Suppression of pattern detection in apparent motion trajectory

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Letter discrimination is impaired when the letter is presented within an apparent motion (AM) trajectory of a spot. This finding suggests that the internal representation of AM stimuli can interfere with perception at a relatively high processing level. Here, we investigated whether AM interference also occurs at an earlier processing level. We found that the detection threshold of patterns defined by a luminance dimension was impaired in an AM trajectory. Further, this suppressive effect of AM became weaker when the contrast polarity, orientation, or shape of the inducers of the AM and the target was inconsistent. These findings suggest that AM stimuli and their internal representation affect early visual processes involved in detecting a pattern and that the internal representation of an AM stimulus reflects the stimulus's attribute.

Key words: apparent motion, internal representation, pattern detection, contrast polarity, orientation, shape

In an apparent motion (AM) display, illusory motion perception vividly occurs even in a motion trajectory where no physical inputs exist. This indicates that the representation of an object undergoing AM can be established in the whole trajectory. For example, Yantis and Nakama (1998) found that letter discrimination was impaired when the letter fell within the path of an AM trajectory of a spot. This suggests that the internal representation of AM stimuli can interfere with our perception. However, it has remained unclear whether this AM interference occurs only in a relatively high processing stage (letter processing) or in a more basic, earlier perceptual process (pattern detection). The current research investigated whether the detection performance of the pattern defined in luminance dimension could be impaired in an AM trajectory.

General Method

Stimuli. We presented two inducers and one target (a square, 1 × 1 deg, Figure 1) at 5 deg below a fixation cross on a gray background (29.96 cd/m²). The horizontal gap between the inducers was 5 deg, and that between an inducer and the target was 2.5 deg. The inducers' durations and interstimulus intervals (ISIs) were 106 ms, and the target's duration was 26 ms.

Procedure. In one condition, the target was presented in-between the inducers (On-AM-path, Figure 1). In a second condition, the vertical position of the inducers was displaced relative to the target by 2 deg (Off-AM-path). And, in a third condition, two inducers simultaneously flickered so that an AM was not perceived (FL). The target was randomly presented once within 20 cycles of the AM sequences. Two series of 1 up, -1 down staircases, were run for estimating the 50% threshold. Whereas the Weber contrast of the inducers was constant (100%), the target luminance varied along 32 log-scaled steps from ±2 to ±100% of the Weber contrast. The threshold was calculated by averaging the last four reversal data. Three conditions (each containing two

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staircases presented in a pseudo-random order) were presented in a random order and counterbalanced among the participants. The task of the participants was to report whether they perceived the target or did not (target detection).

**Experiment 1: Contrast polarity**

Whereas the contrast polarity of both the inducers and target was positive (white) in Experiment 1a, it was negative (black) in Experiment 1b. In Experiment 1c, the contrast of the inducers was positive, and the contrast of the target was negative. Five observers participated in each of the experiments.

**Results and Discussion.** In experiments 1a and 1b (Table 1), a one-way repeated ANOVA revealed a significant main effect of the conditions (Experiment 1a; $F(2, 8) = 8.97, p < .01$: Experiment 1b; $F(2, 8) = 13.02, p < .01$). A post hoc comparison (Tukey's HSD) found that the contrast threshold in the On-AM-path condition became higher relative to that in the Off-AM-path and FL conditions. The same tendency was also found in Experiment 1c ($F(2, 8) = 7.90, p < .05$). However, the effect size ($d$, Cohen, 1988) in the On-AM-path condition compared to the Off-AM-path and FL conditions, was weaker in Experiment 1c ($d = 0.69$ and $0.81$, respectively) than that in Experiment 1a ($d = 2.08$ and $2.29$, respectively) and Experiment 1b ($d = 3.25$ and $2.90$, respectively). These results suggest that the representation of an object undergoing AM can impair even early visual processes, such as pattern detection. Moreover, this suppressive effect can be modulated by the consistency of a stimulus attribute (contrast) between the inducers and target.

**Experiment 2: Orientation**

We manipulated the orientation of the stimuli in Experiment 2 in order to further investigate the effect of the consistency of stimulus attribute on AM interference. We used Gabor patches with vertical stripes (45 x 45 pixel (1.5 deg)), 0.06 cycle/pixel, $\sigma = 10$ pixel) as the stimuli. Whereas the inducers and target were tilted at 45 deg in the Consistent condition, the orientation of the target was -45 deg in the Inconsistent condition. Only the On-AM-path situation was tested. Four observers participated in the experiment.

**Results and Discussion.** A two-tailed $t$-test revealed that the contrast threshold in the Consistent condition was smaller than that in the Inconsistent condition ($t(3) = -2.35, p < .05, d = 2.93$; Table 1). This indicates that AM interference was larger when the orientation of the target and inducers was consistent.

**Experiment 3: Shape**

In Experiment 3, we tested the effect of shape consistency on AM interference. Whereas the inducers and target were square (area: 1 deg$^2$) in the Consistent condition, the shape of the target was circular (diameter: 1.12 deg, area: 0.96 deg$^2$) in the Inconsistent condition. Only the On-AM-path situation was tested. Six observers participated in the experiment.

**Results and Discussion.** A two-tailed $t$-test revealed that the contrast threshold in the Consistent condition was smaller than that in the Inconsistent condition ($t(5) = 2.97, p < .05, d = 2.74$; Table 1). This result suggests that the AM interference was larger when the shape of the target and inducers was consistent.

**General Discussion**

The present study showed that the detection of patterns defined by luminance was impaired when the pattern was presented within an AM trajectory. Moreover, this suppressive effect of AM became stronger when a stimulus attribute (contrast, orientation, or shape) of the target pattern was consistent with that of the objects in AM. These findings indicate that AM stimuli and their representation affect early visual processes involved in detecting a pattern, and that the internal representation of an AM stimulus reflects the stimulus's attribute.

**References**


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**Table 1. Contrast thresholds (Weber contrast, %) obtained in Experiments 1, 2, and 3.**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>On-AM-path</th>
<th>Off-AM-path</th>
<th>FL</th>
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<tbody>
<tr>
<td>Exp. 1a</td>
<td>19.7</td>
<td>11.9</td>
<td>13.9</td>
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<tr>
<td>Exp. 1b</td>
<td>-17.5</td>
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<tr>
<td>Exp. 1c</td>
<td>-10.8</td>
<td>-8.5</td>
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<table>
<thead>
<tr>
<th>Consistent</th>
<th>Inconsistent</th>
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<tbody>
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<td>Exp. 2</td>
<td>25.3</td>
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<tr>
<td>Exp. 3</td>
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