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  Eye to Head Transformation

Contrary to an assumption in 2-D models, visual and motor displacement signals are not trivially interchangeable. Our goal was to determine if the brain performs the 3-D eye position-dependent reference frame transformation required to compute correct eye displacements in Listings plane (LP) from retinal error. 3-D eye position (relative to LP) and target direction in retinal coordinates (retinal error) were computed from search coil signals in 6 head-fixed subjects in the dark. We recorded 60 horizontal saccades between five parallel pairs of lights (over a vertical range of 40) and 30 radial saccades from a central target (with the eye at 0, 1.1-16.2 clockwise (CW), or 4.5-13.2 counterclockwise (CCW) initial ocular counter-roll). These data were input to a 3-D look-up table model to predict the errors produced by a direct visual-motor look-up table. As predicted, retinal error was a non-trivial function of both target displacement in space and 3-D eye position. The look-up table model predicted position-dependent errors in final vertical eye position of up to 19.8 for horizontal saccades in LP. However, such errors were not systematically observed. Plots of predicted vs. actual error produced a slope of only -0.01 +/-0.14 (as opposed to 1), suggesting a slight overcompensation for eye position. Actual directional errors from initial torsional positions were a fraction of those predicted by our look-up table model (32% for CW eye positions, 33% for CCW positions for binocular viewing, and 69% CW, 46% CCW for monocular viewing). Thus, other than sporadic miscalibrations for torsion, saccades were accurate from all 3-D eye positions. These results could only be simulated by adding a position-dependent reference frame transformation to the model. We conclude that the saccade generator takes 3-D eye position into account when reading the retinal code.

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