

## Commentary

# The Distribution of Microsaccade Directions Need Not Reveal the Location of Attention

## Reply to Rolfs, Engbert, and Kliegl

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Rolfs, Engbert, and Kliegl have demonstrated that microsaccades can reveal the direction of covert attentional shifts either toward (Engbert & Kliegl, 2003) or away from (Rolfs, Engbert, & Kliegl, this issue) a peripheral cue under certain circumstances. Our previous analysis (Tse, Sheinberg, & Logothetis, 2002) of the fixational eye movements collected at the same time as the change-detection data upon which Rolfs et al. comment revealed no effect of cue location on mean fixational eye movements. Other researchers subsequently reported finding changes in the distribution of microsaccades after the occurrence of a peripheral cue (Engbert & Kliegl, 2003; Hafd & Clark, 2002), contradicting our null finding. Examining macaques, Horwitz and Albright (2003) found that the incidence of microsaccades around fixation increased after the onset of a peripheral cue, but, like us, they found no relationship between cue location and microsaccade direction. Because we limited our previous analysis to mean trajectories of thousands of fixational eye movement traces, it was possible that we missed changes that would be evident only in the spatial distribution of microsaccades, which could have contributed negligibly to averaged eye movement traces. We therefore reanalyzed our data using Engbert and Kliegl's (2003) code for microsaccade detection. We now report that there was indeed no consistent effect of the location of a peripheral cue on the distribution of microsaccade directions in these data. Thus, we find that the distribution of microsaccades need not correlate with the direction of attentional allocation.

The large polar plots in Figure 1c show the distribution of microsaccade<sup>1</sup> direction probabilities pooled over 4 subjects at 100-ms intervals starting 100 ms after the onset of peripheral cues to the left,

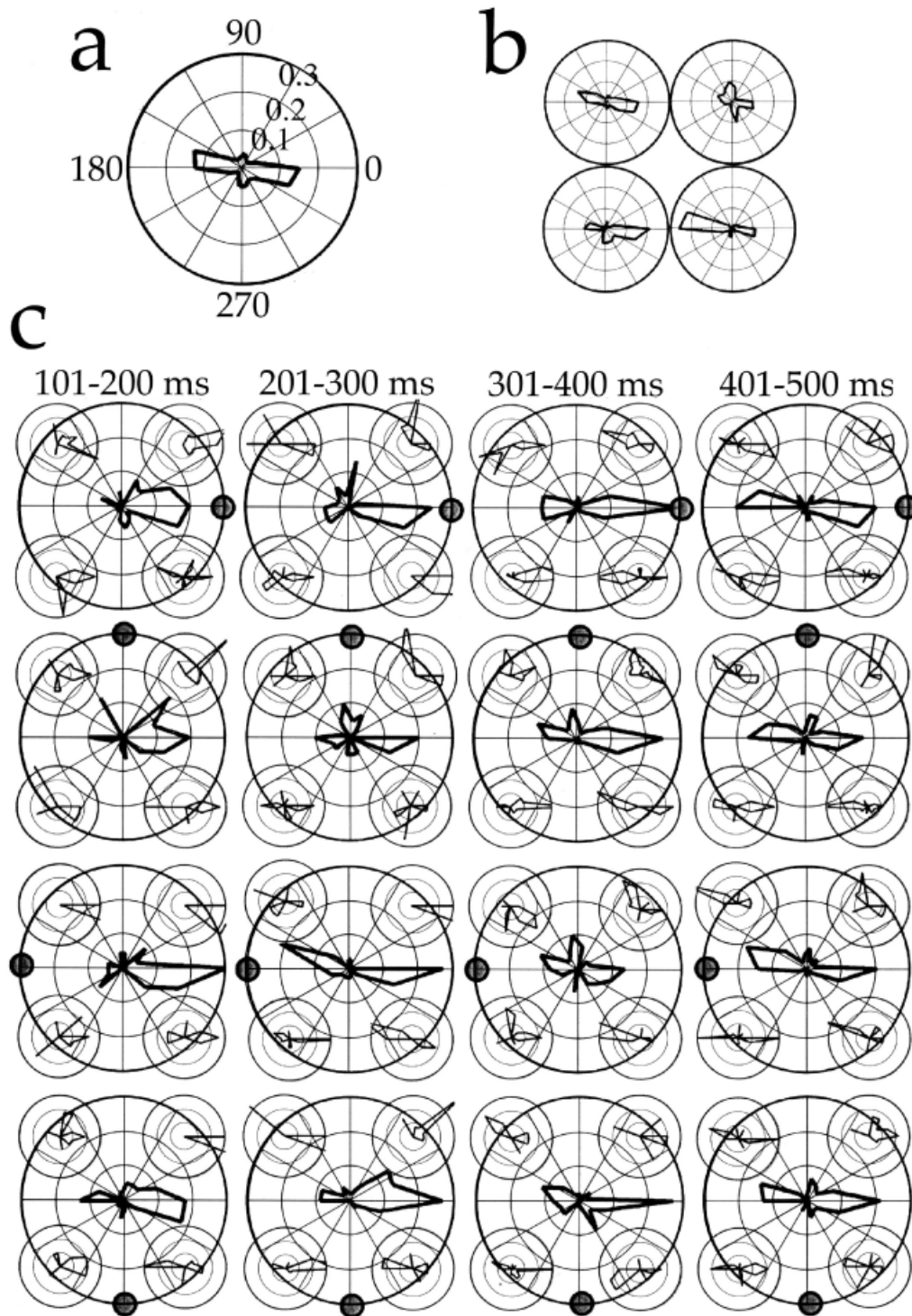
right, top, and bottom of fixation (indicated by the location of the solid gray disk). The no-cue baseline distribution is shown in Figures 1a (averaged) and 1b (individual observers). (Individual data are represented in small plots in corresponding positions in 1c.) The configuration of microsaccades in the 401- to 500-ms interval (Fig. 1c) resembles the baseline data (Fig. 1a), presumably because the effects of the peripheral cue subsided, indicating a return to baseline. It is apparent that briefly flashing a peripheral cue had a dramatic effect on the distribution of microsaccade directions relative to baseline. In the 101- to 200-ms interval, subjects had an increased probability of making microsaccades to the right relative to baseline, regardless of where the peripheral cue appeared. This unexpected result may have arisen because of an asymmetry in hemispheric dominance regarding the control of eye movements or attention. In the 201- to 300-ms and 301- to 400-ms intervals, for some conditions but not all there is weak evidence of an enhanced probability of making microsaccades in the cued direction relative to baseline. For example, there was no enhancement in either the downward or the upward direction when the cue was below fixation. In addition, there is evidence of an increased probability of making microsaccades in uncued directions other than the opposite direction. Crucially, there is no evidence for microsaccades toward the side opposite the cued location even though the accuracy data we collected simultaneously and reported in Tse, Sheinberg, and Logothetis (2003; see also Tse, 2004) did show evidence of an opposite pooling of attention. We are therefore skeptical that changes in the distribution of microsaccade directions provide a particularly robust means of indicating where attention is allocated.

We believe that stimulus parameters and instructions to subjects can account for the opposing results. Although our fixation point was small ( $0.15^\circ$ ) and did not change, in their Posner cuing task Engbert and Kliegl (2003) used a large cross ( $0.73^\circ$ ) that was replaced by an even larger arrow cue. Because the cross was large, subjects may have made small saccades around it, while still maintaining fixation. The sudden change in the shape of the object at fixation may also have induced eye movements. In the experiment Rolfs et al. report in this issue, the fixation point did not change, but was nonetheless large ( $0.78^\circ$ ). Moreover, we emphasized the importance of maintaining close

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<sup>1</sup>These data come from trials in which subjects fixated a  $0.15^\circ$  point in a field of red and green squares on a black background for 506 ms; a peripheral cue was then presented for 47 ms, and finally the same field was presented for 447 ms. We did not consider portions of eye movement traces beyond this time point because the global flash used in our change-blindness paradigm could have affected the eye movement traces examined here.



**Fig. 1.** Polar plots representing the probability density histograms for microsaccade directions pooled across 4 subjects (in the longest condition tested in Tse et al., 2003) using 18 bins. The upper panels represent (a) the baseline (i.e., no cue) data computed over 506 ms of fixation, averaged over the subjects, and (b) the corresponding individual baseline data. The plots shown in (c) represent the distribution of microsaccade directions for 100-ms intervals starting 100 ms after onset of the peripheral cue. The small gray disks indicate the direction of the peripheral cue relative to fixation. The large central plots show group data, and the small inset plots show the corresponding individual data. Inset data correspond to individual data reported in Tse, Sheinberg, and Logothetis (2002) as follows: upper left, upper right, lower left, lower right = Observers 4, 3, 2, and 1, respectively. All plots have a maximum radial extent corresponding to a probability of .3. Values outside this range have been truncated.

fixation to our subjects. Even if Rolfs et al. also emphasized this to their subjects, their fixation spot was large enough to count as a region within which small saccades that would not break “fixation” were possible. Because microsaccades can be voluntarily inhibited (Kowler & Steinman, 1979; Steinman, Cunitz, Timberlake, & Herman, 1967), it is likely that mental set (e.g., readiness to make a saccade) plays an important role in their generation (Tse et al., 2002). Stimulus parameters and mental set can be manipulated to increase or decrease the probability of a correlation between microsaccade direction and attentional location. Although we do not dispute that directions of microsaccades can be influenced by the direction of attentional allocation under some circumstances that foster this influence, our data demonstrate that this is not obligatorily the case. Because our microsaccade data are not particularly informative about the location of attentional allocation, whereas the accuracy data collected at the same time as our eye movement data are highly informative about this (Tse et al., 2003), we advocate mapping the distribution of visual attention with such accuracy measures rather than microsaccade data.

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