Neural activity in macaque V1 accurately predicts the timing of fixations and saccades

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It has long been a mystery how coherent and continuous visual perception results from the succession of snapshots we see during short fixation periods separated by rapid saccadic eye movements. For example, to what extent and how is a visual scene “stitched together” from disjoint fixations? Conversely, how is information on different fixations parsed from continuous neural activity? To answer these questions it seems that analysis in visual cortex must be informed of the times during which the eyes are fixating or moving. Previous EEG and extracellular recording studies suggest that at least some areas of visual cortex show activity associated with eye movements. But how useful is this information and can it be used to infer what the eyes are doing? We addressed this question by investigating whether neural activity in primary visual cortex can accurately and reliably be used to estimate epochs of time during which there are fixations and saccades. Recordings of local field potentials (LFPs) and action potentials were made from a 4x4 mm area V1 of alert macaques using 96-electrode “Utah” arrays. The animals either freely explored visual scenes or executed a series of fixations cued by fixation points. We computed from each channel’s LFP an average signal around the time of saccades and used this LFP signature to predict saccades and fixations. We find that nearly 100% of the time the LFP across channels correctly predicts whether the animal is fixating or making a saccade on a natural scene. The precision in estimating when saccade or fixation intervals begin has a standard deviation of about 10-20 msec. It thus appears that within area V1 there is sufficient information to assess the fixation state of the eyes. Several additional findings further clarify this result. We find that when the visual scene is a uniform gray display, the LFP signals are lower amplitude; they still predict fixation state (90% correct) but with considerably worse temporal precision (+/- 100 msec). Analyses were also conducted on action potentials from the recording array rather than the LFPs. If predictions are based on the best recording channel, spikes are also able to reliably predict saccades and fixations. However, there is a major difference between the spike and LFP results: the great majority of channels carry an LFP signal that reliably predicts fixation state whereas only a small number of channels can be used to predict fixations based on action potentials. In summary, neural activity in V1 is sufficient to predict with high reliability the times of fixations and saccades, particularly from the LFP. Whether the information is used to parse or stitch information across saccades requires further study.