# Spatiotemporal structure of peri-saccadic receptive fields in monkey area V4: A remapping study

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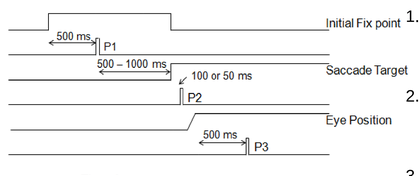
## Hypotheses

1. Predictive remapping of visual receptive fields (RF) prior to execution of a saccade has been observed in multiple visual areas such as LIP (Duhamel et. al., 1992), V3 (Nakamura and Colby, 2002), FEF (Sommer and Wurtz, 2001, 2006), SC (Walker et. al 1996, Churan et. al., 2011). Other findings suggest that RF dynamics in V4 change during the time of a saccade; RF converges towards the saccade target (Tolias et. al., 2001) unlike the classic remapping of 'shifting receptive fields'. Are these two observed phenomena paradigm-dependent – the former observation uses brief flashes of visual probes while the latter uses persistent visual probes?

2. Psychophysics studies suggest that remapping occurs only for certain attended locations on the visual space (Jonikaitis et. al 2012, Rolfs et. al 2010). If so, remapping response of a neuron should be enhanced by priming the future receptive field location of that neuron with a stimulus to draw attention.

3. Do remapped signal also encode features? If remapping is purely a shift of receptive field, the properties of the neuron should remain intact in terms of spatial, frequency and orientation tuning. If remapping signal only encodes attended locations, feature selectivity of the neuron should vanish at the remapped location.

## Conclusions




Experimental paradigm shown in schematics

1. Remapping or pre-saccadic receptive field shift depends on the temporal profile of visual stimuli. In V4, classical receptive field shift was observed with flashed visual probe where as RF shift towards saccade goal was observed with static visual probe.
2. Priming the future field location with visual probes yielded enhanced remapped response consistent with the hypothesis laid out by phychophysicists (Rolfs et al 2011) that only few attended locations get remapped and not the entire visual field.
3. Orientation selectivity of a neuron is either lost or altered at the remapped location.
   **Conclusion: Pre-saccadic remapping aids in keeping few attended locations stable throughout eye movements, but it does not encode features, of those attended locations, in fine detail.**

## Remapping with flashed probe

Figure: 1

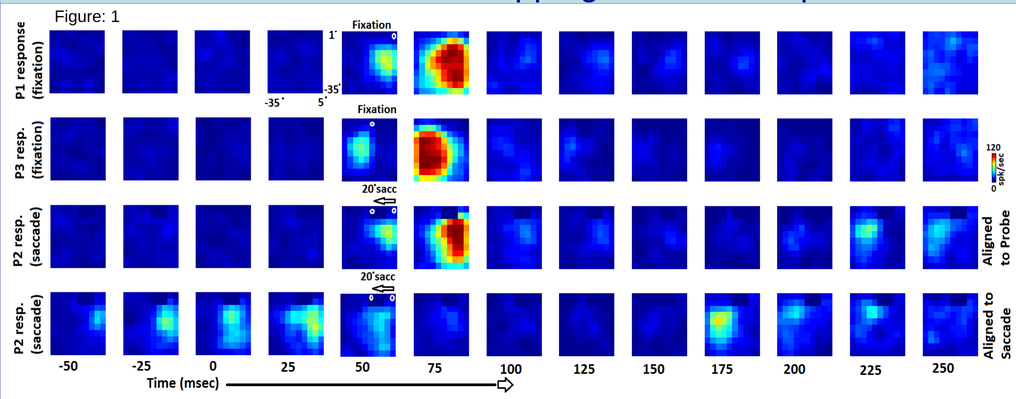



Figure: 2

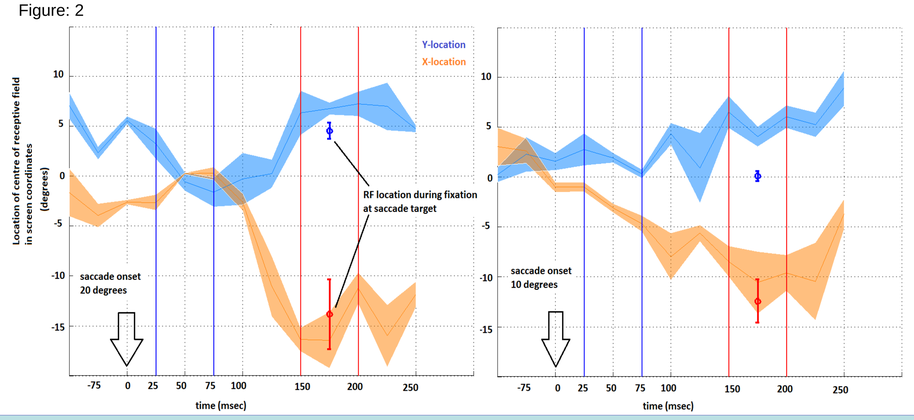
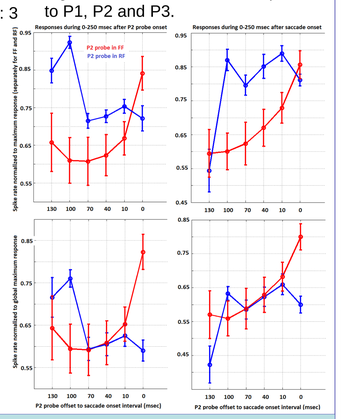



Figure: 3




Electrophysiological recording was done using chronically implanted 10x10 electrode array. Each trial started with the animal fixating for 500 milliseconds(ms) after which a probe **(P1)** was flashed. After 500-800 ms of further fixation, saccade target appeared and a second probe **(P2)** was flashed, 100 ms after the saccade target appearance. Once the animal successfully executed the horizontal saccade and foveated the saccade target for 500 ms, a third probe **(P3)** was flashed. Each probe was 25ms long. Probes were presented in one of the locations on a 10x10 (4 degrees spacing) or a 6x6 (8 degrees spacing) grid. Probes of sizes 2 and 6 degrees were used. Figure 1 on the left shows responses to P1, P2 and P3.

## Remapping with Static probe

Figure: 4

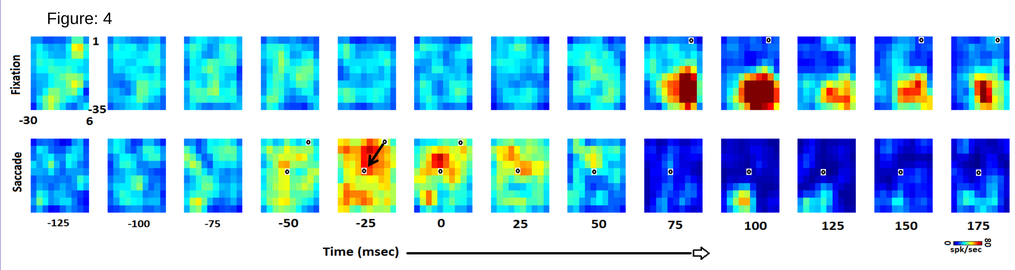



Figure 2: Peri-saccadic time course of receptive field centre for 20 degree (left, n=5 neurons ) and 10 degree (middle, n=13 neurons) saccades. 2D Gaussian functions were fitted to the RFs. Markov Chain MonteCarlo simulation was done to find the uncertainty on the estimated RF centres.

Figure 3: Strength of remapping plotted against time interval between probe offset and saccade onset (replication of Kusunoki and Goldberg 2003).

Figure: 5

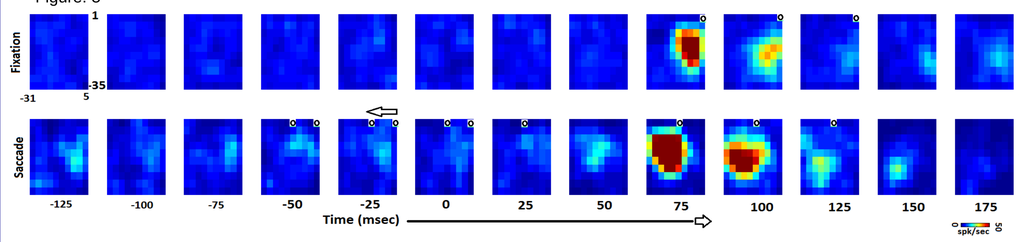



Figure 4-5: Remapping occurs at the time of saccade when static probes are used (replication of Tolias et al 2001). Unlike classical remapping (above), in this case receptive field compresses towards the saccade target. Consistent with literature, this effect is only strongly observed when saccades are made towards the receptive field.

## Feature remapping: Orientation selectivity at remapped location

Orientation selective cell changed its selectivity at the remapped location. Figure 9 on the right shows the time course of a neuron's response to Gabor patches presented during fixation as well as pre-saccadically. Probes were located on a 6x6 grid. Responses were averaged across vertical slices on the spatial map. Horizontal spatial locations are thus plotted in a row on the x-axis. Orientation selectivity of the cell is represented by color code.

Figures 10-12 below shows the orientation selectivity of 8 different cells. 7 out of 8 cells showed reduced or changed orientation selectivity at the remapped location.

Figure: 9

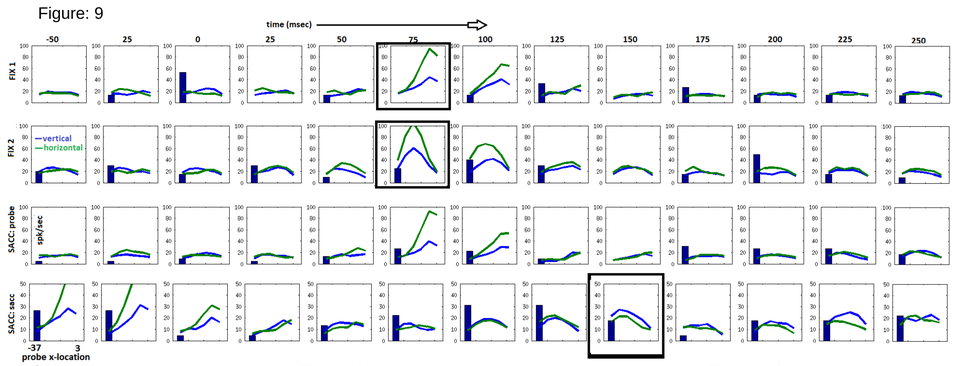



Figure: 10

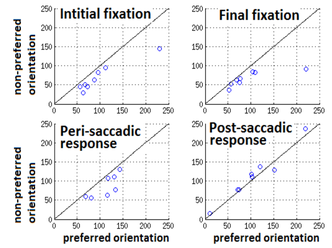



Figure: 11

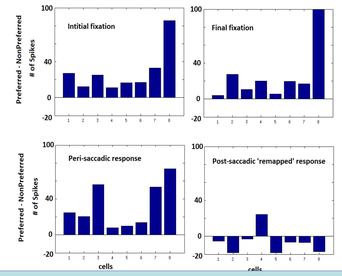
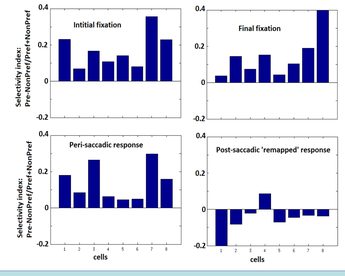



Figure: 12




## Enhanced remapping of attended location

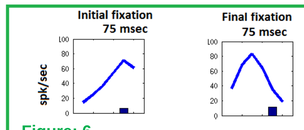



Figure: 6

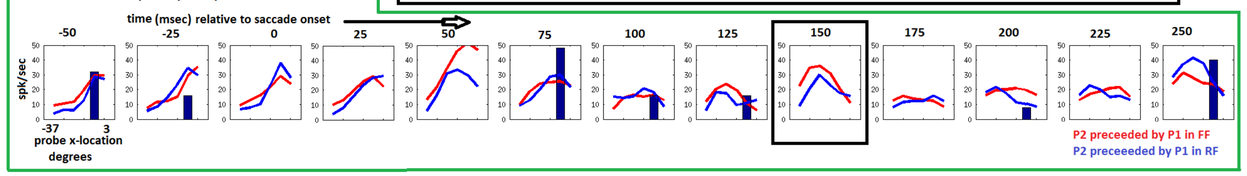
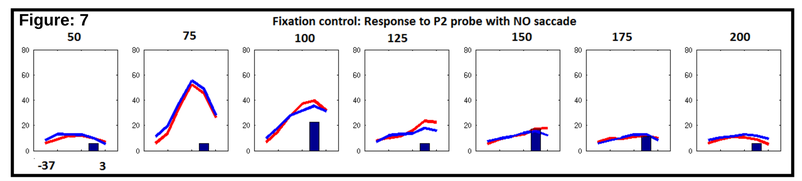



Figure: 7




If P1 probe, flashed during fixation prior to P2, is drawing bottom-up attention, remapping response to P2 probes should be enhanced if only those trials are selected in which P1 falls on the future field. The red traces in the figures 6-8 (Fig 6 above: Gabor patches on 6x6 spatial grid. Fig 8 below: square probes on 10x10 spatial grid) show responses to P2 from trials in which P1 was flashed on the future field. The blue traces show responses to P2 from trials in which P1 was flashed in the receptive field.

Fixation control: Plots in the black box above (Fig 7) show responses to P2 with similar analyses, expect that the animal fixated throughout the trial through P1, P2 and P3 probes. The fixation point was the saccade target location.

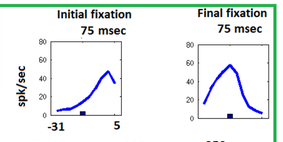



Figure: 8