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A modeling study on the signal transformation for the microsaccade generation

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During visual fixation, stationary images are thought to be input to the visual system. However the actual input images are continuously fluctuating due to miniature eye movements. The miniature eye movements consist of microsaccade, drift, and tremor [1]. To date, while the functional roles of the miniature eye movements in perception, and their kinematic properties are gradually understood [1-3]; the mechanisms of their generation remain unknown. Here we focused on microsaccade, and constructed a model to explore the mechanisms of microsaccade generation.

Methods

Several lines of evidence assure that microsaccades share the same neuronal circuitry with saccades as they follow continuum behavioral profiles called the main sequence [1]. In the saccade related pathway, saccade commands generated in superior colliculus are relayed to motoneurons via burst neurons (BN) that are tonically inhibited by omnipause neurons (OPN) except when saccade (i.e. fixation). Thus, we constructed a model based on the saccade model by Seung et al. [5] as it described explicitly excitatory/inhibitory BNs, the integrator network, and the oculomotor plant. We added OPN as a gain element, and controlled BNs activities to replicate the inter-microsaccade interval [4] and direction of microsaccade [6].

In simulation, our model successfully reproduced both horizontal and vertical microsaccades which were characterized by “square-jerk”or “single sided”. Our model

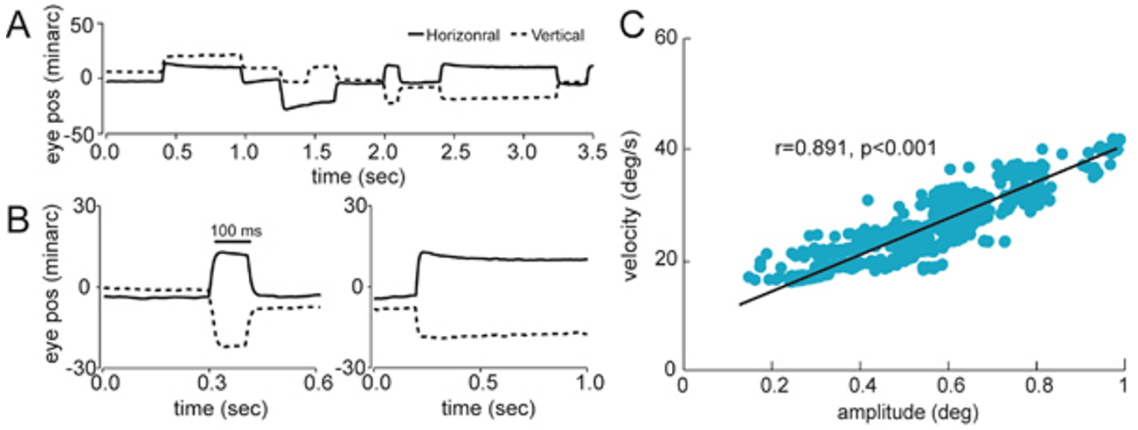

Figure 1 Simulation results. A: Fixating eye movement, B: Square-jerk wave (left) and Single sided (right) microsaccade, C: Main sequence. Solid and dashed line in A and B indicate horizontal or vertical eye movement. In C, solid line is linear regression line; r and p are multiple correlation coefficients and its significance.

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also reproduced the main sequence characterized by the linear relationship between microsaccade amplitudes and peak velocities that is observed in the behavioral experiment (e.g. [8]). Our result suggested that the tonic inhibition from OPN plays a key role in the generation of microsaccades in depressing the activity of BNs that is the source of saccade/microsaccade deriving from superior colliculus. Nakao et al. reported that the BNs fired spikes at a low rate during fixation where the inhibition from the OPN exists [7], and those activities were replicated in our model as decreasing of firing rate of BNs. We conclude that those low rate spikes of BNs might be key activities to drive microsaccades. Figure 1

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