

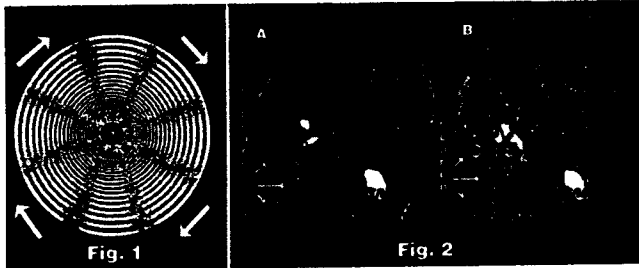
fMRI Analysis of 2nd-Order Visual Motion Perception & Attentive-Tracking

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Introduction: Psychophysical studies [1] argue that the processing of non-luminance defined motion or "second-order" motion is performed by a different neural mechanism than the processing of luminance defined or "first-order" motion. Typical second-order motion stimuli spatio-temporally modulate contrast while keeping luminance locally balanced and thus have no motion energy. One leading theory [2] suggests that second-order motion processing relies heavily on a higher-level attentive tracking motion mechanism. A competing theory [3] argues that 1st- and 2nd-order motion processing may be processed in similar neural substrates, provided that separate pre-processing is performed on the 2nd-order inputs. Here, we have employed fMRI to investigate the neural substrates of non-luminance defined motion perception.

Methods: Normal human subjects were scanned in a 3T GE NMR scanner using a surface coil. 16 slices (4mm thick, no gap) were positioned over occipital, parietal, and temporal cortex. Gradient echo functional scans (TR = 2s; 3.1 by 3.1 mm in-plane) were performed while subjects viewed projected visual stimuli. Data were analyzed in flattened cortical format and retinotopic mapping was used to identify areas V1, V2, V3, VP, V3A, and V4v [4]. In passive-viewing experiments 1st- and 2nd-order stimuli were presented in blocked epochs interleaved with their static counterparts. Stimuli were sinusoidally modulated wedges moving angularly (fig. 1) or concentric circles moving radially. 1st-order stimuli modulated luminance. 2nd-order stimuli modulated the contrast of a carrier pattern of either random noise pixels or thin concentric rings (fig 1). In attentional experiments, subjects fixated the center and performed a 1-back same-different



task on either the direction of motion in the surround or the identity of 5 letters presented foveally. Letter and motion stimuli were presented simultaneously and subjects were cued to alternate between motion and letter tasks on alternate epochs. The purpose of the letter task was to draw attention away from the motion stimuli.

Results: 2nd-order motion stimuli vs. fixation evoked a pattern of activation (see fig 2B) quite similar to that evoked by 1st-order motion (fig 2A). The area MT/MST complex and area V3A were strongly activated. 2nd-order motion stimuli activated areas V1, V2 and/or V3/VP less frequently, and on a per subject basis this pattern of activation closely matched that observed for 1st-order motion. The attentional task modulated activation for both types of motion in area V3A and MT/MST and (less frequently) lower retinotopic regions, notably V3/VP. Although stimulus-dependent activation was largest in areas MT/MST for both types of motion, attentional modulation of activation was substantially larger in area V3A than in areas MT/MST for both motion types. Attentional modulation in area V3A and areas MT/MST was approximately 50% greater for 2nd-order motion stimuli than for 1st-order motion. This imaging result correlates with perception; during the letters task epochs subjects reported little or no awareness of the 2nd-order moving stimulus, yet maintained motion awareness of 1st-order stimuli. Interestingly, attentional modulation in area V3A for second-order motion typically equaled or exceeded the stimulus modulation.

Conclusions: 2nd-order motion stimulus processing utilizes similar neural substrates to 1st-order motion processing. A strong attentive-tracking component was evident both in the perception of 2nd-order motion and in the amplitude of fMRI activation. These data are consistent with both leading theories [2,3], but constrain their possible implementations. The strong attentional modulation of activity in area V3A suggests this area may play a pivotal role in attentive tracking of moving stimuli.

1. Cavanagh & Mather (1989) *Spat. Vis.* 4:103-129; Chubb & Sperling (1989) *J Opt Soc Am* 511:1986.
2. Cavanagh (1992) *Science* 257:1563-1565; Seiffert & Cavanagh (1998) *Vision Res.*, in press.
3. Chubb & Sperling (1989) *PNAS* 86:2985-2989; Lu & Sperling (1995) *Vision Res.* 35:2697-2722.
4. Sereno et al. (1995) *Science* 268: 889-893; Tootell et al. (1997) *J. Neurosci.* 17:7060-7078.