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, Hays & 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 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.

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 (2003, 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) 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.

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.

Conclusions

The temporal frequency threshold was no higher for ladders than snakes. If anything, there was a slight trend for snakes to perform better, and for ladders to be 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.

Results of Experiment 1

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

<table>
<thead>
<tr>
<th>Subject</th>
<th>Snake jitter SD</th>
<th>Ladder jitter SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCH</td>
<td>21.5</td>
<td>16.2</td>
</tr>
<tr>
<td>KAM</td>
<td>19.4</td>
<td>18.3</td>
</tr>
<tr>
<td>PCH</td>
<td>18.1</td>
<td>17.7</td>
</tr>
</tbody>
</table>

Fig. 3a shows the data for individual conditions, along with the best-fitting cumulative Gaussian psychometric functions.

Results of Experiment 2

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

<table>
<thead>
<tr>
<th>Subject</th>
<th>Snake path angle</th>
<th>Ladder path angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCH</td>
<td>32.1</td>
<td>21.7</td>
</tr>
<tr>
<td>KAM</td>
<td>20.6</td>
<td>14.2</td>
</tr>
</tbody>
</table>

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

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.

Figure 3a

Figure 3b

Figure 4a

Figure 4b

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