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MOTION CAPTURE IMPLIES MOTION EXTRAPOLATION

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Romi Nijhawan has provided convincing psychophysical evidence that the visual brain can compensate for delays in the transmission of motion information from photoreceptors to higher visual centers.[1,2] By the time this information reaches higher centers, a moving target is no longer at the locations that correspond to its earlier motion signals. Nijhawan's experiments suggest that "an 'early' visual mechanism corrects the spatial lag by extrapolating the moving object's instantaneous location." (l, p. 257). Cavanagh has asked "why bother?" (3, p. 19), since neural delays affect all of our sensations. The present note suggests that the extrapolation effect follows naturally from the basic motion process of "motion capture", whereby the visual cortex computes an unambiguous percept of object direction and speed.

Motion capture is needed because, when an object moves, aperture ambiguity and image or detector noise often prevent all but a small subset of its image features, such as its bounding contours, from generating unambiguous motion direction cues. Despite this limitation, an entire moving object often seems to pop-out with a well-defined motion direction and speed. Psychophysical experiments suggest that unambiguous feature tracking signals at the bounding contours of objects propagate to their interiors where they capture and transform ambiguous motion signals into coherent representations of object direction.[4] A classical example of this process is the barberpole illusion.[5] It is also true that an object's direction and speed tend to pop-out together, as when plaid components appear to move independently with one speed or as a coherent pattern with a different speed.[6] This observation raises the question: What type of feature tracking process can concurrently select unambiguous direction *and* speed signals from ambiguous motion signals?

We[7-9] have modeled this process and used it to simulate psychophysical and neural data about motion perception. A key property of this Motion Boundary Contour System model is that speed tuning derives from the action of multiple spatially short-range filters of different size. These filters model the short-range motion process of Braddick[10]. In the model, larger receptive fields respond preferentially to faster speeds. This property helps to simulate how visual speed perception and discrimination are affected by stimulus contrast, duration, dot density, and spatial frequency.[7] The filters are directionally tuned in order to accumulate evidence of feature tracking motion so that it will be strong enough to overwhelm ambiguous motion signals through the motion capture process. Such directional tuning enables the model to explain how, say, one dot moving in a constant trajectory is readily detected among identical dots in brownian motion.[11]

Such a multiple-scale directionally-tuned motion filter can also help to explain how motion extrapolation occurs. The main idea is that a faster motion selectively activates a larger receptive field, whose cell body is positionally displaced more in the direction of motion (Figure 1). This selectivity of response also provides a way to map different speeds into different anticipatory motor responses.

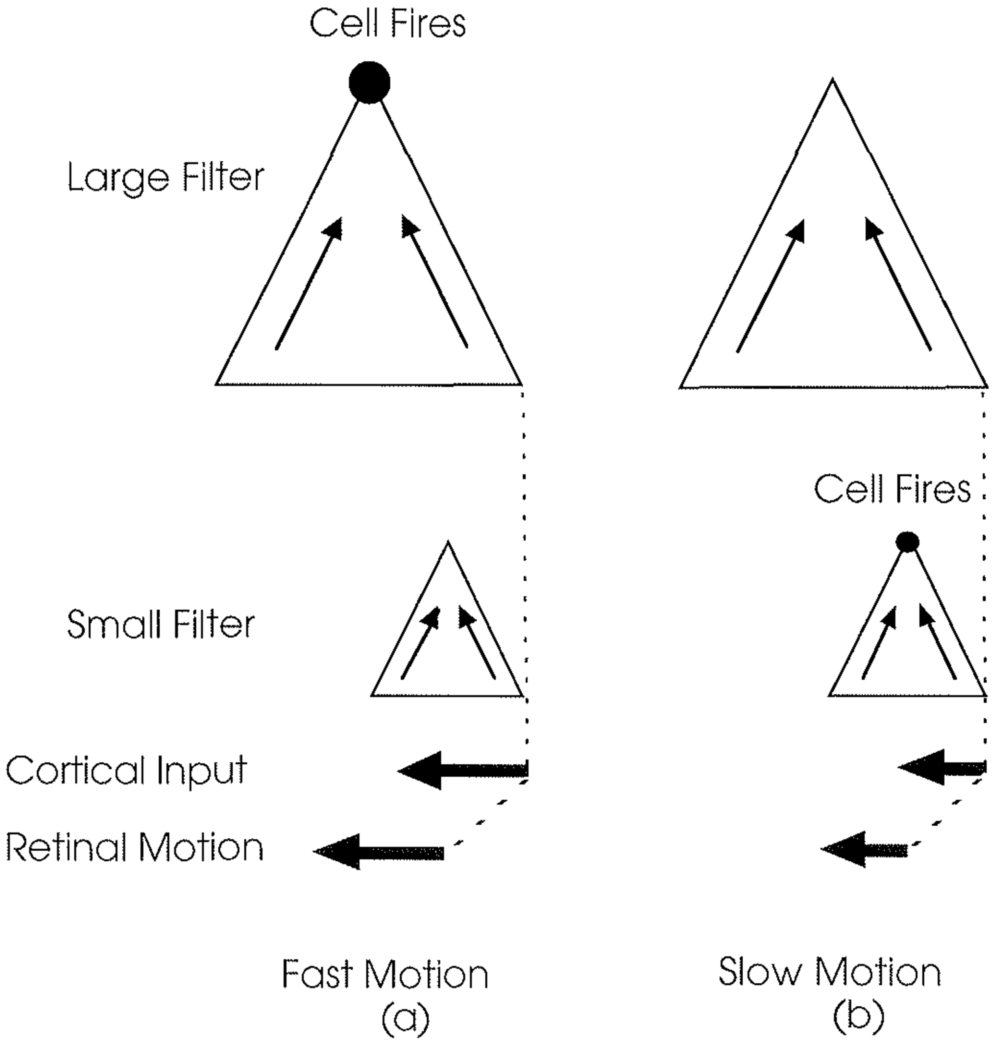

Figure 1. The cortical input is shifted in time relative to the retinally detected motion. (a) Larger-scale filter selectively responds to faster motion (black dot indicates an active cell population); (b) Smaller-scale filter selectively responds to slower motion. Thus, the faster the motion, the further the extrapolation, thereby tending to compensate for how delay and distance traveled interact. The selectively responding cells can then be adaptively mapped to actions that predict the expected target location.

Both Nijhawan[1] and Cavanagh[3] have noted that visual persistence may contribute to the extrapolation effect, since visual persistence is briefer for a moving stimulus than it is for a flashed static stimulus.[12] This property deblurs the smeared traces which could otherwise trail moving objects. A static object can hereby appear to lag behind a moving object. Our model explains the link between persistence and motion percepts by showing how emergent forms within the cortical interblob processing stream from V1 to V2 can influence processing within the V1 to MT motion processing stream via a V2 to MT interaction.[13] This interaction does not explain, however, why a static object *initially* lags behind a simultaneously presented moving object. The existence of a multiple-scale motion filter whose larger scales process faster speeds clarifies this property, and thus how motion capture implies motion extrapolation.

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