Snakes are as fast as ladders: evidence against the hypothesis that contrast facilitation mediates contour detection

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Introduction

It is easy to detect a "snake" consisting of spatially separated, collinear elements, embedded in a field of randomly oriented elements (Field, Hayes & Hess, 1993, *Vision Research*, *33*, 173-193). Performance is poor when elements are oriented at 45° to the contour, but improves when elements are orthogonal to the contour ("ladders") (Ledgeway, Hess & Geisler, 2005, *Vision Research*, *45*, 2511-2522).

Contour detection has been related to a phenomenon known as *contrast facilitation* or *flanker facilitation*, whereby the contrast threshold for detection of an element is reduced when it is flanked by other elements: many models assume that contours are detected through the modulation of neuronal activity by the facilitatory signals that underlie contrast facilitation.

If this were the case, one would expect contour detection to show similar temporal properties to contrast facilitation. Cass & Spehar (2005, *Vision Research*, *45*, 3060-3073) estimated that the facilitatory signals from non-collinear flankers (Fig. 1b) propagate about ten times faster than those from collinear flankers (Fig. 1a). If the same mechanism underlies both contrast facilitation and contour integration, we would therefore expect ladders to be integrated about ten times faster than snakes.

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Methods

We assessed the integration speed of snakes and ladders, with small and large inter-element separations, using a similar procedure to Hess, Beaudot & Mullen (2001, *Vision Research*, *41*, 1023-1037). In this procedure, the display alternated between the stimulus and a mask in which all element orientations were rotated by 45° (see Fig. 2). We varied the temporal frequency at which the display flipped between stimulus and mask, and found the frequency at which contour detection performance reached threshold (67.5% correct). We reasoned that a higher temporal frequency threshold would correspond to a higher propagation speed because, at a higher temporal frequency, the integration process would need to be faster in order to integrate the contour before the interruption occurred.

For the lowest temporal frequency, the time allocated to an interval allowed only the stimulus, and not the mask, to be presented, so this condition was unmasked.

In Experiment 1, to compare the effects of the mask on nearly straight snakes and ladders, we forced the performance level for snakes and ladders to be the same (85% correct) on the lowest temporal frequency (unmasked) condition. This was achieved by randomly jittering the orientation of the contour elements relative to the path.

In Experiment 2, performance on the unmasked condition was adjusted by varying the *path angle* (i.e. the angle between adjacent segments of the contour), instead of orientation jitter.

The jitter standard deviations, and path angles, were determined with pilot experiments. These levels are given in the results sections.

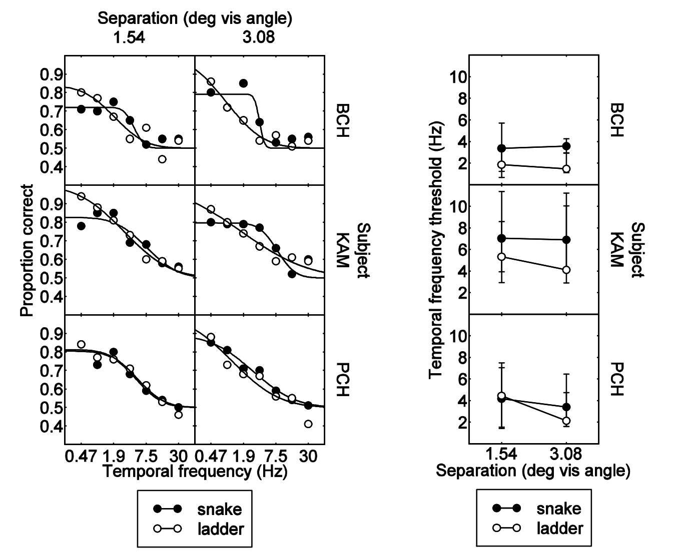
Results of Experiment 1

The jitter levels (in degrees) are given in the following table:

Subject	Snake jitter SD		Ladder jitter SD	
	Low sep	High sep	Low sep	High sep
BCH	21.5	16.2	18.7	15.7
KAM	19.4	18.3	18.1	13.5
PCH	18.1	17.7	13.2	4.8

Fig. 3a shows the data for individual conditions, along with the best-fitting cumulative Gaussian psychometric functions. Fig. 3b shows the temporal frequencies corresponding to 67.5% correct (i.e. half-way between chance and 85%).

Figure 3a **Figure 3b**



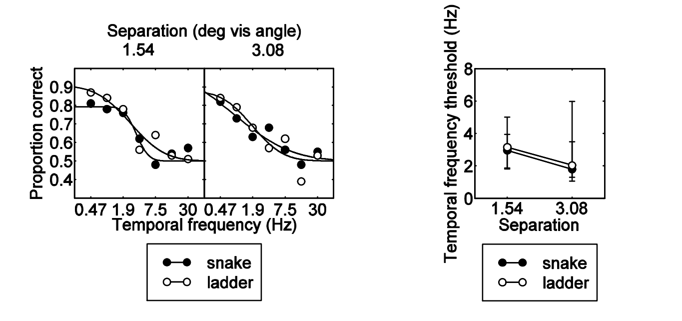
Results of Experiment 2

The path angles (in degrees) are given in the following table:

	Low sep	High sep
Snake path angle	32.1	21.7
Ladder path angle	20.6	14.2

Only KAM participated in this experiment. Fig. 4 shows the data in the same format as Fig. 3.

Figure 4a **Figure 4b**



Conclusions

The temporal frequency threshold was no higher for ladders than snakes. If anything, there was a slight trend for snakes to have a higher threshold. This suggests that ladders are integrated no faster than snakes.

This contrasts with the results of Cass & Spehar's experiments on the temporal properties of contrast facilitation.

We conclude that contour integration and contrast facilitation are mediated by different mechanisms.

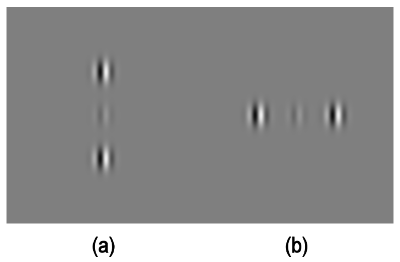


Figure 1. (a) Collinear flankers. (b) Orthogonal flankers. Both configurations can make the central target easier to detect. The facilitatory signal in (b) propagates about ten times faster than that in (a) (Cass & Spehar, 2005, *Vision Research*, *45*, 3060-3073).

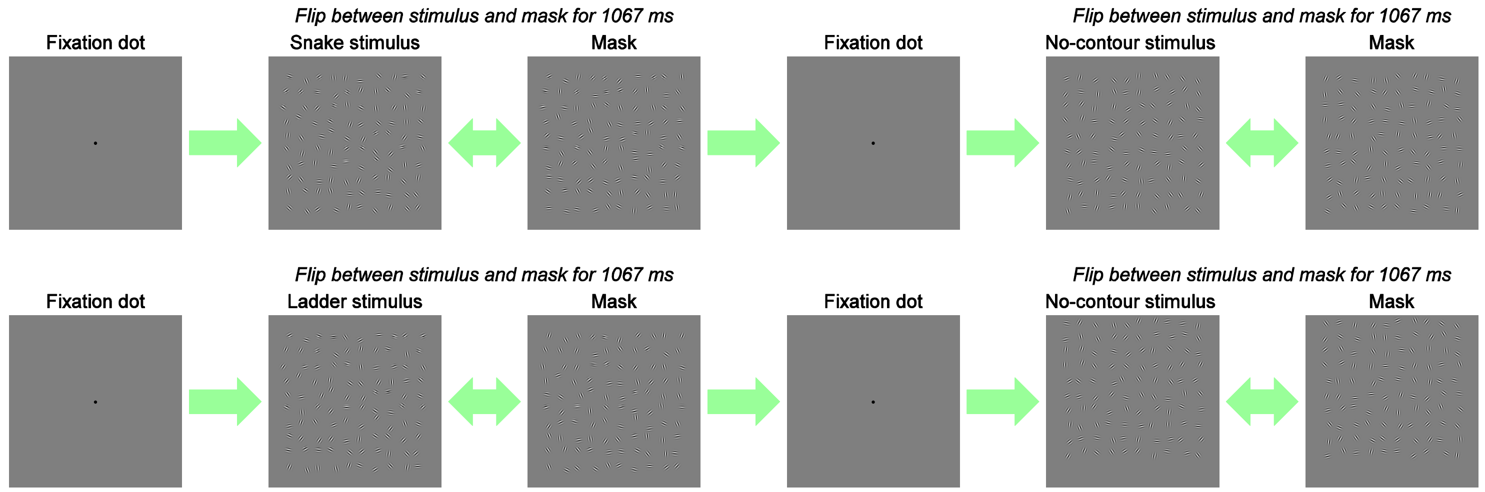


Figure 2. Each row shows the sequence of events within one trial. The top row shows a trial with a snake contour, and the bottom row shows a trial with a ladder contour. In these examples, the first interval contains the contour. In the experiments, the interval containing the contour was randomly selected on each trial. The subject had to indicate which interval contained the contour. Each interval lasted for 1067 ms. During the interval, the display alternated between stimulus and mask, each displayed for t ms, where t took values of 1067, 533.3, 266.7, 133.3, 66.67, 33.33, and 16.67. The temporal frequency of modulation was defined as $1/(2t)$, giving values of 0.46875, 0.9375, 1.875, 3.75, 7.5, 15, and 30 Hz.