1 Appendix: Motion Energy analysis

We model observers' responses to stimuli as being in response to their motion-energy content. This is mainly controlled by the "direction content" parameter as described above. However, constructive/destructive interference between successive pulses of the motion stimulus, depending on spatial displacement, may result in the motion energy changing slightly (see figure A). For this reason we avoided using direction contents of zero (pure counterphase), as subjects' responses in that condition would be determined by this interference-based motion energy response, rather than the direction content (see figure B). As an adjunct to our main analysis we calculated the motion energy of each distinct stimulus used in our experiment.

For each unique configuration of the stimulus that was tested, up to a rotation, we reconstructed the luminance values along the circle transecting the element centers, sampling a time series at the frame rate of the monitor used in the experiment. To this reconstructed stimulus data we applied a motion-energy model similar to [Adelson and Bergen, 1985], defining the motion energy as the squared output of a set of linear analysis filters. We used odd- and even-symmetric spatial filters, and causal temporal filters withan approximate quadrature relationship. Specifically, the spatial analysis filters used were Cauchy filters [Klein and Levi, 1985] with the center frequencies matched to those of the stimuli. The temporal components of our filter were the same as used Kiani et al. [2008] which are intended to approximate the temporal frequency response of MT cells something or other (movshon) Evidence from human psychophysics suggests that temporal frequency response does not appreciably change as a function of either eccentricity or spatial frequency [Virsu et al., 1982, Wright and Johnston, 1983]; therefore we used the same temporal components in all filters. However, evidence from human psychophysics suggests that the spatial bandwidth of channels in early vision changes as a function of both eccentricity and spatial frequency; in particular, at a given eccentricity, the bandwidths of the filters decrease somewhat with increasing spatial frequency, lending more lobes to the impulse response function [Anderson and Burr, 1987, Banks et al., 1991, Anderson and Burr, 1991]. We interpolated the measurements of Banks et al. [1991] to select the bandwidth parameters of our filters. The values we selected are shown in 1. We calculated the response of our spatiotemporal filters in several overlapping spatial frequency bands and weighted the response according to a typical contrast sensitivity function for human observers () For each stimulus this analysis produced two numbers, a "clockwise" motion energy and a "counterclockwise" motion energy.

- For our stimuli, the displacement interacts somewhat with motion energy, so that covarying displacement and direction content does not cleanly separate direction content and
- Plot a surface or collection of lines illustrating this.
- Illustrate closer model fit with motion energy versus direction content?

	Spatial frequency		
Eccentricity			
2.96			

Table 1: Bandwidth settings used in motion energy analysis. These values were chosen by interpolating measurements performed by Banks et al. [1991].

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