

Feature-Based Attention Increases the Selectivity of Population Responses in a Model of the Primate Visual Cortex

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Background. It has recently been demonstrated by Martinez-Truillo & Treue (*Curr. Biol.* **14**, 744-751, 2004) that cell responses in area MT of the macaque dorsal stream are modulated by feature-based attention mechanisms (see Fig. 1c). Results revealed that **(a)** feature-based attention to the preferred direction tuning of a cell enhances its activity in a modulatory fashion irrelevant of the presented motion stimulus, and **(b)** that no modulation effect occurred when directional attention was withdrawn. In the latter task, monkeys had to attend a colour square at the fixation point (*attend-fixation* condition). If the attended direction was coherent with the presented stimulus direction (*attend-same*) the cell responses increased when the stimulus corresponds with the cell's preferred stimulus, while they decreased for the anti-preferred direction. The aim of our study was to investigate the computational mechanisms of these attention enhancement and suppression effects and how they related to the inter-cortical mechanisms of motion integration and disambiguation.

Neural Model. We have previously developed a neural model of the feed-forward and feedback mechanisms between areas V1 and MT that are involved in generating the percept of coherent shape motion while disambiguating local flow measures (Bayerl & Neumann, *Neural Comp.*, **16**, 2041-2066, 2004). Responses are generated by firing-rate model cells. Model feedback is modulatory and combines with mechanisms of shunting interaction to implement key mechanisms of the principle of biased competition (Desimone & Duncan, *Annual Rev. of Neurosci.*, **18**, 193-222, 1995). In particular, the model demonstrates how modulatory MT-V1 feedback signals help to stabilize localized feature responses at, e.g. corners, disambiguates initial flow estimates along estimated contrasts, thus solving the motion aperture problem. Here, we investigate how feature-based attention signals to MT cells influence the disambiguation process that is realized by early V1-MT feedback. The attentional bias is modelled to share similar basic circuitries as in the recurrent model V1-MT interaction of the Bayerl-Neumann model. Furthermore, we add a tonic input activity to all cells in the input layer of each model area which generates a small non-zero activation baseline which is mandatory to generate the presented results.

Stimuli and Simulation Results. We employed moving random-dot patterns as input stimuli (see Fig. 1a). **(1)** Feature-based attention to the preferred direction of an individual model cell modulates its response, independent of the given input motion direction (see Fig. 1b, blue vs dashed black line). **(2)** Directional attention to the presented motion cue increases the model cell's response if a direction similar to the preferred direction is shown. The responses decrease for the anti-preferred direction (compare Fig. 1b, red vs. dashed black line). We observed that the amount of tonic neural activity in our model influences modulatory effects in the computational biased competition (not shown). **(3)** With the same model parameterizations the neural model is capable to process sequences that show multiple objects moving in different directions. The output activities roughly indicate the actual velocities presented to the model (see Fig. 2).

Conclusion. We demonstrated that a model of the neural mechanisms of early motion processing (Bayerl & Neumann, 2004) replicates physiological findings on feature-based attention by Martinez-Truillo & Treue (2004). The computational results were obtained with the existing model architecture and demonstrate how early feedback and attention are processed by the same mechanisms. In all, the model architecture suggests how biased competition could be implemented by basic mechanisms such as feed-forward, modulatory feedback processing and mechanisms of shunting competition to build the fundamental principles in cortical information processing.

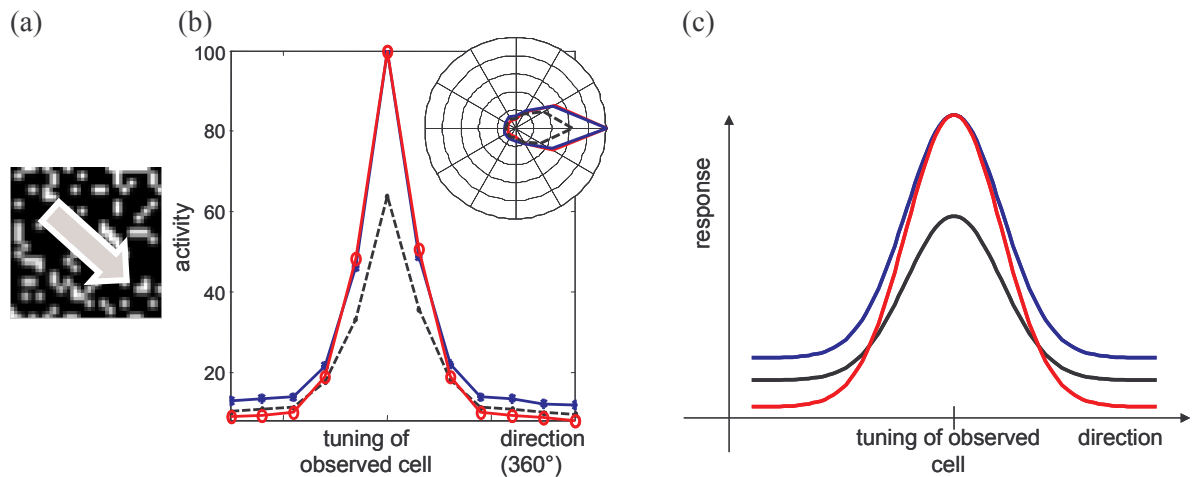


Figure 1. (a) One frame of an input sequence consisting of random-dots moving to the lower right (12 directions were tested). (b) Neural activity (mean spike rate) of a cell tuned to rightward motion (0°) at the center of the stimulus after 5 iterations of feedback processing (relaxed activity; polar plot as inlay). Responses without attention are shown in black (dashed line; *attend fixation*). While attending rightward motion the neural response (blue line) is amplified independently of the presented motion direction. Attention towards the presented motion cue increases the cell's response (red line; *attend same*) if a direction similar to the preferred direction is shown and decreases the cell's response for the anti-preferred direction. (c) Observed enhancement of neural activity in macaque area MT, sketch based on data from (Martinez-Trujillo and Treue, 2004) and (Martinez-Trujillo and Treue, 1999).

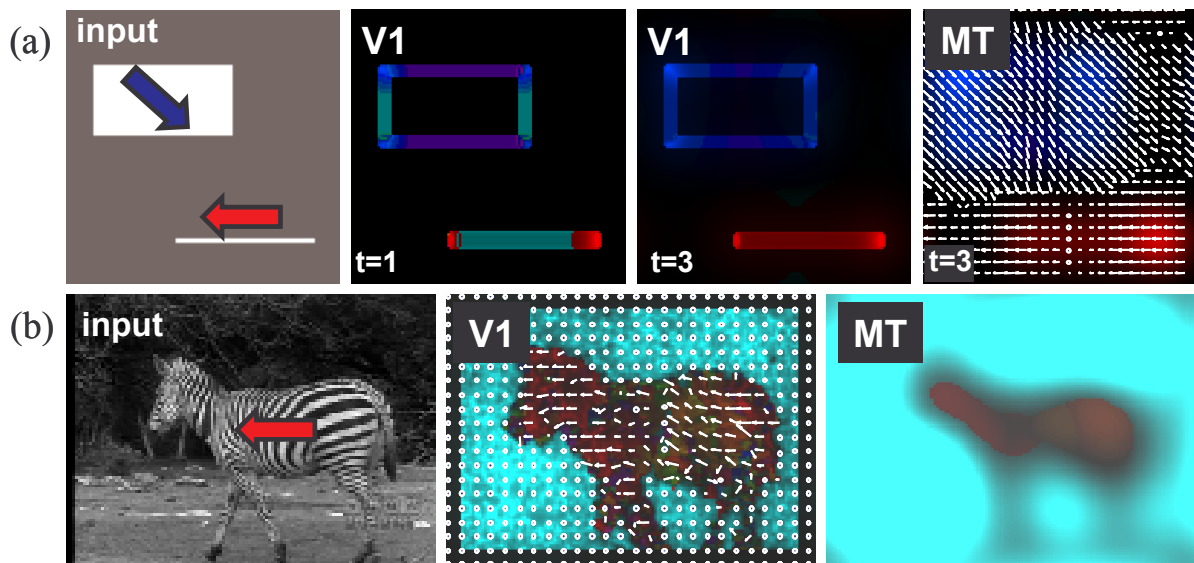


Figure 2. Results processing other motion sequences than the random dot stimuli shown in Fig. 1a. These results were obtained using the same model parameterization as for the results shown in Fig. 1 including the tonic input but without attentional bias. (a) Results processing an artificial motion sequence showing a rectangle moving to the lower right and a bar moving to the left (compare arrows on input frame; 120×120 pixel). Detected motion in model area V1 are color coded at different time steps ($t=1$, $t=3$). Motion cues in model area MT are shown as small arrows. (b) Results processing a real-world sequence showing a zebra moving to the left (128×96 pixel). The model output is shown after two steps of feedforward/feedback processing ($t=2$) for both model areas.