Changes in Perception of Induced Motion Based on Voluntary Eye Movements in an Attentional Task

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Abstract. Sometimes a static object in video content is perceived to move. This motion illusion has been classified into two types: (1) induced motion and (2) motion capture. The purpose of this paper is to clarify how voluntary eye movements affect perceptions of induced motion and motion capture. By the results of a subjective assessment experiment, it is clarified that induced motion is inhibited by attention in both the horizontal and the vertical directions for reading textual information. It is also clarified that in contrast to induced motion, motion capture is not inhibited by attention. Specifically, motion capture is not inhibited by attention when viewers move their eyes in the same direction as the movement of the background.

Keywords: Motion illusion · Induced motion · Motion capture · Voluntary eye movement · Attention

1 Introduction

Sometimes a static object in video content is perceived to move left when the background moves right, a phenomenon called induced motion. A related type of induced motion, called motion capture [1], occurs when a static object is perceived to move left when the background moves left. Elucidation of these illusions may help lead to elucidation of the visual function. For example, previous research has reported that induced motion is inhibited by attention [2]. Subtitles, annotations, and other textual information in video content will inhibit the perception of induced motion because this textual information captures the viewer's attention.

Japanese text may be written either vertically or horizontally. Vertical writing is a traditional Japanese format and can be seen in samurai drama, anime, manga, and other Japanese content. When attending to or reading vertical Japanese textual information, viewers move their eyes from top to bottom. However, relationships among motion illusions and voluntary eye movements have not been sufficiently studied. The purpose of this paper is to clarify how voluntary eye movements affect perceptions of induced motion and motion capture in an attentional task. We examine the perceptual characteristics of these motion illusions using a subjective assessment experiment.

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2 Subjective Assessment Experiment

Twenty Japanese individuals aged 19–25 participated in this experiment. The participants watched experimental video content with textual information and features that produce the following two illusions: (1) induced motion and (2) motion capture.

2.1 Experimental Video Content

The experimental video content consisted of a centralized foreground and a dot-patterned background, as shown in Fig. 1. The foreground presented numerical expressions of addition and subtraction equations using single-digit numbers. The size of each character was approximately 0.5°. In the background, the size of each dot was one degree in diameter, and the dot density was 25 percent of the screen size. The background moved UPWARD, DOWNWARD, LEFTWARD, or RIGHTWARD at a velocity of 8°/s, with a frame rate of 60 frames per second. The resolution of the experimental video content, which was presented using a head-mounted display (Sony, HMZ–T3 W), was 1280 × 720 pixels (approximately 45 × 25°), and the foreground was 142 × 142 pixels (approximately 5 × 5°).

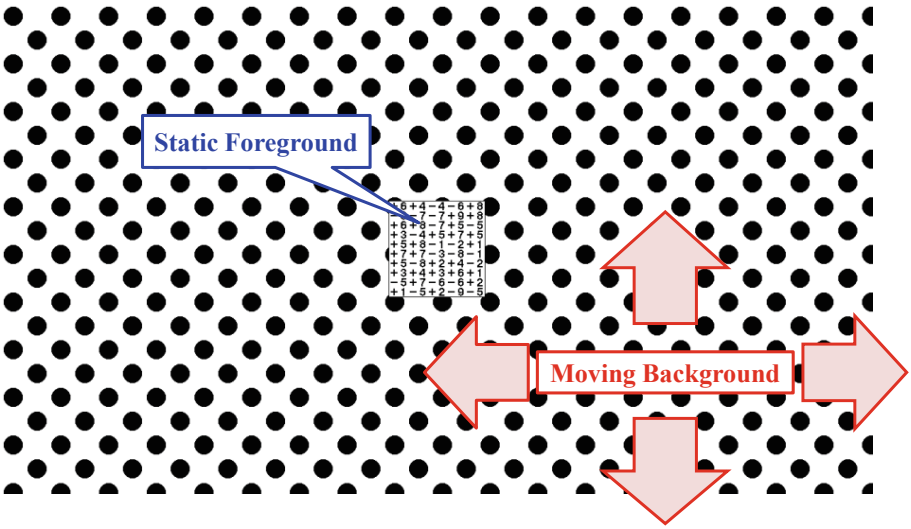


Fig. 1. An example of the experimental video stimuli

2.2 Experimental Methodology

Each time the participants watched the experimental video content, they were instructed to perform one of the following three tasks:

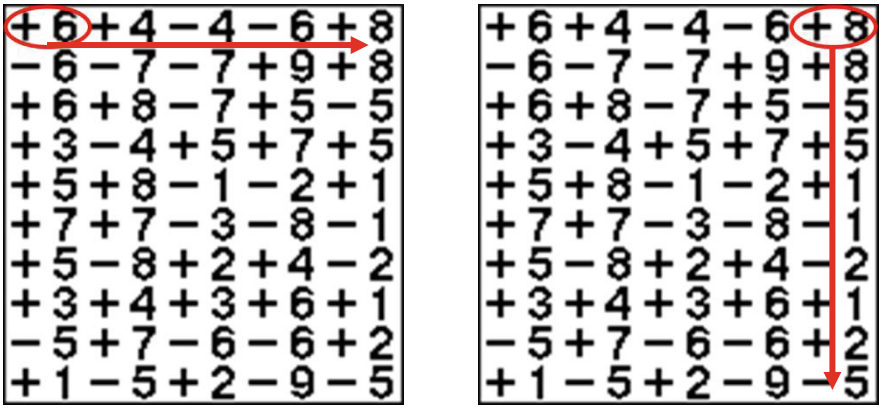
- CALCULATE (Please add and subtract the numbers in the foreground),
- READ (Please read the numbers in the foreground silently), or
- LOOK (Please look at the foreground naturally).

The task of calculating requires attending to the numerical expressions, as opposed to the task of silent reading; by contrast, the task of looking does not require particular attention. In addition, when participants were instructed to CALCULATE or to READ, they did so in one of two directions:

- HORIZONTAL (Please read from upper left to right, as shown in Fig. 2a), or
- VERTICAL (Please read from upper right to bottom as shown in Fig. 2b).

Table 1 shows the combinations of these instructions and the directions of motion of the background. Each participant watched the video content twenty times; the order of the twenty conditions varied for each individual at random.

Figure 3 shows the procedure for this experiment and a typical viewing environment. Participants watched the video content in a seated position on the couch; they then responded to a number of questions related to their impressions of the video content. Figure 4 shows an example of a slide used in the questions. In the example shown, the question relates to perception of the foreground. The experiment was designed so that combinations of responses to the question and the direction of motion of the background would reveal patterns of perception. For example, the perception of induced motion would be identified in participants who responded to choice A in Fig. 4 after having watched video content with a background that moves in the DOWNWARD direction.



(a) HORIZONTAL (b) VERTICAL

Fig. 2. Images instructing how to read the numerical expressions in the static foreground

Table 1. Experimental conditions. "Cross direction" indicates the relationship between the direction of motion of the background and the reading direction. For example, the cross direction is SAME when a participant reads in the HORIZONTAL direction and the background moves RIGHTWARD because the instruction of HORIZONTAL means to read in a rightward direction.

No.	Task (Attention)	Reading direction (Voluntary eye movement)	Direction of motion of the background	Cross direction
1	CALCULATE	HORIZONTAL	UPWARD	ORTHOGONAL
2			RIGHTWARD	SAME
3			DOWNWARD	ORTHOGONAL
4			LEFTWARD	OPPOSITE
5		VERTICAL	UPWARD	OPPOSITE
6			RIGHTWARD	ORTHOGONAL
7			DOWNWARD	SAME
8			LEFTWARD	ORTHOGONAL
9	READ	HORIZONTAL	UPWARD	ORTHOGONAL
10			RIGHTWARD	SAME
11			DOWNWARD	ORTHOGONAL
12			LEFTWARD	OPPOSITE
13		VERTICAL	UPWARD	OPPOSITE
14			RIGHTWARD	ORTHOGONAL
15			DOWNWARD	SAME
16			LEFTWARD	ORTHOGONAL
17	LOOK	–	UPWARD	–
18			RIGHTWARD	–
19			DOWNWARD	–
20			LEFTWARD	–

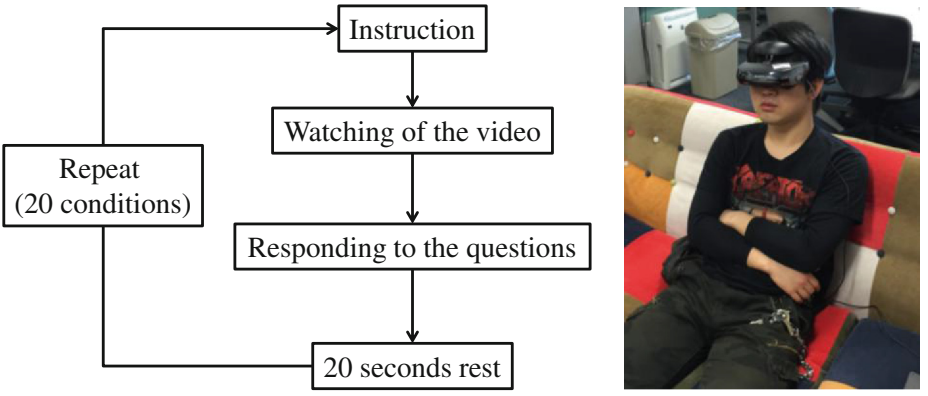


Fig. 3. The procedure for the experiment and a typical viewing environment

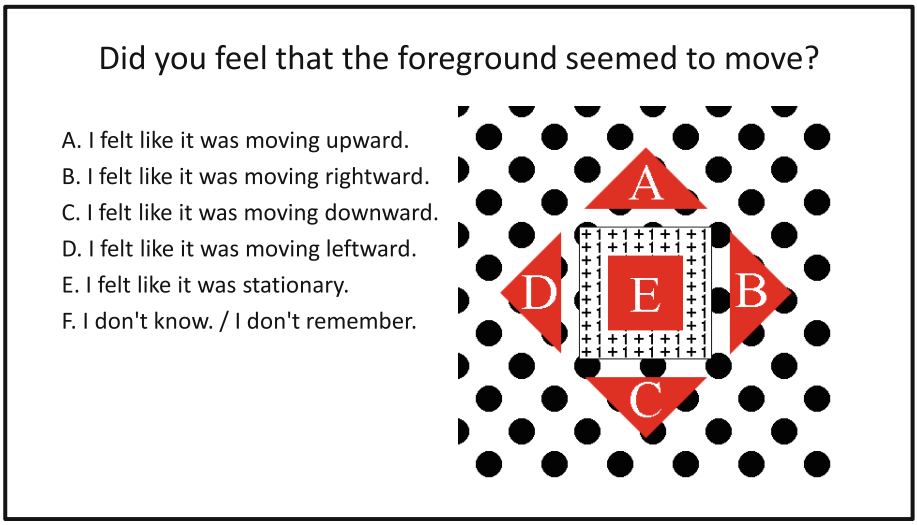


Fig. 4. An example of a slide used in the questions

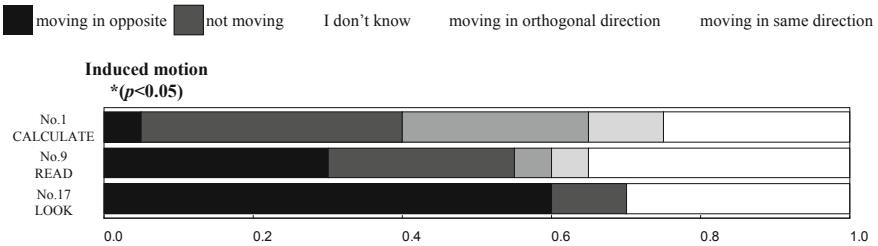
3 Results and Discussion

Figures 5 and 6 show the proportions of the various responses to indicating the perceived movement of the foreground against the movement of the background. Figure 5 summarizes the responses when the reading direction was HORIZONTAL, and Fig. 6 summarizes the responses when the reading direction was VERTICAL. In these figures, the colors represent the following three categories:

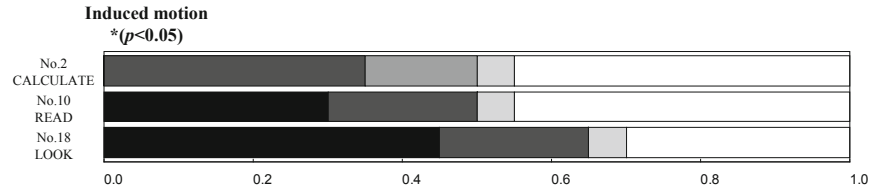
- The black area shows the proportion of responses indicating that induced motion was perceived because the participants responded that the foreground seemed to move in the opposite direction to the movement of the background.
- The three gray areas show the proportion of responses indicating that apparent motion was not perceived.
- The white area shows the proportion of responses indicating that motion capture was perceived because the participants responded that the foreground seemed to move in the same direction as the movement of the background.

Results of Cochran's Q test applied to the relationship between the black areas and the other areas in Figs. 5 and 6 show that perception of induced motion was significantly changed by attentional tasks in all the combinations of conditions ($p < 0.05$). We can therefore conclude that induced motion is inhibited by attention. This result is similar to that found in previous research [2]. In addition, it was revealed that this phenomenon occurs in both the horizontal and the vertical directions for reading textual information.

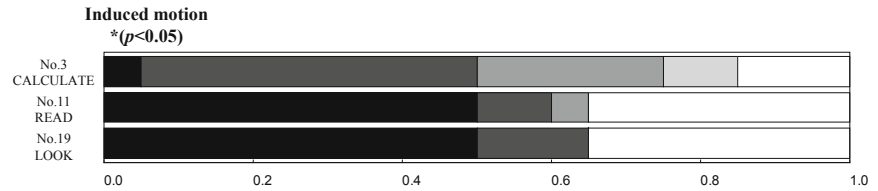
In contrast, the results of Cochran's Q test applied to the relationship between the



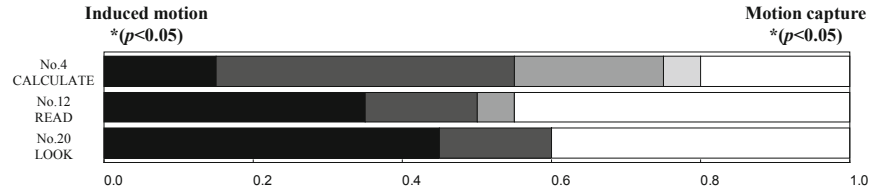
(a) Background: UPWARD



(b) Background: RIGHTWARD



(c) Background: DOWNWARD



(d) Background: LEFTWARD

Fig. 5. Proportions of responses indicating perceived foreground movement against the movement of the background when reading direction was HORIZONTAL. The condition numbers refer to the descriptions given in Table 1.

white areas and the other areas in Figs. 5 and 6 show that perception of motion capture was significantly changed by attentional tasks in only two conditions, as shown in Figs. 5d and 6b ($p < 0.05$). Therefore, it was revealed that motion capture is not always inhibited by attention and that voluntary eye movements do affect the perception of motion capture. Specifically, in this experiment, motion capture was not inhibited by

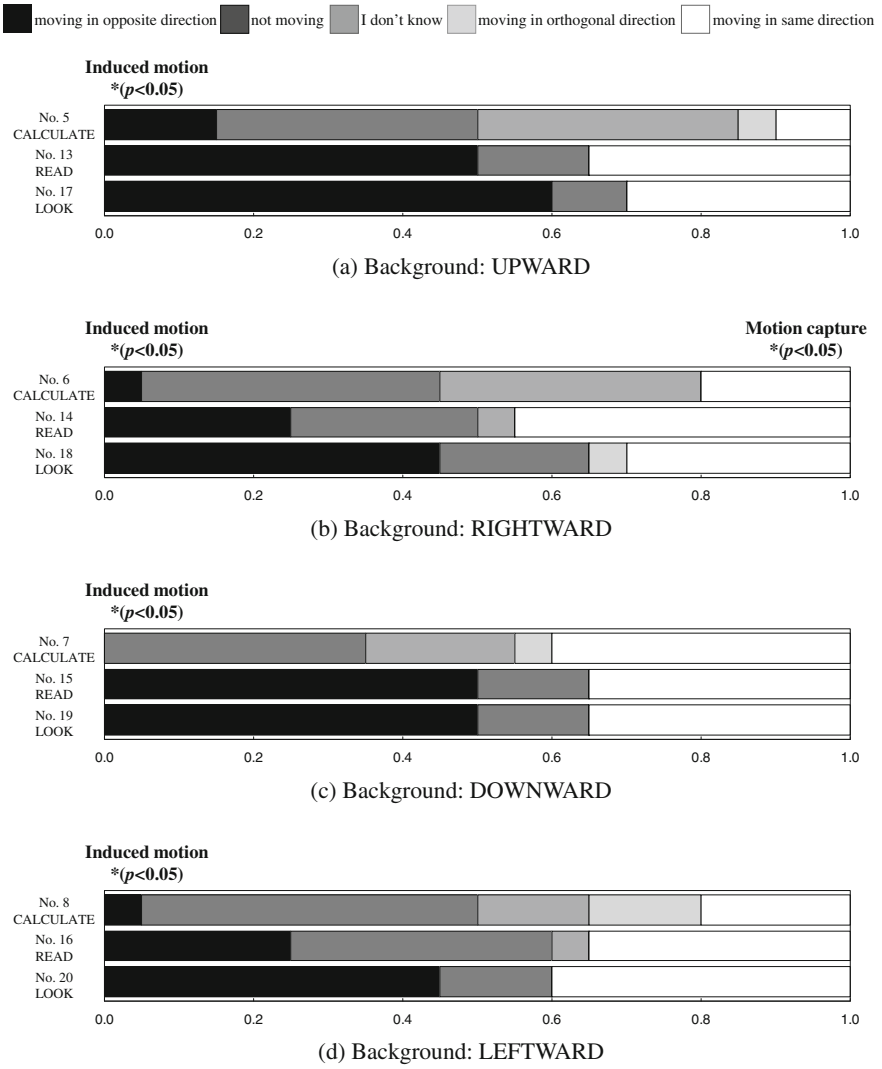


Fig. 6. Proportions of responses indicating perceived foreground movement against the movement of the background when reading direction was VERTICAL. The condition numbers refer to the descriptions given in Table 1. The proportions of responses for LOOK (Nos. 17, 18, 19, and 20) are used in both Figs. 5 and 6 because a reading direction for LOOK was not specified.

attention when the participants moved their eyes in the same direction as the movement of the background. This result contrasts with that for induced motion: during calculating, no participants perceived induced motion when the direction of reading and of movement of the background were the same, as is shown in Figs. 5b and 6c (conditions No. 2 and No. 7).

These results suggest that the mechanism of perception of induced motion is different from that of perception of motion capture.

4 Conclusion

The purpose of this paper is to clarify how voluntary eye movements affect perceptions of induced motion and motion capture in an attentional task. The results of this experiment are summarized as follows:

- Induced motion is inhibited by attention in both the horizontal and the vertical directions for reading textual information.
- In contrast to induced motion, motion capture is not inhibited by attention. Specifically, motion capture is not inhibited by attention when viewers move their eyes in the same direction as the movement of the background.

The difference between the perceptual characteristics of induced motion and motion capture suggests the possibility that the mechanisms of perception of these illusions are different.

In this experiment, the participants were instructed to move their eyes in order to read the textual information. However, their eye movement might be different from the direction given in the instruction. The authors of this paper did not measure the participants' eye movements with an eye tracker. Eye tracking data may be an important clue to understanding the results of this experiment in detail. Therefore, as a future study, it is worth considering performing the experiment using an eye tracker.

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