Modelling transient dynamics and attentional modulation in MT cells in a structurally simple model

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In the primate brain, area MT is largely responsible for the processing and perception of motion in visual scenes. MT neurons are tuned for the direction and the speed of moving stimuli and they respond with pronounced firing rate transients upon a change in visual stimulation. These transients increase the neurons' sensitivity and they are directly related to behavioural performances. Therefore, to gain a better understanding of the processing of dynamic visual scenes it is important to understand the neural processes that shape the transients in MT responses. We present a dynamical model of MT cells that takes the cells' speed and direction tuning into account and that is able to reproduce their experimentally observed transients. In its simplest version, the model consists of only two coupled differential equations, representing an excitatory and an inhibitory population that make up a single direction column. Both populations receive the same external input and additionally the inhibitory population provides divisive inhibition to the excitatory one. Using a simple optimization procedure, we fit the model to find close to perfect fits for the sustained and transient phases in MT single cell responses. Based on the fit for each cell, the model reproduces and predicts neuronal responses to arbitrary accelerations and decelerations of a moving stimulus starting from both low and high base speeds, including experimentally observed deviations of the actual transient as compared to the expected firing rate change as deduced solely from a neuron's speed tuning profile. We also investigated the possible effects of spatial and feature-directed attention in our model and reproduced psychophysical reaction time distributions under different attentional conditions. In particular, we found increasing relative firing rate differences during the transients the stronger the attentional modulation was prior to a stimulus change. This effect reversed in the sustained phase of the neurons' response, where relative activation decreased with increasing attentional modulation. Our finding provides a mechanistic explanation for the shaping and attentional modulation of neuronal response transients, and underlines the importance of this dynamical mechanism for change detection.

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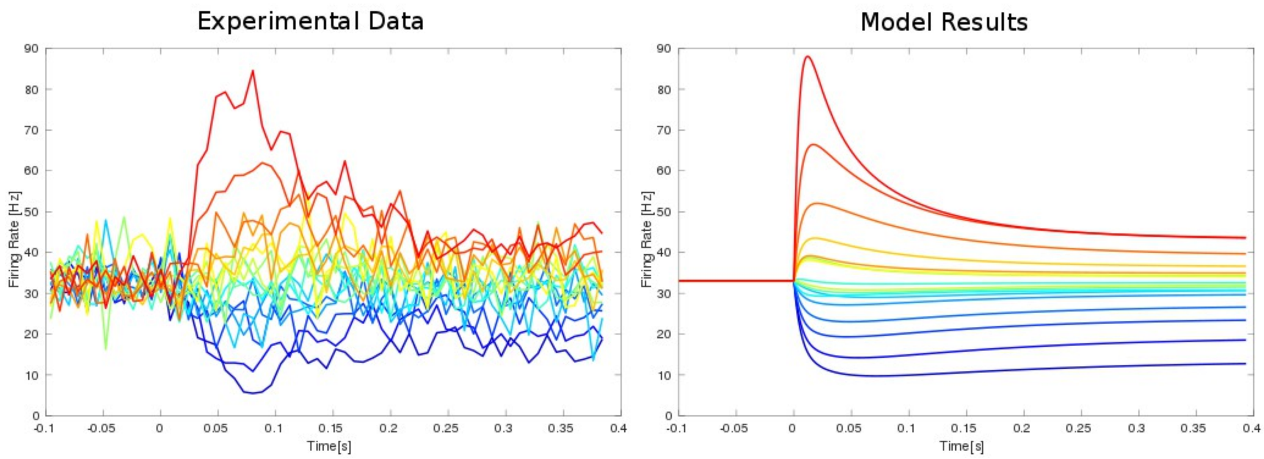

Figure: Comparison between experimental and model results for speed changes of different magnitude starting from the same base speed. Same color indicates the same speed change. The model's variables were chosen based on a prior fit of the model to the responses to a movement onset.