Scleral search coils provide accurate estimates of eye position

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Introduction

- Fixational eye movements scatter stimuli about the retina, inflating estimates of receptive field (RF) dimensions, reducing estimates of peak responses, and blurring maps of RF subregions.
- Scleral search coils are used to measure eye position.
- Stimulus position is shifted by the eye coil signal, and stabilized on the retina.

Aims

- What is the noise level and stability of the eye coil system?
- Can coils sutured to the sclera signal eye position more reliably than those used by Read and Cumming (2003)?

Methods

Monkey fixation training Two monkeys (Macaca mulatta) were trained to fixate within a ±1 degree window for 5 sec trials.

Eye coil implantation Coils with 3 turns (Monkey 46) or 4 turns (Monkey 49) were sutured to the sclera. The eye coil system is Remmel Labs EM7 with preamps close to the monkey.

Stimuli Bright and dark bars having optimal orientation, color, and spatial configuration were swept across the receptive field in each direction at 1-15 deg/s. Comparisons were made between stabilized and unstabilized conditions.

Extracellular recording Single units were recorded extracellularly.

RF measurement Peristimulus time histograms were compiled, and then integrated to obtain cumulative curves. A tanh function was fit to the curves. RF width was taken as the length of the central segment of the distance between the 5% and 95% points of the tanh function (fig. 6B).

Fig 1

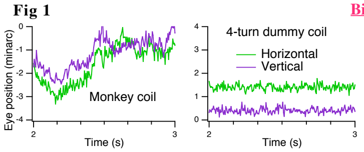


Fig 1: Eye position sample from Monkey 49 (same as fig. 2B) and dummy coil (same as fig. 2D) at expanded scale to show noise levels.

Results

Eye position graphs from monkey and dummy coil

Fig 2

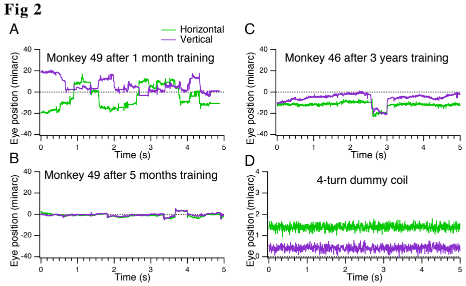
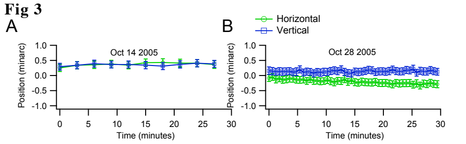


Fig 2: Characteristic eye movements exhibited by two monkeys. A) example eye position record from monkey 49 after one month's training. B) eye position after 5 months' training, in which saccades were fewer and saccade amplitude was lower. C) eye position of monkey 46 who was highly trained. D) dummy coil, with noise in a range of 0.5 minarc.

Noise level and long-term stability of the eye coil system

Fig 3



Intertrial SD = 0.05 minarc	Intertrial SD = 0.07 minarc
Intratrial SD = 0.12 minarc	Intratrial SD = 0.11 minarc

Fig 3: Modal position from a 4-turn dummy coil for 5s trials over half hour runs on two different days.

Fig 4

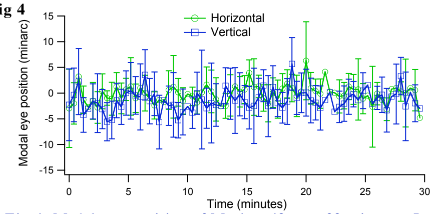


Fig 4: Modal eye position of Monkey 49 over 30 minutes. Intratrial SD was 2.6 minarc (horizontal) and 3.4 minarc (vertical), intertrial SD was 2 minarc (horizontal) and 2.7 minarc (vertical).

Binocular measurement

Fig 5

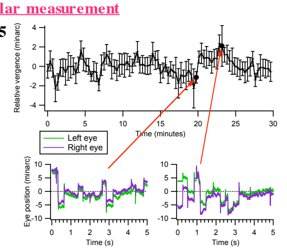


Fig 5: Relative vergence at 2° of Monkey 49 over half an hour. Intratrial SD was 0.9 minarc and intertrial SD was 1.0 minarc.

Receptive field width

Fig 6

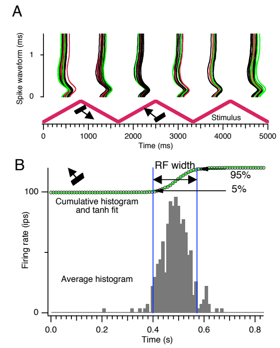


Fig 6: A) Spikes in response to sweeping bar during 5s trial.

Fig 6: B) Cumulative histogram with tanh fit to measure RF width.

Fig 7

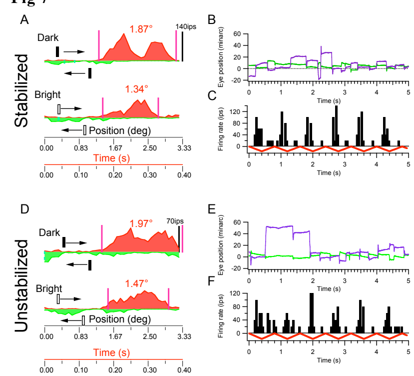


Fig 7: RF width was measured in a simple cell with and without stabilization. Upper half depicts stabilized condition while lower half depicts unstabilized condition. Left column shows the RF measurement. Right column is eye position and corresponding response in one trial.

Fig 8

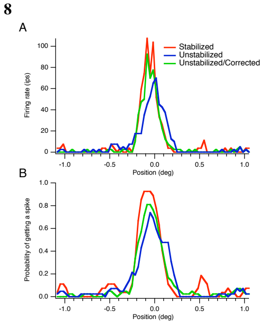


Fig 8: A) RF measured with stabilization, and without stabilization before and after offline correction.

B) Probability of getting a spike in each condition.

RF width comparison in stabilized vs unstabilized conditions

The mean RF width over the population using stabilization is 1.2 deg (SD 0.92 deg), which is narrower than without stabilization (1.3 deg, SD 1.02), by a shift of 8 minarc ($p<0.01$, N=127, paired t-test).

Fig 9

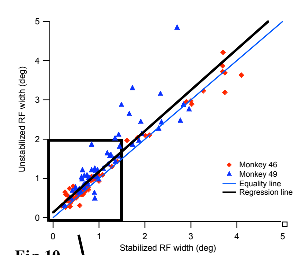


Fig 9: Unstabilized RF width vs. stabilized RF width. The regression line (thick black) is above the equality line (thin blue) with slope of 1.04. The offset between them is about 0.13 deg (8 minarc) for all RF widths, presumably reflecting eye movement jitter.

Fig 10

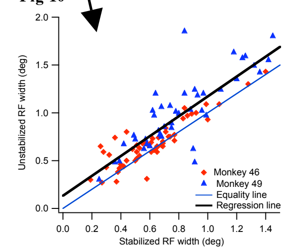


Fig 10: Expanded view of fig 9 for small RF widths.

Fig 11

Stabilization Index := $(RF_{unstab}-RF_{stab})/RF_{stab}$

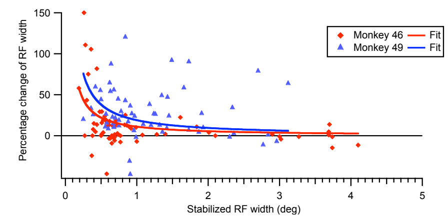


Fig 11: SI as a function of stabilized RF size in two monkeys. The fit across the combined data set is shown. Given the jitter in eye position, small RFs are affected proportionally more.

Conclusions

Search coils can provide highly reliable eye position signals. RF widths measured with stabilization were smaller than without. Offline correction does not recover what is seen with stabilization, because spikes are missed. Stabilization using scleral search coils improves the accuracy with which stimuli can be positioned on the retina. This permits study of fine receptive field structure. Stabilization affords needed stimulus control to accurately test parafoveal receptive fields.