SUPPLEMENTARY RESULTS AND DISCUSSION

Vestibulo-thalamic neuron rotational and translational sensitivities as a function of stimulus velocity and acceleration

Responses to stimuli with various angular velocities and linear accelerations were recorded from neurons after the experiments described in "Coding self-motion signals" had been carried out. Recordings of sufficient length to conduct the entire experimental protocol were only obtained in a limited number of cells.

In seven neurons, six canal and one canal-otolith units, the responses to sinusoidal rotation with angular velocities in the range of 10-100 deg/s were recorded. In all neurons the response amplitude increased with the rotational velocity but not directly proportionally to it. As a result, the ratio of the response amplitude to the peak rotational velocity, which is the rotational sensitivity of the neuron, decreased with increasing stimulus velocity. Representative neuron responses to 1 Hz sinusoids with four different peak angular velocities are shown in Figure 1S,A-D. The rotational sensitivity ($gain_R$) of this and other neurons is plotted as a function of the peak angular velocity in Figure 1S, E. Only three neurons were tested with 3-4 different peak angular velocities. Because of small amount of these neurons we did not fit the data of a pool of neurons, instead fit the data of each neuron separately. In all cases rotational sensitivity plotted as a function of angular velocity was well fitted with the power function $Gain_R = k \times PeakVelocity^p$. The exponents (power) p of these fits were –0.77, –0.92 and –1.16, with determination correlation coefficients (R^2) of 0.98-0.99. In these fits the exponent of power function was close to negative unity indicating inverse proportionality between rotational sensitivity and angular velocity. The phase shifts of responses to stimulating rotational sinusoids did not vary significantly between neurons (Fig. 1S, F). Responses were in phase with angular velocity, or led in phase, not exceeding 45 deg, angular velocity. The phase shifts of the rotational responses of individual neurons did not vary with angular velocity.

In four neurons the responses to sinusoidal translation with peak accelerations in the range of 0.05-0.4 g were tested. The magnitude of responses to translation increased with linear acceleration but was not directly proportional to an increase in stimulus acceleration. As a result, the ratio of response magnitude to peak acceleration, i.e. the translational sensitivity, decreased with an increase in linear acceleration. The responses of one neuron are shown in Figure 2S, A-D. To analyze the quantitative relationship between translational sensitivity and linear acceleration the data of each neuron were fit separately. Because of the small size of the sample the data from these four neurons were not pooled together. Data from each neuron were approximated with the power function; in all cases the R^2 of fit achieved value of 0.98. The exponent (power) of those fits varied between –0.47 and –0.65, and was on average –0.54±0.07. This average exponent of power function fitting the data was almost equal to –½, indicating that translational sensitivity was inversely proportional to the square root of linear acceleration (Fig. 2S, E). In all neurons the response to translational sinusoids lagged behind linear acceleration and the response phase did not vary with the acceleration. In two neurons the phase lag of responses to the accelerations applied was about –30 deg, and in two neurons about –60 deg relative to acceleration (Fig. 2S, F).

The results of this study show that rotational and translational sensitivity of vestibular nuclei neurons decreases with an increase in velocity and acceleration of motion stimuli. This observation is similar to those of other authors studied dynamics of vestibular nuclei neurons in anesthetized gerbils, decerebrated and normal cats, and alert monkeys (Fuchs and Kimm 1975; Heskin-Sweezie et al. 2007; Melvill Jones and Milsum 1970; Schneider and Anderson 1976). In this respect vestibulo-thalamic neurons are similar to ventro-posterior thalamus neurons sensitive to rotational and translational stimuli (Marlinski and McCrea 2008a). We found that relationship between rotational sensitivity and stimulus velocity or acceleration could be approximated with a power function that is in full agreement with the results of pioneering work of Melvill Jones and Milsum (1970). Such a ratio between the neuronal responses and the magnitude of angular or linear movement allow vestibular nuclei neurons to encode a wide range of motion velocities and accelerations within a limited diapason of the firing rate. In these dynamics of signal processing the vestibular nuclei neurons are similar to neurons of other sensory systems (Drew and Abbott 2006).

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LEGENDS TO SUPPLEMENTARY FIGURES

Fig. 1S. Rotational response as a function of angular velocity. Representative neuron responses to 1 Hz sinusoids with increasing angular velocity (A-D). In each panel the upper trace represents head angular velocity (H'), deg/s; a histogram is an average discharge rate, spikes/s; a curve superposed on a hystogram is a sinusoidal function fit. Peak angular velocity, the amplitude of a sinusoidal fit to the response, and response $gain_R$ are given in each panel. Rotational $gain_R$ plotted as a function of peak stimulus velocity (E). Response phase shift plotted as a function of peak angular stimulus velocity (F). Black circles in panels e and f are data from the neuron shown in panels A-D. The monkey graphic indicates the mode of motion, wbr - whole body rotation.

Fig. 2S. Gain and phase of translational responses of vestibulo-thalamic neurons. Representative neuron responses to 1 Hz sinusoids with increasing linear acceleration (A-D). In each panel the upper trace represents head linear acceleration (H"), g; the rest is as in Fig. 3. Translational $gain_T$ plotted as a function of peak acceleration (E). Response phase shift plotted as a function of peak acceleration (F). Black circles in panels E and Fare data from the neuron shown in panels A-D. The monkey graphic indicates the mode of motion, wbt - whole body translation.