A Theory to Explain the Perceived Motion Direction of Equal-Spatial-Frequency Plaid Stimuli

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A plaid is the superposition of two sinewave gratings that move independently in different directions, with different speeds, and contrasts. Five themes emerged in our study of same-spatial-frequency plaids

1. The components of velocity, direction and speed, are computed separately in early stages of motion processing. The focus here is exclusively on direction.

2. Procedure: In studying motion, context matters. When most stimuli occur in a restricted range of directions, the representation of directions is distorted, therefore motion stimuli must occur in random directions;

3 (a) First-order theory and data. There are three different early motion computations:
When only first-order system is stimulated (e.g., by temporal frequencies >10 Hz), a remarkably simple pattern emerges: Only the contrast ratio of the two plaid components matters in determining perceived direction, direction is completely independent of the absolute contrast over the visible range.

(b) When each component sinewave is represented as a contrast-strength vector (direction perpendicular to stripes of sinewave, length determined by a factor ρ representing the relative effectiveness of that temporal frequency) times contrast to a power β ($\beta \cong 2$, β varies among subjects), perceived direction is completely determined by contrast-strength vector summation, velocity is irrelevant.

(c) Once the β and ρ for a subject have been determined for a reference set of plaids that all have the same angle between components which vary only in contrast,
the same β, ρ predict 99% of the variance of new data with plaids composed of a full range of possible angles and different contrasts

4. For 1 & 2 Hz high-equal-contrast plaids, exclusively third-order motion is perceived--movement in the direction of rigid translation (pattern direction, intersection of constraints). At intermediate contrast ratios and temporal frequencies, a combination of 1st & 3rd order motion is perceived. Second-order motion is irrelevant for these plaids.

5. A purely theoretical,-one-parameter-alpha theory that embodies the above principles, captures the essence of the full range of the data for same-spatial-frequency plaids.

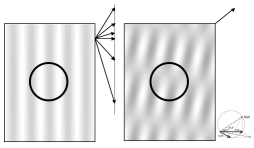
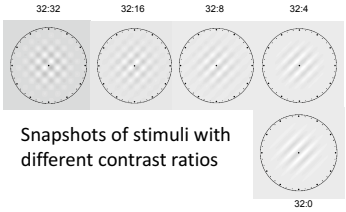


Figure 1, Sinewave grating and plaid, showing true directions of motion that are equivalent when viewed thru the circular aperture.



Snapshots of stimuli with different contrast ratios

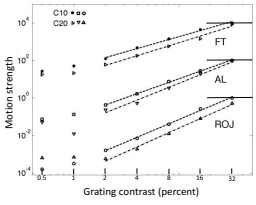
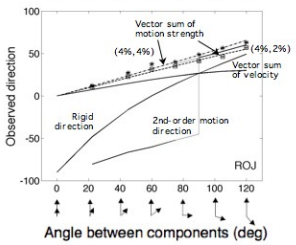
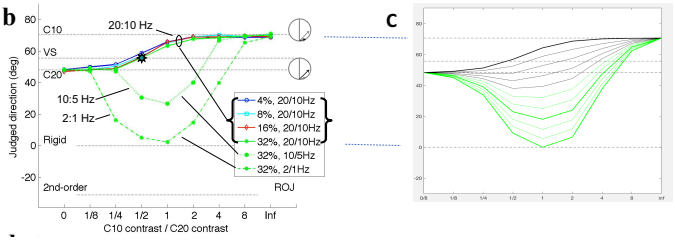


Figure 3, log-log plot of estimated motion strength as fc of grating contrast for two plaid-component sinewaves (10Hz, 20Hz) for three subjects. All slopes are approximately equal to 2.0



Perceived directions of randomly oriented plaids as the angle between the component gratings is varied plus the predictions of four theories. Components are 10, 20Hz to activate only first-order system. Data are shown for plaid contrasts 2%, 4%.



(**b**) Data for one subject judging motion direction of type-2 plaid stimuli (10Hz, 20Hz) as a function of the component contrast ratios (abscissa) with overall contrast and temporal frequency as the parameters. Ordinate: Judged motion direction relative to the rigid direction. C10, C20 horizontal lines represent the angles (relative to rigid direction) of the two temporal-frequency components. VS represents vector summation of their velocities. 2nd-order represents the direction of second-order motion. Note that at the highest temporal frequency, four curves lie precisely on each other indicating that only the contrast ratio matters. (**c**) Theory. Predictions of the one-parameter-alpha-theory as alpha varies from 0 (pure first-order motion, top) to 1 (pure third-order motion).