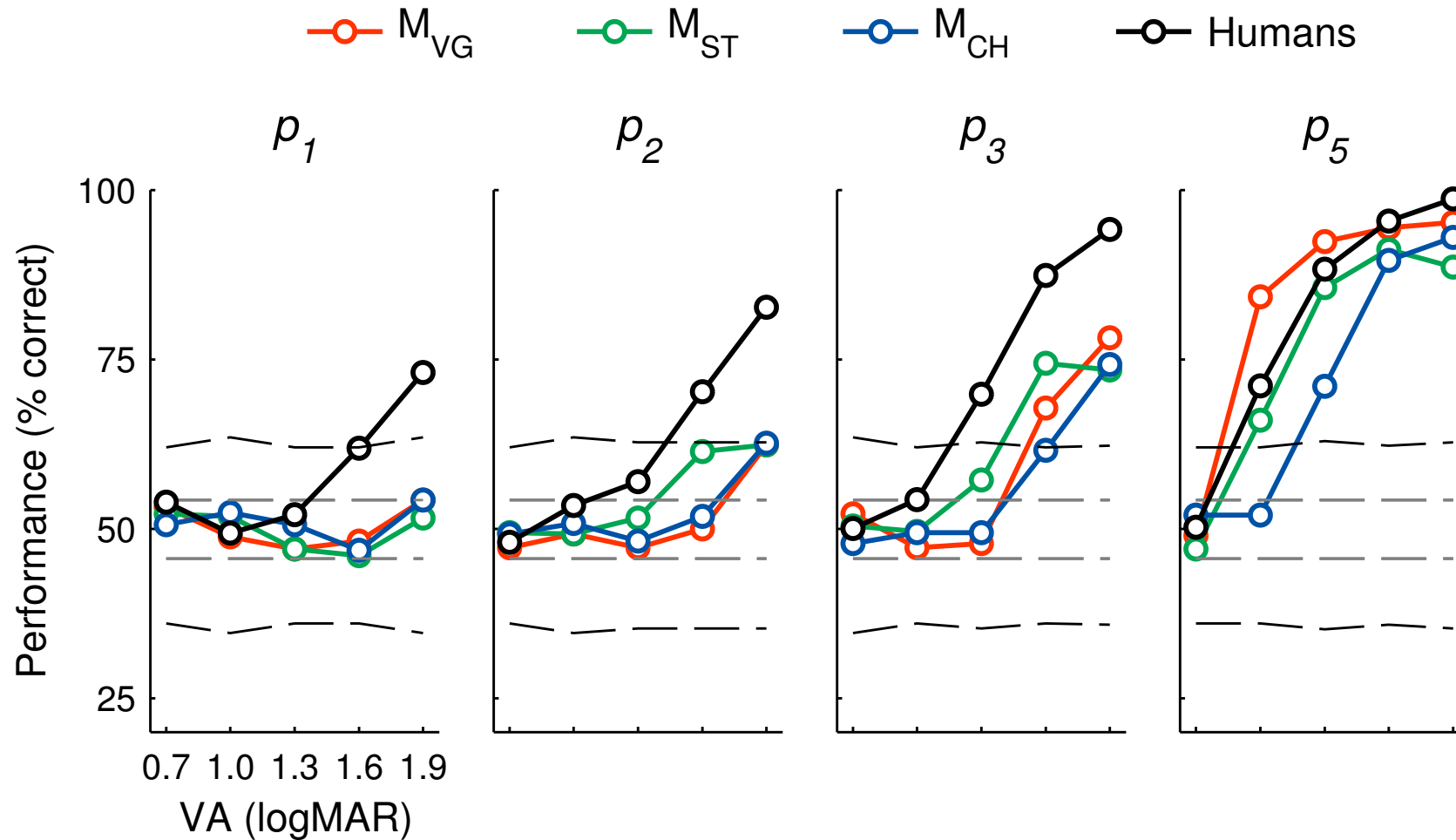
## Experiment 5: Methods

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**A B C D E F G**  
**H I J K L M N**  
**O P Q R S T U**  
**V W X Y Z**

Stelio Font, inspired by Sloan optotypes

# Experiment 5: Results, Acuity

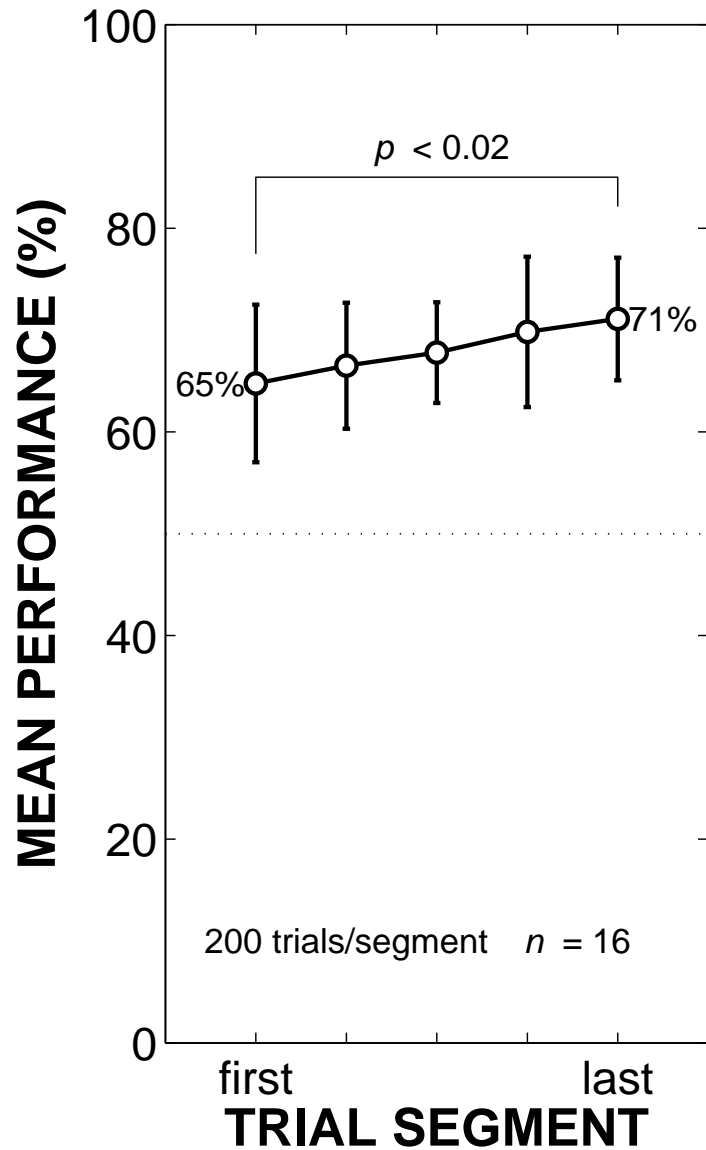


p1-p5: 250(50), 500(120), 1000(230), 2000(450) phosphenes

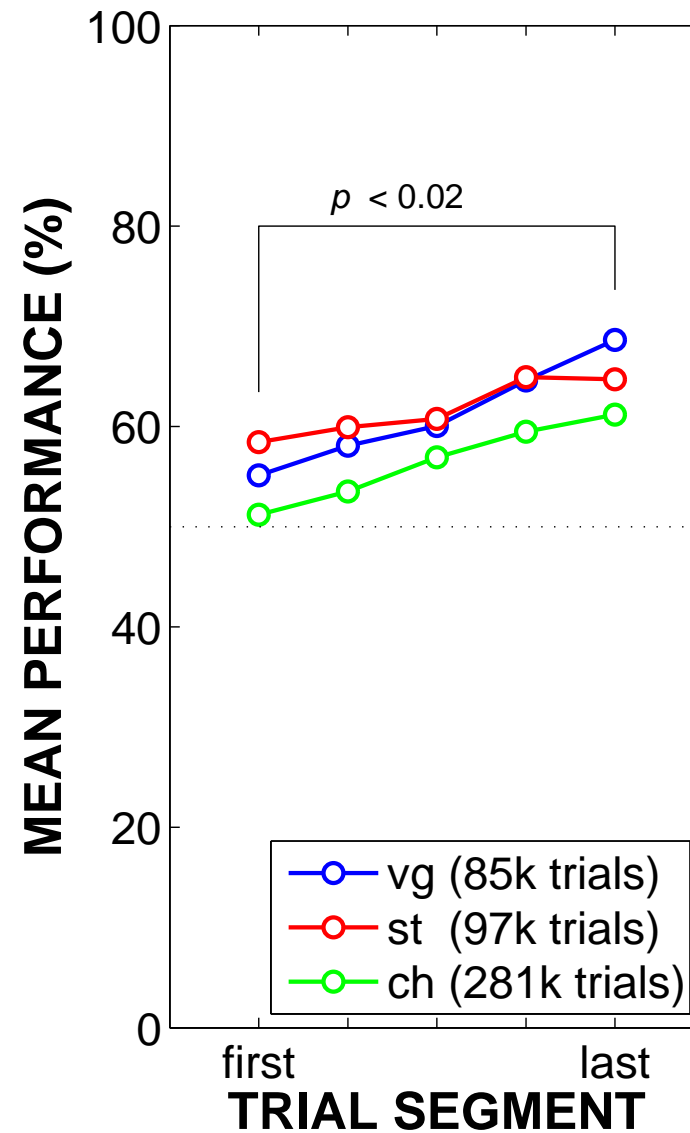
Killian, et al., under revision

# Experiment 5: Results, Learning

## Human (population)

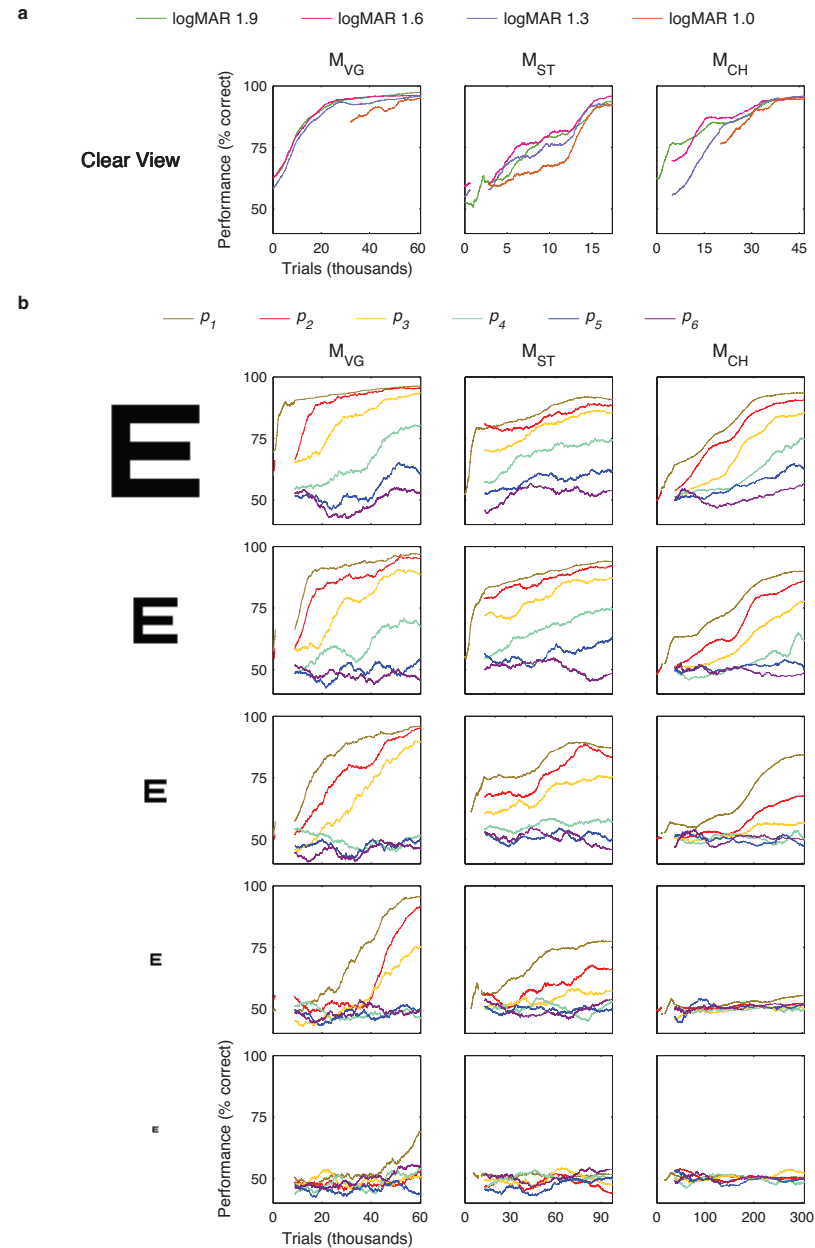


## Monkey (individuals)





# Experiment 5: Results, Learning





# Experiment 6: Monkey Prosthetic Vision

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**Q: Can monkeys use prosthetic vision in a cognitive task?**

**(Real visual prosthesis in sighted monkeys.)**

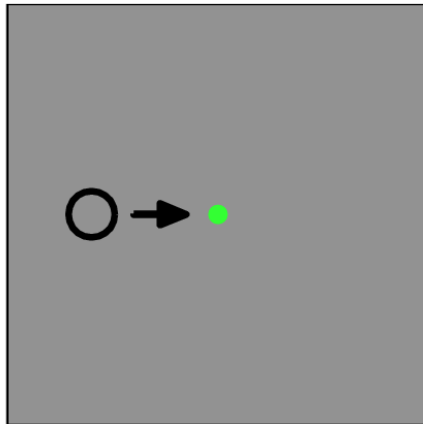
**— ongoing —**

# Experiment 6: Task

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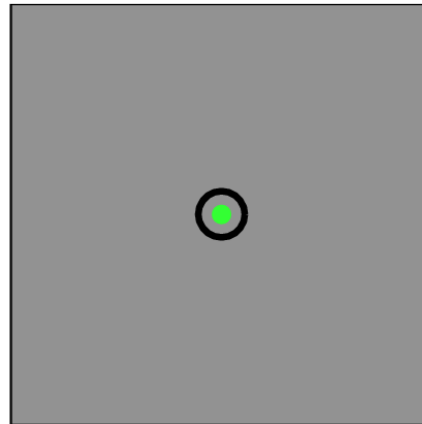


**FIXATION  
ACQUIRE**



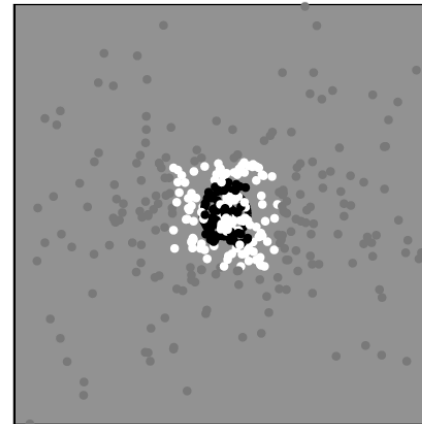
1000 ms

**PRE-  
STIMULUS**



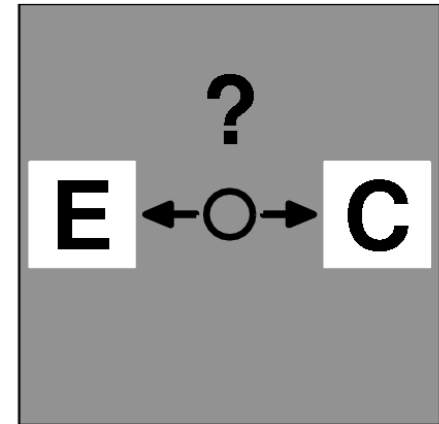
200 ms

**FREE  
VIEW**



1000 ms

**CHOICE**



500 ms

Task as before, except cues presented electrically.

## Experiment 6: Methods

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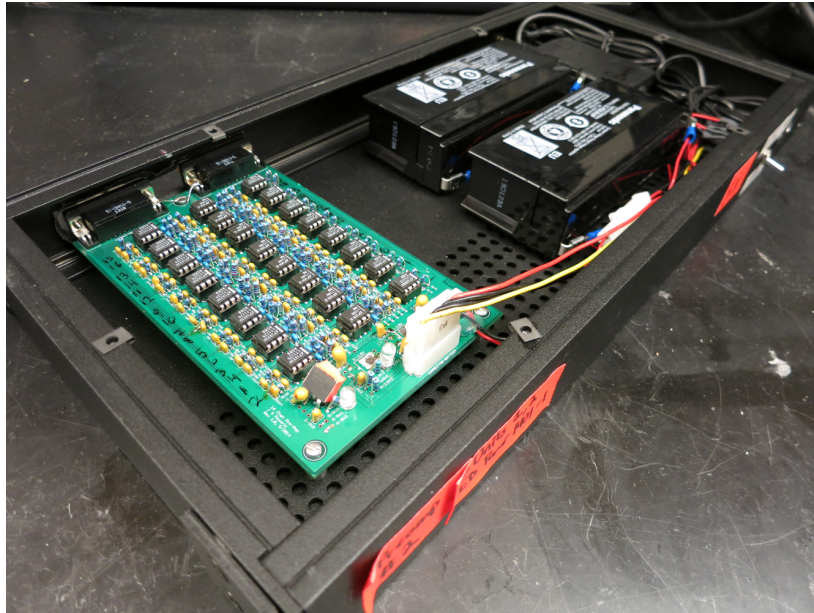


**64 Channel Microwire Bundle Electrode**

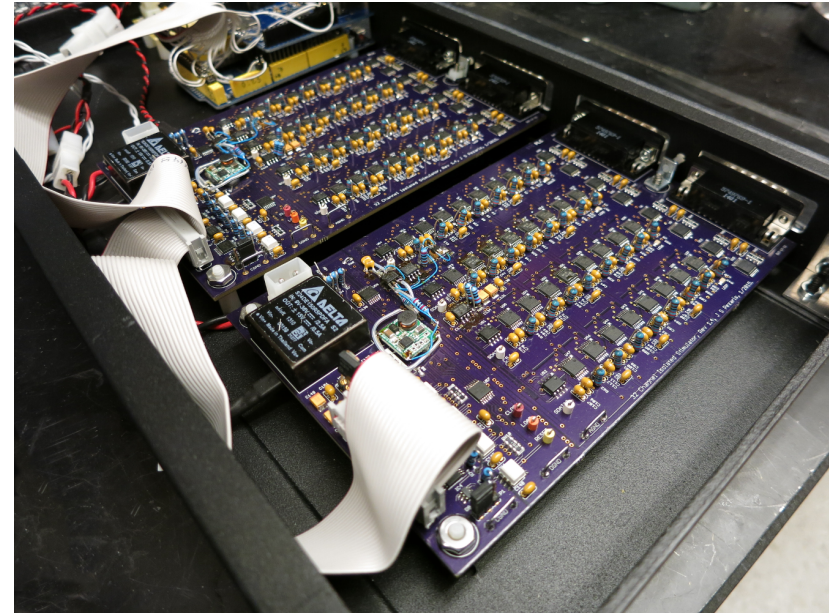


# Experiment 6: Methods

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**16 Channel Precision Amp**



**64 Channel Stimulator**

# Experiment 6: Results

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— Results Shortly —

# Experiment 7: Human Prosthetic Vision

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**Q: Can humans use prosthetic vision in a cognitive task?**

**(Real visual prosthesis in blind humans.)**

**— Near-future work —**



# Summary

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- Expt. 1: Proof of Concept** . . . . . **done**
- Expt. 2: Engineering Validation** . . . . . **plenty of room**
- Expt. 3: Human Acuity** . . . . . **good performance**
- Expt. 4: Human Reading** . . . . . **good performance**
- Expt. 5: Monkey Acuity** . . . . . **hard to learn**
- Expt. 6: Monkey Prosthetic Vision** . . . . . **ongoing**
- Expt. 7: Human Prosthetic Vision** . . . . . **near future**

# **Institutional and Individual Sponsors**

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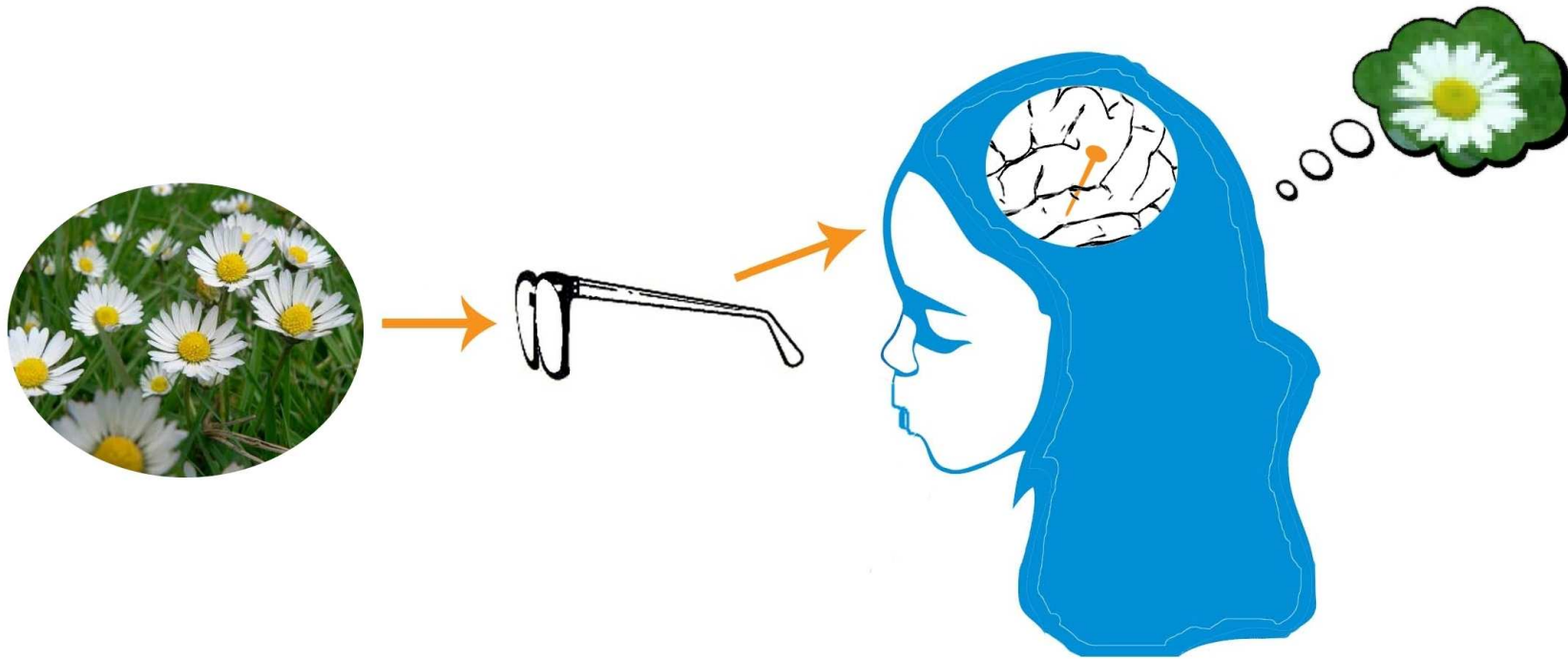
**National Eye Institute (NIH)  
Campbell and Hall Charity Fund  
Rappaport Foundation  
NIMA Foundation**

**George, Daphne Hatsopoulos  
Philippe Laffont  
John and Genevieve Wolfe  
Jeffrey Pisarek  
Geoffrey Marcus**

**Peter Pezaris  
William and Lori Goldenthal  
Christopher Lewis  
Michael Gersh  
Teddy and Sumi Cho**

# Sight2Blind

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Digital Camera  
Eyeglasses + Wireless Electrode  
Implant in Brain = **Sight for  
the Blind**

<http://www.sight2blind.org>