Supplementary Movie and Figure Legends

Supplementary Movie 1 This video shows a sample trial of extrafoveal tracking, running at half the actual experimental frame rate. The green crosshair shows the monkey's eye position during this trial. The monkey successfully tracked the invisible center of the stimulus composed of only two peripheral bars.

Supplementary Figure 1 This figure shows a zoomed-in representation of the initial transient response of the neuron in Figure 3C,E of the main text. The black and gray curves correspond to the two different phases of initial stimulus motion, just like in Figure 3C,E of the main text. The neuron exhibited an initial transient response at around 50 ms after onset of the peripheral bar inside its response field. The magnitude of this response was similar for the two phases, and it was also similar across the two conditions shown (extrafoveal tracking and extrafoveal stimulation). This response, however, was smaller than the initial response during memory guided saccades (Figure 3A of the main text) – probably because of the use of a large extended stimulus as opposed to a small, punctate spot. The second sample neuron of Figure 3 of the main text is not shown here because it did not exhibit an initial transient response to stimuli presented inside its response field.

Supplementary Figure 2 Tiling of retinotopic space by neurons representing the instantaneous location of the inferred movement goal during extrafoveal tracking. The figure shows normalized activity for the four sample neurons of Figure 5 of the main text as a function of the retinotopic eccentricity of the movement goal along the tracking axis. This analysis is identical to that of Figure 4B of the main text. Red, blue, green, and magenta correspond to the neurons of Figure 5A, B, C, and D of the main text, respectively. As can be seen, each neuron individually signaled when the movement goal occupied a certain region in and around the fovea, and this region differed across neurons. This indicates that as an entire population, the neurons provided a distributed representation of the instantaneous goal location.

Supplementary Figure 3 Comparison of extrafoveal tracking and extrafoveal stimulation responses when taking neuronal preferred eccentricities into account. We binned all neurons (from both the peripheral and central groups) according to their preferred eccentricity (see Materials and Methods of the main text for more details). We then

plotted the average difference in firing rate between extrafoveal tracking and extrafoveal stimulation (involving fixation of a small, foveal spot) as a function of bin location (when the goal was aligned on the center of gaze). The most central neurons exhibited similar activation in the two conditions (giving rise to a small average difference in firing rate), but slightly more eccentric neurons were more active during extrafoveal tracking than during extrafoveal stimulation. This pattern of results – also consistent with the results of Figure 9A,C of the main text – explains why some of our neurons in Figure 6 of the main text exhibited similar activity levels in the extrafoveal tracking and extrafoveal stimulation conditions, and why the central neurons were generally more active than the peripheral ones during both conditions. Since both conditions involved a foveal goal, both of them were expected to activate the most central SC neurons. Consistent with this, the data in this figure (circles) could be fit well by a difference-of-Gaussians function (solid line) whose logic is explained by the inset. Please also see Figure 9 of the main text. Error bars indicate s.e.m.

Supplementary Figure 4 An additional illustration of how a single neuron in the SC can appear to be issuing fixation commands if its spatial tuning is not taken into consideration. The top left column shows the average eye position of a monkey performing memory guided saccades to a peripheral location in the contralateral visual field. The bottom left panel shows the average firing rate (as well as individual trial spike rasters) from a neuron in the rostral SC – representing central locations – recorded during this behavior. This neuron maintained a fairly constant firing rate during fixation, and it completely paused its activity during the saccade. This is one of the hallmarks of the so-called 'fixation neurons' in the rostral SC (other tests not shown here, but see Materials and Methods in the main text). However, the right column of the figure indicates why this neuron should not be classified as a 'fixation neuron'. When the monkey made a much smaller memory guided saccade to the contralateral visual field (top right), the neuron gradually increased its activity during the delay interval before saccade onset, and it also burst during the saccade itself. This pattern of activity is almost identical to that observed with other neurons in the remainder of the SC map for saccades towards locations inside these neurons' response fields.