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# An explanation of why component contrast affects perceived pattern motion

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ABSTRACT

Component contrast is an essential element in computing spatio-temporal motion energy, and has been shown to bias perceived motion (Thompson, 1982). More recently, Champion, Hammett, and Thompson (2007) concluded that two-dimensional features in the stimulus was the explanation for this motion bias. Here a method was used that eliminated two-dimensional features as the source of the bias. Bowns (1996) showed that Type II plaids shifted from the intersection of constraints direction (IOC) to the vector average direction (VA) as a function of the speed ratio of the components at short durations. It was therefore argued that if the speed of the components could be increased or decreased by varying the component contrast, then this should be reflected in the change from the IOC to the vector average. Perceived direction was markedly affected by contrast. Contrast can bias perceived motion even when two-dimensional features are controlled for, but the source of the bias is not from computing the IOC from motion energy, or by tracking two-dimensional features, but instead is predicted by the Component Level Feature Model developed to be predominantly invariant to contrast.



## 1. Introduction

Spatio-temporal energy models of motion (Adelson & Bergen, 1985; van Santen & Sperling, 1984; Watson & Ahumada, 1985) are arguably the most influential type of motion model in vision research. Although the models have increased in complexity to accommodate more recent results (Simoncelli & Heeger, 1998) they all share two important properties, (1) decomposition of the moving pattern into individual components, and (2) extraction of motion energy based on motion contrast.

With component contrast playing such an important role in motion processing it is important to understand its effect on perceived motion. A study by Thompson (1982) using single component gratings showed that gratings with a higher contrast were perceived to move faster and those with a lower contrast were perceived to move slower. This has implications for perceived direction of moving plaids and predicts direction bias; this was investigated by Stone, Watson, and Mulligan (1990). They used plaids with components of unequal contrast that moved in different directions about vertical. The perceived directions of the plaids was reported to be biased towards the higher contrast component by up to 20° compared to a similar plaid where the contrast of the components was equal. They assumed that the source of this bias was the perceived speed change at the component level that depended upon contrast, and suggested that the "Intersection of constraints rule" (IOC) (Adelson & Movshon, 1982) be amended to take account of perceived speed rather than veridical speed. The IOC was introduced to solve the aperture problem.[1] To compute the IOC, each component is plotted as a vector in velocity space and a constraint line is drawn perpendicular to each vector, the resultant that goes through the point of the intersection of the constraint lines is the predicted direction. The IOC in addition to solving the aperture problem also predicts the veridical direction, and has received a good deal of support (Adelson & Movshon, 1982; Bowns, 1996; Bowns & Alais, 2006; Yo & Wilson, 1992).

A more recent study by Champion, Hammett, and Thompson (2007) revealed a more complex picture. Using similar stimuli they showed that the bias was different depending on the speed of the plaids; at faster speeds the bias was towards the higher contrast component but at lower speeds the bias was towards the lower contrast component. They were also able to show that computing the IOC from perceived speed did not predict their results. They concluded that the source of the motion bias was to be found in the two dimensional features of the plaids of the type described by Bowns (1996). Specific dominant two-dimensional features were correlated with the motion bias. The aim of this experiment was to test the hypothesis that two-dimensional features were the source of the motion bias as suggested by Champion, Hammett, and Thompson (2007). Two-dimensional features are defined as

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[1] When a one-dimensional stimulus such as a single component is viewed through an aperture, veridical motion is identical for a family of components moving in different directions.

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any features occurring in the two-dimensional pattern that occur as a result of combining two components.

In order to control for two-dimensional features, a series of plaids similar to those used by Bowns (1996) were used. These were Type II plaids that were perceived to shift from the intersection of constraints direction (IOC) to the vector average direction (VA) as a function of the speed ratio of the components at short durations. Type II plaids are plaids where the predicted IOC direction falls to one side of the components, and hence predicts a quite different direction to that of the vector average (Wilson, Ferrera, & Yo, 1992). The vector average was also hypothesised as a method for solving the aperture problem (Wilson, Ferrera, & Yo, 1992).

By using the Type II plaids used in the (Bowns, 1996) study it is possible to vary contrast and control for two-dimensional features. Fig. 1a illustrates the three types of plaid used in the (Champion, Hammett, & Thompson, 2007) study. There are clear two-dimensional features (indicated by the white lines), the perpendicular direction (indicated by the white arrows) of which is consistent with the motion bias reported by Champion, Hammett, and Thompson (2007). Compare these with the plaids used in the current study shown in Fig. 1b the most salient and high contrast two-dimensional spatial features, indicated by white lines, vary only slightly compared with those shown in Fig. 1a. It is argued that if the perceived speed of the components could be increased or decreased by varying the component contrast, then this should be reflected in the function relating perceived direction to component speed ratio, in the absence of the bias from these two-dimensional spatial features.

### 1.1. Equipment

Stimuli were generated on an Apple Macintosh Pro computer with a gamma-corrected Mitsubishi Diamond CRT monitor Plus 73 with a screen resolution of 1024 × 768 pixels running at a frame rate of 85 Hz. The screen subtended 31.5° of visual angle when viewed at a distance of 57 cm, therefore 1 pixel subtended 1.83 min/arc All experiments were programmed and run in MATLAB version R2010a, and the screen timing was maintained using the screen commands from the Psychophysics Toolbox (Brainard, 1997). The screen background was maintained at a constant level corresponding to the mean luminance of the stimuli. There were three observers. They had normal or corrected vision, and two of them were naïve observers. All observations were carried out in a dimly lit laboratory. This experiment was carried out in accordance with the University of Nottingham ethics procedure.

### 1.2. Stimuli

The plaids were in cosine phase and always had components with orientation 202 and 225 deg from 0 deg at the horizontal, with a spatial frequency of 4 cpd. The speed of each component was determined by the size of the phase shift angle. There were 16 frames and each frame appeared for 11.76 ms, a duration of 188 ms. The component oriented at 202 deg was updated on every other frame by a phase shift of 40 deg, this is referred to as the faster component. The component oriented at 225 was updated on every other frame by a phase shift that varied between 18° and 30° in steps of 2 deg, this is referred to as the slower component. The speed ratio therefore varied between 1:0.45 and 1:0.75, where

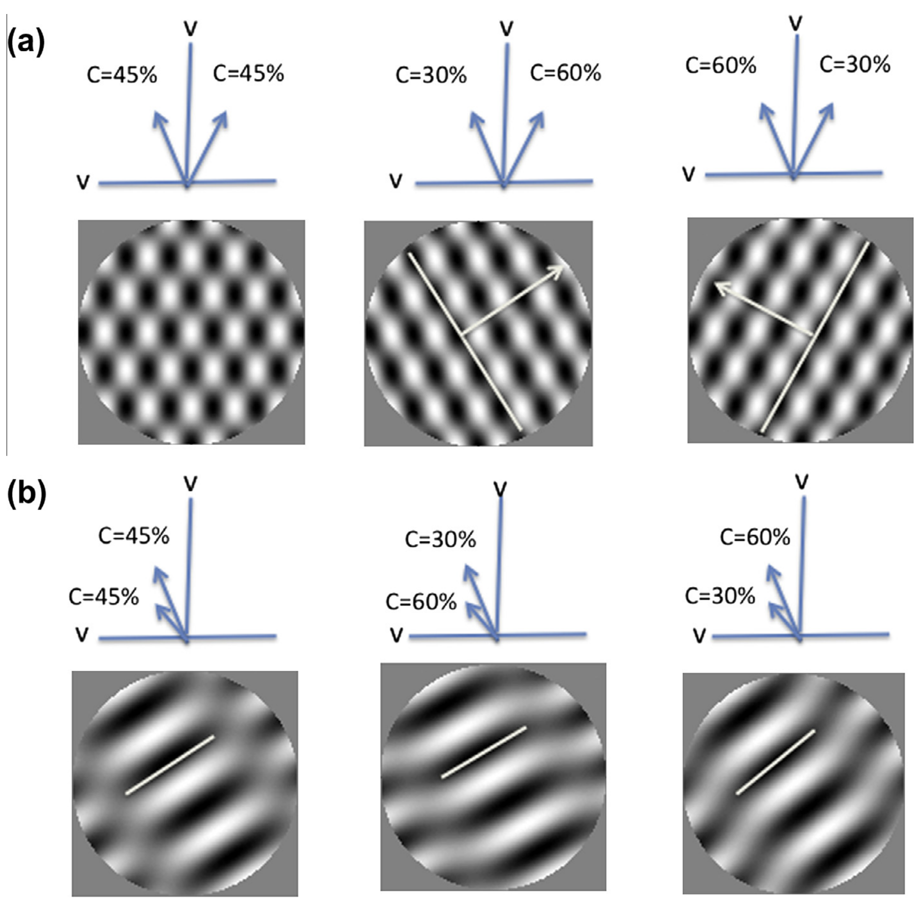


**Fig. 1.** (a) Velocity space diagrams are shown for three plaids used in earlier studies where only the contrast varies as indicated. There is no dominant orientation in the plaid where the contrast is equal, but there is when contrast is not equal, as indicated by the lines. (b) Velocity space diagrams are shown for the three plaids used in the current study where only the contrast varies as indicated. The dominant orientation is similar across the three plaids, again indicated by lines.