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Angle illusion in a straight road

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Abstract. We report a new angle illusion observed when viewing a real scene involving a straight road. The scene portrays two white lines which outline a traffic lane on a road and converge to a vanishing point. In experiment 1, observers estimated the angle created by these converging lines in this scene or in its image projected onto a screen. Results showed strong underestimation of the angle, ie over 50% for observations of both the real scene and its projected image. Experiment 2 assessed how depth cues in projected images influence the angle illusion. Results showed that this angle illusion disappeared when scene information surrounding convergent lines was removed. In addition, the illusion was attenuated with projection of an inverted scene image. These findings are interpreted in terms of a misadoption of depth information in the processing of angle perception in a flat image; in turn, this induces a massive angle illusion.

1 Introduction

Human observers sometimes overestimate or underestimate angles in pictures. These phenomena are known as angle illusions. Researchers have tried to explain them in terms of local feature processing. For instance, overestimation of apparent angle has been explained as a side effect of an inhibitory process that improves viewer's resolution of orientation within visual system (Blakemore et al 1970). This inhibition hypothesis explained several types of the angle illusion, including the Zöllner, Wundt – Hering, and Poggendorff illusions, although there is a claim that the Poggendorff illusion is due to misperceived orientation of the transversals, rather than being due to an inhibitory process (Wenderoth and Burke 2006).

In most cases, the stimuli used to examine these illusions are schematic line drawings. In the present study we report an angle illusion, which is obtained in viewing a landscape, and which cannot be explained by the inhibition hypothesis. That is, observers drastically underestimate the perspective angle that is created by converging lines on both sides of a long, extended, road in a real scene or in a projected image on screen (figure 1).

To understand the basis of this angle illusion, we conducted two experiments. In the first experiment, we compared the magnitude of this illusion resulting from viewing a real scene with its magnitude when a viewer sees a projected image of the same scene. Previous studies have demonstrated that the perceived size and distance of objects in a photograph are different from those perceived in a real space (Gibson 1947; Smith and Gruber 1958; Nagata et al 2008; Watanabe 2004). Therefore, we expected that the apparent angle in the real-scene condition would be different from that in the projection condition. In the second experiment, we examined how a depth cue in projected images affects the angle illusion because previous studies have demonstrated that the processing of perspective depth cue induces several geometrical illusions, such as the Ponzo illusion (Leibowitz et al 1969; Fujita 1996), and Müller-Lyer illusion (Gregory 1966). Results of these experiments suggest that this illusion is based on processing of depth information in the visual image, rather than on inhibitory processing.

2 Experiment 1

We prepared two different scene conditions. In the first condition (real-scene condition), participants sat (in a car) at the centre of the leftmost traffic lane of the four-lane road; they estimated the angle created by two street lines indicating the traffic lane. In the second condition (projection condition), participants observed a photograph of the same scene, taken from the same perspective, as in the first condition. This photograph was projected onto a screen. In both conditions, participants estimated the same angle from lines indicating the leftmost traffic lane.

2.1 *Methods*

2.1.1 *Participants.* Ten undergraduate and graduate students served as observers (aged 21 – 24 years; three females and seven males). All were naive to the purpose of the study, and had normal or corrected-to-normal vision.

2.1.2 *Stimulus.* A scene of a straight four-lane road was used in the experiment (figure 1). The width of one lane was 3 m. The road ended at a white barrier (a guardrail), at a distance of 620 m from the participant. Evergreen trees, about 5 m in height, were lined up on both sides of the road at approximate intervals of 15 m.

Figure 1. [In colour online, see http://dx.doi.org/10.1068/p7068] Photograph of the natural scene used in experiments 1 and 2. Observers estimated the angle created by the converging lines A and B.

In the real-scene condition, participants viewed the scene from the front passenger seat of a station wagon. The car was parked in the leftmost lane of the road. The level of participants' eyes was about 120 cm above the ground. A white solid line and a white dashed line, respectively, outlined the two sides of the leftmost lane.

In the projection condition, participants viewed the image of the scene that was displayed by a projector (CP-X430, Hitachi) on a screen in a dark room. In order to reproduce the visual image observed in the real-scene condition, the pictorial image was taken from the same station point of the observer as in the real-scene condition. A digital camera (EOS Kiss Digital, Canon, 18 mm focal length, 3 : 2 aspect ratios) was used to photograph the scene. An image of 4:3 aspect ratios was trimmed from the original image in order to produce 50 mm equivalent focal-length photo taken (figure 1). The projected size was 140.7 cm × 105.5 cm. The distance from the screen to the participant was about 220 cm. Participants viewed the projected image from an office chair with a back support. The eye level was about 120 cm high. The visual angle of each object in the image was identical to its corresponding angle in the real space. The actual angle between the left solid line and the right dashed line in these images was 100°.

2.1.3 *Procedures.* In both the real-scene condition and projection condition, participants were required to estimate the angle that is composed of the leftmost solid line (A in figure 1) on the road shoulder and the dashed line (B in figure 1) in terms of degrees. They answered the question verbally once at each condition. The order of conditions was counterbalanced among the participants. There were no time restrictions for the participants.

2.2 *Results and discussion*

Figure 2 shows the averages and 95% confidence limits of the estimated angles for ten observers for each condition. In the real-scene condition, the mean angle was 39°. The maximum and minimum angles were 71° and 20°, respectively. The mean angle in the projection condition was 47°. The maximum and minimum angles were 80° and 35°. Because the actual angle was 100°, these data reflect massive angle illusions in all conditions. A paired *t*-test confirmed that the angle for the real-scene condition was significantly larger than that for the projection condition ($t_9 = 2.47$, $p < 0.05$).

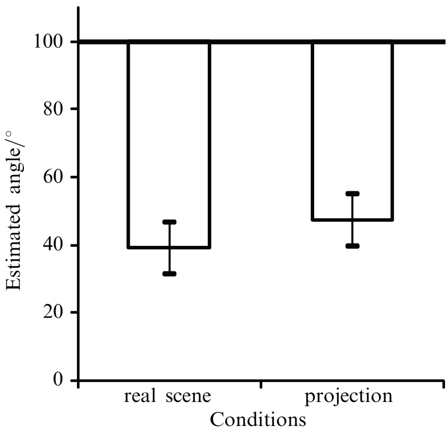

Figure 2. Mean and 95% confidence limits of estimated angle for each condition in experiment 1. Bold lines shows the actual angle (100°).

3 Experiment 2

In experiment 1, the perspective view of road induced a strong angle illusion. This appears to be true regardless whether the observation was that of a real-scene or a projected image of that scene, although the illusion for the real-scene was the larger of the two. In viewing an upside-down picture of road, human observers as well as other primates have difficulty in extracting depth information from the picture (Fujita 1996). In experiment 2, we examined how inverting the perspective image, and reducing the effects of perspective as depth cue impairs the angle illusion. In addition, as control stimuli we used upright and inverted angles based on converging lines only (ie scene information was omitted) to examine how the converging lines, without any scenic information, would induce the angle illusion in terms of the inhibitory processing between the lines.

3.1 *Method*

3.1.1 *Participants.* Forty undergraduate and graduate students took part in this experiment as observers (aged 19–25 years, six females and thirty-four males). All were naive to the purpose of the study. Each participant had normal or corrected-to-normal vision.

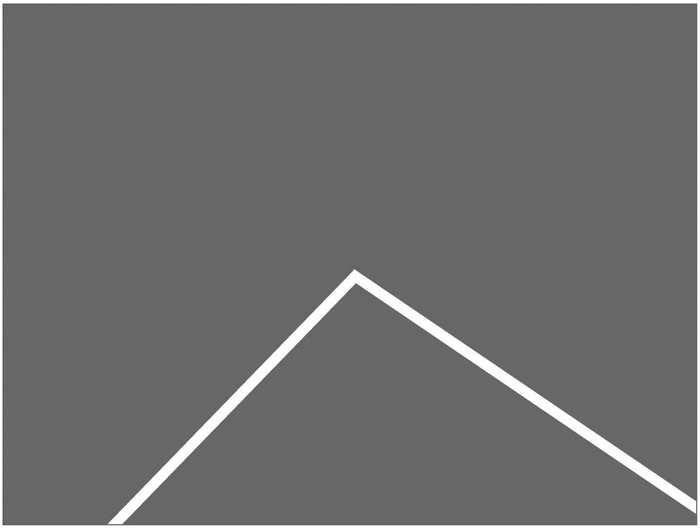

Figure 3. Convergent lines for upright control condition in experiment 2.

3.1.2 *Stimuli.* The projected image used in experiment 1 was used in experiment 2; however, it was presented in an inverted (upside-down) as well as an upright orientation in this experiment. We also prepared two control conditions which showed only the two convergent lines; all elements of the picture were deleted (figure 3). Instead of the deleted elements, we placed uniform grey pattern in the control conditions.

3.1.3 *Procedures.* Procedures used to present the upright-condition stimulus were identical to those used in the projection condition in experiment 1. In the upside-down condition, although the same photographic picture was used as in the upright condition, when projected onto the screen, this image was rotated by 180°. Procedures used to present all stimuli followed those of experiment 1.

Each of the four stimulus conditions was presented once to each observer. The order of observation of the four stimulus conditions was counterbalanced among the participants. In each trial, the participants estimated the angle as in experiment 1.

3.2 *Results and discussion*

Figure 4 shows the averages and 95% confidence limits of the estimated angle for forty observers for each condition. In the upright condition, the mean angle was 39°, although the actual angle was 100°. The maximum and minimum angles were 85° and 10°, respectively. The mean angle in the upside-down condition was 52°. The maximum and minimum angles were 100° and 15°. A paired *t*-test showed that the estimated angle for the upside-down condition was significantly larger than that for the upright projection condition ($t_{39} = -4.113$, $p < 0.001$).

For the control stimuli, the mean angles in the upright and upside-down conditions were, respectively, 98° and 97° (figure 4b). The maximum and minimum angles for these stimuli were 130° and 80°, respectively. There was no significant difference between the upright and upside-down conditions ($t_{39} = 0.819$, $p > 0.10$), although the apparent angles for the upright condition and upside-down condition tended to be smaller than the actual angle of 100°.

These results indicate that both for the upright and upside-down conditions the participant underestimated the angle. The extent of the underestimation for the upright condition was larger than that for the upside-down condition. In addition, without the scenic information of the picture, the convergent lines themselves do not induce any significant underestimation of the angle between the two convergent lines.

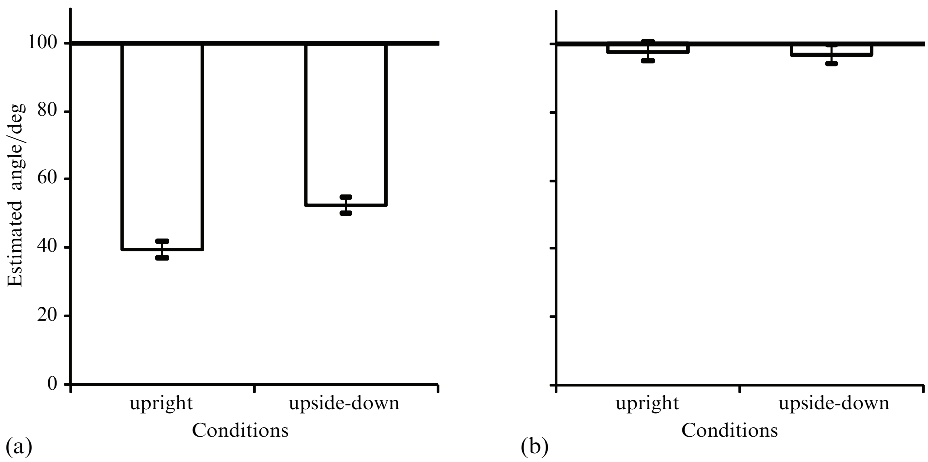

Figure 4. Mean data and 95% confidence limits of estimated angle for each condition in experiment 2. Bold line shows the actual angle (100°). (a) Straight road image. (b) Control stimulus.

4 General discussion

Results from two experiments show that observers drastically underestimated the angle created by convergent lines in the two conditions involving viewing of the real-scene and projected images of this scene. In both scene conditions, the extent of the underestimation of upright images exceeded 50°; this disparity was greater than 50% of the actual angle. This new angle illusion is much larger than the classical geometrical illusion of angles. That is, classical angle illusions have typically induced errors in the region of 1°–6° (the Zöllner illusion, Oyama 1975; the tilt illusion, Wenderoth and Johnstone 1988; the rod and frame illusion, Daini et al 2003).

The strength of this new angle illusion became quite evident when the authors tried to explain to participants that the actual angle was larger than a right angle by superimposing a square paper onto a projected scene image. Surprisingly, many of the observers reported that the square paper looked like a vertically elongated rhombus, in spite of the fact that they knew that it was a square paper. This indicates that this angle illusion, which is induced by the perspective image, even captured the perception of the square paper, and distorted its appearance.

Previous studies have shown that the perceived size and distance of objects in a photograph differ from those in a real space observation (Gibson 1947; Smith and Gruber 1958; Nagata et al 2008; Watanabe 2004). However, we obtained massive angle illusions both in the real-scene condition and in the projection condition while the angle illusion in the real-scene condition was larger than that in the projection condition. This results suggests that the same factor which is embedded both in the real-scene condition and projected image condition is responsible for the induction of this new angle illusion.

Blakemore et al (1970), and Carpenter and Blakemore (1973) have proposed an inhibition hypothesis which holds that the perceived orientation of a line can be influenced by the presence of a second abutting line (Bouma and Andriessen 1970; Greene and Levinson 1994). The inhibition hypothesis successfully explains classical angle illusions, such as the Zöllner and Wundt–Hering illusions. However, it cannot explain the mechanism of the present new angle illusion because there was no illusory effect for the control conditions in which converging lines were identical to those in upright and upside-down conditions in experiment 2. That is, if the inhibitory processing between the converging lines determines the induction of this angle illusion, the illusion should exist both for the experimental and control stimuli because in both stimuli the configuration of the converging lines is the same.

Alternatively, we assume that this new angle illusion is based on a misadoption of perspective depth cue processing in angle processing. The two lines converge and make a junction at the vanishing point on the retina, although they are parallel to each other on the road. In processing of depth information, produced by two converging lines as well as by other cues such as relative object size (in scenes), the visual system may underestimate the angle by conflating the actual angle (100°) with the null angle associated with parallel lines (0°). This notion is compatible with the results of our experiments. That is, the extent of the illusion in the real-scene condition, which would include rich spatial information about objects in the scene, was greater than that in the projection condition (experiment 1). In addition, the extent of the illusion in the upright condition was greater than that in the upside-down condition in which the effects of perspective as a depth cue from the converging lines would be weaker (experiment 2).

Previous studies have proposed that misadoption of perspective may cause illusions of size. For instance, Kingdom et al (2007) proposed that the leaning tower illusion, in which the tilt of one of the two identical tower pictures is exaggerated, is based on the adoption of a perspective depth cue in the perception of object direction. In addition, others have proposed that the processing of perspective depth cues underlies the Ponzo illusion (Leibowitz et al 1969; Fujita 1996), and Müller-Lyer illusion (Gregory 1966). Moreover, several studies have proposed that misadoption of the processing of depth information in a picture on a flat plane contributes to certain geometrical illusions. For instance, occlusion would cause the Poggendorff illusion in terms of inappropriate correction to compensate the monocular region in three-dimensional space when viewing a two-dimensional drawing (Ono et al 2002). The processing of depth information extracted from the T-junction and Y-junction in the drawing as effective signatures, respectively, for occlusion and three-dimensional apex would cause the Shepard's table illusion by specifying the same parallelograms in two-dimensional drawing as rectangular parts of different three-dimensional objects (Shepard 1981). Together with these previous studies, the present study offers another example that depth processing can contribute to different types of illusion. Depth information, which is extracted from the two-dimensional image, such as a photograph and a drawing, would force the visual system to modulate the apparent angle, shape, and size in those two-dimensional images to fit them to the three-dimensional interpretation. Future studies must examine how depth processing from perspective cues leads to induction of an angle illusion, and also determine the role of depth perception in this illusion.

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