Supplementary Materials

Eye movement analysis

Horizontal eye position was recorded at 120Hz, and the continuous eye position data was segmented into epochs from 500 ms before motion onset to response time (when the participants judged the occluded process to be complete). The purpose of eye position analysis was partly to exclude trials where fixation was broken. However, ocular behavior on the Position extrapolation task was also of interest, because it allowed confirmation of previous results (Makin & Poliakoff, 2011).

When tracking a moving target, pursuit and saccadic eye movements work synergistically to keep the fovea approximately aligned with the target (Orban de Xivry & Lefevre, 2007) and the relative contribution of catch-up saccades increases after the first 200 ms of occlusion (Bennett & Barnes, 2006). Rather than separate the pursuit and saccadic components of the eye movement signal, we smoothed the raw eye movement traces with a 200 ms moving-average filter. This probably masked small catch up saccades, but nevertheless gave a reasonable approximation of ocular tracking. After this, position smoothing procedure, eye velocity in degrees per second was computed at each data point \[\text{[(eye position – eye position at previous time sample) X sampling frequency]}\] and the resulting velocity vector was also smoothened with a second 200 ms moving average filter.

To gain insight into the relationship between ocular tracking and CTEs, eye position just before the button press was also obtained on each trial. This was defined as mean eye position from -400 ms to -200 ms prior to button press (the penultimate 200 ms was used because the last 200 ms was potentially
distorted by the filtering process). This established that eye position was very near to the end of the track when the button was pressed on the pursuit trials of the Position extrapolation task.

Fixation trials were excluded from all analysis when significant tracking occurred (20 trials across all participants, 1.3%). Fixation breaks were defined by two relatively liberal criteria: First, fixation trials were excluded if the inter-quartile range of eye position data points exceeded 4 degrees, and second, if overall ocular displacements exceeded 20 degrees. These criteria probably passed some trials with a saccadic eye movement, or where the eye tracker lost signal. However the criteria were designed to detect erroneous tracking during the fixation trials, and ensure that ocular behavior was substantially different during fixation and pursuit conditions. The exclusion criteria were validated by a secondary test which confirmed that nearly all the pursuit trials in the Position extrapolation task were flagged as fixation breaks according to this criteria (715 out of 720 trials in total).

**Fixed parameter and Eye instruction analysis in Experiment 1**

The three occlusion durations were produced by varying speed while keeping distance fixed, or vice versa (Table 1, Figure 1C and D in manuscript). Moreover, trials were presented in fixation and pursuit conditions (or fixation and free viewing in the Number task).

Results are shown in Supplementary Figure 1, and analyzed with 4 factor repeated measures ANOVA [Task (Position, Number) X Eye instruction (Fixation, pursuit) X Fixed parameter (Distance, Speed) X Occlusion duration (1, 2 or 4
seconds). Rather than report every result, we highlight only those involving fixed parameter or eye instruction, and we follow up interactions selectively.

For CTEs, there were three way interactions between Eye instruction, Fixed parameter and Occlusion duration (F (1.16, 22.04) = 4.478, p = 0.041) and between Task, Eye instruction, Fixed parameter (F (1,19) = 4.851, p = 0.040). We explored these by analyzing the tasks separately.

In the Position task, there were complex interactions involving Eye instruction [Eye instruction X Fixed parameter, F (1,19) = 9.570, p = 0.006; Eye instruction X Occlusion duration, F (2,38) = 6.263, p = 0.004; Eye instruction X Fixed parameter X Occlusion duration; F (1.22, 23.09) = 5.031, p = 0.029]; Supplementary Figure 1A and C]. This contrasts with the Number task, there were no effects involving Eye instruction (largest effect, F (1,19) = 2.301, p = 0.146, Supplementary Figure 1B and D).

Next we consider the effect of Fixed parameter on CTEs in each task. In the Position task, there was a cross over interaction between Fixed parameter and Occlusion duration (F (1.16, 22.12) = 27.319, p < 0.001). The nature of this interaction can be seen best in the Error data in Supplementary Figure 1C. When distance was fixed, participants responded too late at the short occlusions and too early at the long occlusions. Conversely, when speed was fixed, this range effect disappeared. The same cross over interaction was even more pronounced in the Number task (F (1.12, 21.20) = 85.676, p < 0.001, Supplementary Figure 1D).
Supplementary Figure 1- Extended results of Experiment 1. The left column shows performance metrics from the Position extrapolation task, the right column shows performance metrics from the Number extrapolation task. The graphs show the same results as Figure 3, but with additional factors of eye instruction and fixed parameter.
Variable error is shown in Supplementary Figure 1E and F. There was a main effect of Fixed parameter, resulting from the fact that variable error was greater in the speed fixed trials (F (1,19) = 6.055, p = 0.024). The Fixed parameter X Occlusion duration interaction was also significant (F (1.26, 23.90) = 12.324, p = 0.001), because the increase in variable error with occlusion duration was greater in the speed fixed conditions. There were no other effects of interactions: the next largest effect being Task X Fixed parameter X Occlusion duration (F (1.54, 29.25) = 3.081, p = 0.073). CoV is shown in Supplementary Figure 1G and H. There were no effects or interactions involving Fixed parameter or Eye instruction (the largest being a borderline main effect of Fixed parameter (F (1,19) = 4.391, p = 0.05).

In summary, the analysis of eye instructions provided a partial replication of the results of Makin and Poliakoff (2011) and Benguigui and Bennett (2010). These studies also found small effects of fixation CTEs. Makin and Poliakoff (2011) found that fixation increased VE, however, we found no effect of eye instructions on VE in this work. Like Makin and Bertamini (2014), we found systematic differences between CTEs on distance and speed fixed trials. When distance was fixed, participants responded too early at short occlusions, and too late at long occlusions (a range effect). This implies participants responded as if every trial moved at a typical speed of around 20%/s. This pattern was more pronounced for the Number extrapolation task, which is probably not surprising. After all, the visual system has dedicated networks sensitive to motion through physical space but not higher-order motion through feature space (see Burr & Thompson, 2011 for recent review).
References


