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The activity of retinal ganglion cell ensembles in the turtle retina encode velocity of moving objects

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In a natural environment, detection and estimation of object motion features are crucial for a correct behavior. The brain relies on the activity of retinal ganglion cells (RGC) as the only source of visual information to estimate moving stimuli. We analysed simultaneously recorded responses of RGC of isolated turtle retinas to a moving stimulus. The stimulus consisted of a pattern of squares that moved with a constant velocity for 500 ms and then changed abruptly to one of nine possible velocities in a pseudo-random fashion as described in [1]. Spike-cost based metrics [2] were applied to the responses of single RGC to test the relevance of spike rate and spike timing precision in the encoding of velocity. Furthermore, an extension of the method that considers the simultaneous activity of several neurons [3] was used to test if velocity discrimination improves if their spike responses are combined and if individual spikes are assigned to individual neurons.

Our results show that responses of single RGC allow for discrimination of different velocities based on the spike count rather than on the spike timing precision. In general, higher velocities were better discriminated than lower ones. Classification performance of certain velocities depends on the cell type. Responses of non-direction selective cells (NDSC) allow for good classification of all speeds but fail in the discrimination of movement direction (Figure 1a), whereas activity of direction selective cells (DSC) allow for better classification of velocities in the preferred direction but worse for velocities in the anti-preferred direction (Figure 1b). For all types of cells, mean velocity classification performance reached ~35%. When the activity of different RGC is combined, classification performance of velocity improves with the number of RGC and only if the neuron of origin of each spike is known (Figure 1c). Nevertheless, mean classification performance is lower than the one expected by summing the performances of single cells, suggesting some redundancy in the encoding of velocity parameters also by different types of RGC.

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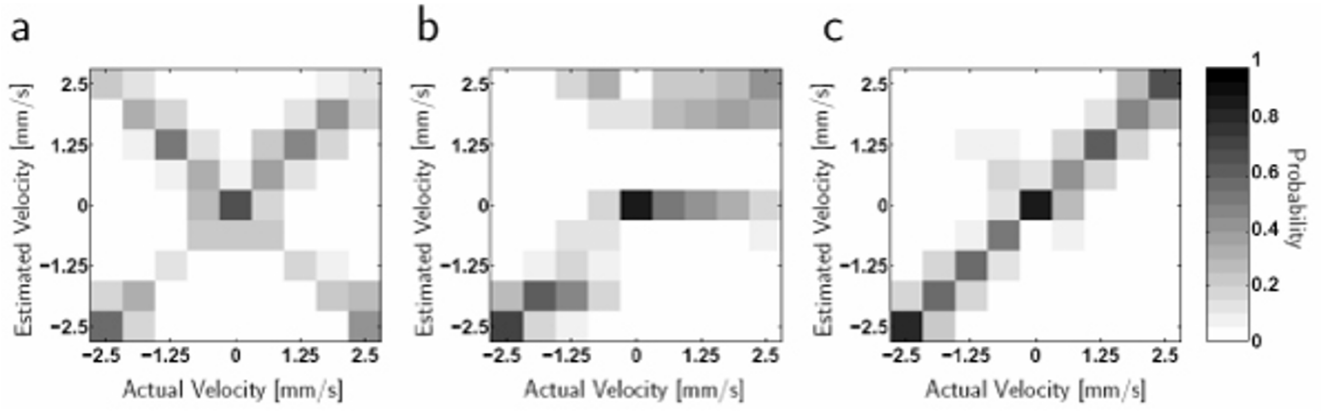

Figure 1
Probability of correct estimation of the actual velocity. a) Classification based on the activity of a NDSC. b) Classification based on the activity of a Left-DSC. c) Classification based on the simultaneous activity of the same NDSC and Left-DSC knowing the neuron of origin for each spike.