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VISUAL-MOTOR TRANSFORMATIONS ACCOUNT FOR THREE-DIMENSIONAL EYE POSITION

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INTRODUCTION

The ability to simplify complex sensorimotor transformations is both attractive and advantageous when investigating intricate brain functions. But simplicity has its own pitfalls. For example, psychophysicists and neurophysiologists have long treated the retina as a flat surface and have largely treated eye movements as if they were two-dimensional (2-D) translations of this surface. However, although the retina is a 2-D surface, it is curved along the back inner wall of the globe and, for the most part, the eyes do not translate – they rotate. This changes the way objects in space project onto the retina, especially when the eye is oriented at secondary positions (i.e. positions with non-zero horizontal and/or vertical components) (3, 4). Furthermore, the eyes move with three degrees of freedom – horizontally (about a vertical axis), vertically (about a horizontal axis) and torsionally (about a naso-occipital axis). Thus, at tertiary positions the eyes are rotated torsionally by various amounts about their line of sight (so called false torsion) and these rotations, though small, also affect the pattern in which targets project onto the retina and consequently complicate the visuomotor transformations that follow (9, 10).

The differences between retinal errors induced by certain targets, and the motor commands necessary to foveate these targets, are outlined in figure 1. In the most basic example, fovea position A, the eye is looking straight ahead, and we equate this with primary position. A target that causes a horizontal retinal stimulation of 40° right necessitates (as shown on the screen) a purely rightward eye rotation of precisely 40°. Similarly, a horizontal retinal error of 80° to the right requires a rightward eye rotation of 80°. The equivalence between sensory input and motor output at primary position seems trivial and supports a simple one-to-one correspondence between input and output structures. However, the relationship is quickly complicated when the eye is oriented toward other positions in space.

With the four remaining foveal positions (B-E), the eye has been rotated vertically by various amounts and identical retinal stimulations have been applied – either 40° or 80° right. But now, a glance at the corresponding trajectories on the screen outlines a non-trivial mapping. The trajectories required to foveate either the 40° or 80° retinal errors are not just horizontal, but oblique – with the amount of curvature

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