Microstimulation in LGN Produces Focal Visual Percepts: Proof of Concept for a Visual Prosthesis

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Background: Visual Prostheses

- Blindness due to Diseases of the Eye
  - glaucoma
  - macular degeneration
  - retinitis pigmentosa

- Electrical Stimulation
  - sensory neurons failed
  - silicon sensor
  - microstimulation

- Current Approaches
  - retinal stimulation
  - cortical stimulation
Background

- Novel Approach: LGN
Hypothesis

- Electrical Response Similar to Optical Response
  - place electrode in LGN
  - measure receptive field (RF)
  - stimulate same physical location
  - generate focal percept at RF?
Methods: General

- 1 M. Mulatta (Rhesus macaque), 2 hemispheres
- head fixed, scleral coil to measure eye position
- tetrodes: 10 & 13 μm, ML-insulated tungsten, 0.2–0.6 MΩ
- daily electrode insertion
- mapping paradigm to measure RF
  - standard white-noise reverse-correlation techniques
- saccade paradigm to measure response to stimulation
  - charge-balanced stimulation between 2 of 4 tetrode wires
  - 25-200 ms pulse train, 1 ms sinusoid pulses, 100–200 Hz
Methods: Mapping Paradigm

- **EYE POS**
- **FIX POINT**
- **PRE-STIMULUS**
- **MAP**
- **POST-STIMULUS**

Fixation points are marked with circles, and stimulus images are shown sequentially.
Methods: Saccade Paradigm

- **Fixation (0–1000 ms)**: Eye position (EYE POS) fixation point (FIX POINT)
- **Pre-stimulus (300 ms)**: Optical target
- **Optical Target**: Various dots and shapes are shown
- **Saccade (< 300 ms)**: Electrical target
- **Electrical**: Two blue dots with a yellow ignition
- **Blank (50–200 ms)**: Single blue dot
Results: Optical, Electrical, and Blank Targets

- Optical (80%): $n = 76$
- Electrical (10%): $n = 8$
- Blank (10%): $n = 9$
RF Maps and Electrical Target Saccades

RF Map

Electrical Saccades

RF/Saccade Overlay

$EYE\ POS\ X\ (deg)$

$EYE\ POS\ Y\ (deg)$

$n = 9$
RF Maps with Electrical Target Saccades
Optical, Electrical Saccade Latencies

![Graph showing optical versus electrical saccade latencies](image)
Main Sequences

![Graph showing relationship between saccade size and peak speed. The graph includes data points for optical, electrical (L), and electrical (R) measurements.](image-url)
Comparative Accuracy

ERROR DISTANCE

ENDPOINT SCATTER

DEGREES

DEGREES
Dual Electrodes: Two Discriminable Targets

040721  TETRODE 1

040721  TETRODE 2
Probably not Directly Evoking Saccades
Conclusions

- LGN electrical stimulation can produce focal percepts
  immediate effectiveness in saccade task
  electrical saccades are comparable to optical saccades
  saccade endpoints tightly clustered
  10 degree (likely better) discrimination
  double-saccade hints at perceptual rather than motor effect

- 2 now, 10 soon, ... form vision?
  currently running 2-electrode experiments
  plan for 10 electrodes soon
  eventually, enough for form vision?
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