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PHYSICAL ARRANGEMENT OF EXTRAOCULAR MUSCLES IN THE RAT

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The knowledge of the physical arrangement of the extraocular muscles is a necessary prerequisite for the quantitative tensorial treatment of ocular motor reflexes, as introduced by Pellionisz and Llinas (1980, Neuroscience 5:1125). Muscle insertions, muscle fibre directions, and the surface of the bulbus were measured in 3 adult brown rats in a stereotaxic apparatus; based on these data, the 6 axes of rotation evoked by the individual muscles were determined in a head-fixed coordinate system. For 'antagonistic' muscles, misalignment of rotational axes can be as large as 40° . This finding renders the simplifying approach of characterizing muscle pairs by one rotational axis inadequate.

The directions of these axes form a 6×3 matrix which allows to describe the proprioception of eye movements according to the rule of orthogonal projection onto the intrinsic muscle frame of reference, while the transpose of this matrix allows to calculate eye movements from ocular motor activity according to the parallelogram rule of vector addition. The cosines of the angles between the directions of rotational axes form a 6×6 matrix that acts as a covariant metric tensor describing the physical transformation of the ocular motor vector into the proprioceptive vector. As the muscle frame of reference is overcomplete, the proper inverse of this matrix does not exist; therefore the Moore-Penrose generalized inverse given by another 6×6 matrix was calculated, which provides a contravariant metric describing the neuronal transformation of a covariant intention vector into a contravariant ocular motor vector. Such a transformation is essential for the generation of coordinated eye movements. The determination of the geometry of the eye muscles may support the use of rats as experimental animals in the tensorial analysis of ocular motor reflexes and proprioception.

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