Motion Integration and Segmentation

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Over the last two decades much has been learned about human ability to detect and discriminate information within local patches of image motion. Indeed, a model consisting of spatio-temporal motion energy detectors is an excellent descriptor of both human low-level motion perception and visual processing within the primary visual cortex of the primate brain. This simple quasilinear view however does not adequately describe human performance in motion tasks which require either global integration across the image or segmentation of multiple overlapping motions presented simultaneously, yet these two abilities are essential components of many real-world aerospace tasks. The overall goal of this project is to measure human performance in motion integration and segmentation tasks and to develop and test computational models of human performance. The specific aim is to examine the mechanisms (abilities and limitations) of the human brain 1) to perform the global spatio-temporal integration used to estimate object direction, and 2) to use speed cues to segment images into discrete objects.

Most current models of human motion processing use a first stage of local motion-energy sensors and various spatio-temporal integration rules to derive a global object-velocity signal. Drs. Beutter, Mulligan, & Stone have shown that none of the current dominant models could account for errors in human performance induced by skewing the aperture shape (Beutter et al., 1996). Further examination of human direction perception has shown that simple vector averaging of local motion signals cannot account for human direction judgments (Beutter & Stone, 1997, 1998; Stone et al., 1997; Lorenceau, 1998). Indeed, no algorithm that merely combines local edge motion information can account for perceived object motion (Stone & Beutter, 1998, Stone et al., 1999). Drs. Stone, Beutter, & Lorenceau are currently exploring how static spatial configurations influence the motion-integration process.

Another difficult problem facing the human visual system is deciding when to combine motion information (by assuming it comes from the same object) and when to segregate it (by assuming it comes from different objects). A clear understanding of this ability and its limitations is critical for the design of heads-up displays and virtual environments, because a failure to properly segment an image will have adverse consequences on any applied task being performed using these interfaces. A number of studies have shown that speed cues play an important role in the segmentation process (e.g. Verghese & Stone, 1996, 1997). Drs. Masson, Mestre, and Stone are measuring the limitations in human performance, in particular the role of three factors mean speed, eccentricity, and spatial scale (Masson et al, 1998). The two most important findings to date (Fig. 1) are: 1) that segmentation from speed cues breaks down at mean speeds above ~16°/s, well below speeds for which simple speed discrimination is still possible, and 2) that the spatial resolution of the segmentation process is quite fine even in the visual periphery. Both of these findings are consistent with the visual signals available in the primate visual cortex (V1).

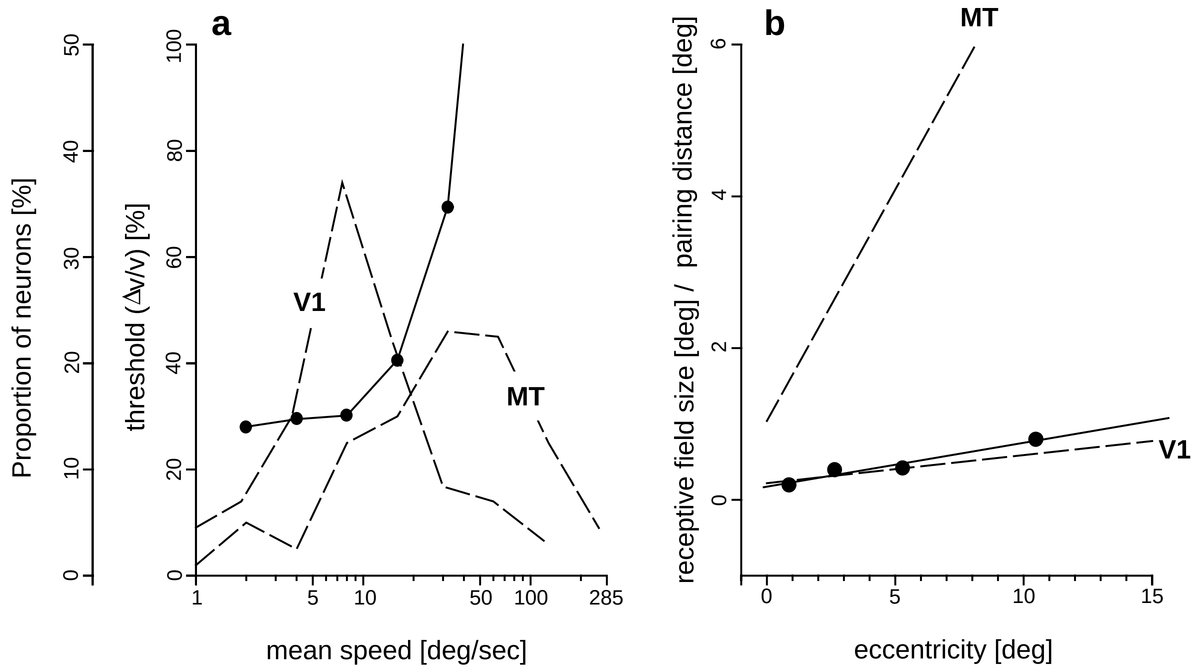

Figure 1. Speed-based segmentation thresholds (from Masson et al., 1998). a. Effect of mean speed. Note the sharp cutoff at ~16°/s consistent with the speed tuning of V1 neurons and inconsistent with the higher speed processing abilities of extrastriate visual areas beyond V1, such as the Middle Temporal area (MT). b. Effect of eccentricity on spatial scale. Note that the smallest effective spatial scale (plotted as pairing distance) for segmentation remains small (~1°) even out to ~15° of eccentricity. Again this is consistent with the receptive field size of V1 neurons, and inconsistent with those of MT neurons.

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