PERCEPTUAL DISAPPEARANCE OF A VISUAL OBJECT IN A DRIVING SITUATION

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This study was conducted to investigate whether perceptual disappearance of visual objects occurs during driving situations and if so, to identify factors that may limit this phenomenon. In Experiment 1, perceptual disappearance of a peripherally-presented critical stimulus lasted longer and occurred more often when participants viewed a movie of driving scenes than when they observed a static frame of the movie. These results suggest that perceptual disappearance of visual objects may occur in driving situations due to motion-induced blindness. In Experiment 2, we investigated whether eye movements could suppress this disappearance in simulated driving situations. Participants observed the movie of driving scenes with or without saccades. Perceptual disappearance of the critical stimulus lasted for shorter periods and occurred less often with saccades than without them. These data indicate that eye movements may be an important factor in limiting perceptual disappearance of visual objects in driving situations.

Key words: perceptual disappearance, driving situation, motion-induced blindness, traffic accident

The human visual system occasionally produces discrepancies between the physical and perceptual properties of visual objects. Many researchers have considered the appearance of such discrepancies (e.g., visual illusions) as good clues to the nature of visual perception (e.g., Shimojo, Kamitani, & Nishida, 2001; Tsuchiya & Koch, 2005). However, there has been little discussion regarding the extent to which perceptual discrepancies affect everyday behaviors. This is because there are few natural scenes that could induce such discrepancies, and these would likely have little effect on everyday behaviors when they occur. For example, geometric illusions, which are among the most prevalent illusions, do not have a serious impact on our everyday behavior. On the other hand, if a given perceptual discrepancy produces undesirable consequences for behavior and can be shown to occur frequently, then the conditions under which it occurs should be investigated extensively.

Bonneh, Cooperman, and Sagi (2001) demonstrated a new visual illusion that may occur frequently in everyday life, one that has the potential to have a serious impact on our
behavior. They showed that a static (critical) stimulus presented in the peripheral visual field can temporarily disappear from visual awareness when it is surrounded by moving stimuli. Converging evidence indicates that this phenomenon, motion-induced blindness (MIB), can be facilitated by at least two factors. The first factor that facilitates MIB is proximity of the moving stimuli to the critical stimulus. For example, the duration of MIB is longer when moving stimuli are presented near the critical stimulus than when they are presented farther from the critical stimulus (Bonneh et al., 2001). The second important factor is that the critical stimulus is projected to the same retinal position. Stable retinal images disappear more frequently than unstable ones (New & Scholl, 2008).

Taking into account these two factors that facilitate MIB, it is reasonable to assume that the perceptual disappearance of visual objects can occur in daily life, especially in driving situations. In driving, the visual field includes both the stable retinal images and the optical flow patterns surrounding these objects (the patterns of motion caused by relative motion of viewer and objects). Imagine that two cars are moving at the same speed in adjacent lanes; one is ahead of the other. The retinal position of the leading vehicle would be relatively stable for the driver of the vehicle in the rear. In another situation in which two vehicles are orthogonally approaching an intersection with collision timing, the retinal position of one vehicle is also relatively stable for the driver of the other vehicle. Although it is unlikely that visual objects would be projected to exactly the same retinal position in these driving situations, MIB can be associated with slowly moving (i.e., retinally unstable) objects (Bonneh et al., 2001). Thus, it is reasonable to assume that perceptual disappearance of objects may occur in driving situations due to MIB, with some conditions having more serious impact on our behavior than others. For example, drivers may not have enough time to react to potentially dangerous situations when experiencing an occurrence of MIB of even short duration. Furthermore, sudden disappearance and reappearance of visual objects in the peripheral visual field may capture the driver’s attention and thus divert attention to those objects and away from the primary driving task (Most & Astur, 2007; see also Jonides & Yantis, 1988; Theeuwes, 1991). In order to prevent these potentially dangerous situations, it is important to first investigate whether visual objects could disappear from our visual awareness due to MIB in real driving situations. And secondly, it is important to determine what factors are most important in limiting this phenomenon and their respective parameter ranges.

Therefore, Experiment 1 was designed to investigate whether optical flow patterns induce perceptual disappearance of visual objects in simulated driving situations. We focused on MIB during viewing optical flow patterns because of the following reason. Although Bonneh et al. (2001) revealed that cumulative disappearance time of MIB depended on the type of moving stimuli, there have been no investigations of MIB using optical flow patterns. In natural scenes, especially in driving situations, the motion most frequently perceived is optical flow patterns caused by relative motion of viewer and objects. Therefore, it is important to investigate whether this frequently perceived motion actually induces perceptual disappearance in a driving situation, and, if it does, how frequently the disappearance occurs.

In Experiment 2, we examined whether saccadic eye movements could reduce the
MIB phenomenon, given that researchers have suggested that stabilization of the retinal image with eye movements could modulate MIB (Bonneh et al., 2001; New & Scholl, 2008). Although Bonneh et al. (2001) claimed that saccadic eye movements brought back a disappearing stimulus, they did not provide supporting data. Therefore, it is unclear whether saccadic eye movements prevent the occurrence of MIB, in addition to disrupting the persistence of MIB.

We believe that it is reasonable to focus on saccadic eye movements as a limiting factor of MIB in driving circumstances because drivers can easily control the stabilization of the retinal image with eye movements. In order to avoid potentially dangerous situations in real driving situations, it is important to find the factors that prevent the occurrence of the perceptual disappearance. Thus, in Experiment 2, we investigated whether saccadic eye movements reduced the perceptual disappearance effect in driving situations. More specifically, we investigated whether saccadic eye movements reduced the frequency as well as the duration of the perceptual disappearance. In both experiments, we used a movie of driving scenes as stimulus in simulated driving situations.

**EXPERIMENT 1**

Although Bonneh et al. (2001) demonstrated that cumulative disappearance time of MIB differed depending on the motion pattern, there have been no investigations of the effect of optical flow patterns, the motion most frequently perceived in driving scenes, on MIB. Therefore, Experiment 1 was designed to investigate whether the optical flow pattern perceived by drivers in a simulated driving scene induces perceptual disappearance of visual objects due to MIB, and, if it does so, how frequently the perceptual disappearance occurs.

In our study of the perceptual disappearance of the critical stimulus, participant reports do not necessarily reflect the occurrence of MIB. The retinal image of a stable object disappears from visual awareness, irrespective of the presence of moving stimuli (Troxler fading; Troxler, 1804). Therefore, a critical stimulus superimposed in a movie may disappear due to Troxler fading, which is similar to MIB because both are induced by adaptation (Clarke & Belcher, 1962; Hsu, Yeh, & Kramer, 2004, 2006). However, MIB cannot be attributed only to adaptation. Bonneh et al. (2001) demonstrated that slowly moving objects disappear from awareness. This cannot be explained by a local adaptation mechanism, suggesting that Troxler fading and MIB have different underlying mechanisms. In order to dissociate MIB from Troxler fading, static frames extracted from the movie of driving scenes were used as the background in the baseline condition of Experiment 1. Any perceptual disappearance that occurs in the baseline condition can be attributed to Troxler fading because participants perceive no motion when observing a static frame. Therefore, if the movie induces more disappearance than the static frame from the movie, the result can be attributed to MIB.
**Participants**

Nine undergraduate students participated in Experiment 1.

**Apparatus and Stimuli**

All stimuli were presented at 800 × 600 resolution and at a 60 Hz refresh rate on a 22 inch CRT monitor. Participants viewed the monitor at a distance of 57.3 cm, with a chin rest and forehead restraint.

A white cross (1 deg in height and width) with luminance of 75.5 cd/m^2^ was presented as a fixation point. The critical stimulus was a red disk with luminance of 14.25 cd/m^2^ and diameter of 0.5 deg. The critical stimulus was always presented 5 deg to the left of the fixation point, with its vertical position the same as that of the fixation point. A movie of driving scenes was used as the moving stimulus. This movie was generated by recording the forward view from the passenger seat of a car in the outer lane of a highway traveling at about 100 km/h. We extracted a continuous 30 sec section from the movie (3 min and 52 sec in length) that included few curves and landmarks. The critical stimulus always appeared as it was superimposed on a brushy bank or the edge of a forest in the movie (Fig. 1). For the background stimuli in the baseline (static frame) condition, we extracted 30 static frames from the movie for 1sec each. The average luminance of the areas around the critical stimulus in these frames was 4.47 cd/m^2^ (SD = 6.97). These 30 frames were equally and randomly divided into three sets. These sets were the same across participants. Each set of ten frames was randomly assigned to the same number of participants (three participants for each set) to control for possible set effects. The movie and the static frames subtended 18.5 deg in width and 11 deg in height. They were presented on a black screen with luminance of 0.5 cd/m^2^.

**Procedure**

This study was approved by the Ethics Committee at the University of Tsukuba, and all procedures were performed in compliance with relevant laws and institutional guidelines. Fig. 1 illustrates an example of a trial sequence. Each trial began with the presentation of the fixation point at the center of the display. Two seconds after the onset of the fixation point, in half the trials, the movie of driving scenes was presented for 30 sec (the movie condition). In the other half of the trials, a static frame from the movie was presented for 30 sec (the static frame condition). The critical stimulus was presented at the same time as the onset of the movie or a static frame. All stimuli remained until 32 sec after the onset of the fixation point. Participants...
were asked to press and hold down a mouse button when they perceived that the critical stimulus disappeared and release it when they perceived that the critical stimulus reappeared, while fixating on the center of the display. Participants were encouraged to press (or to release) whenever they perceived the disappearance (or reappearance) of the critical stimulus during a trial. Twenty trials (ten in each stimulus condition) were administered in a random order. In the movie condition, the same movie was presented on all trials, whereas in the static frame condition, one static frame, randomly selected from one of the three sets without repetition, was presented during a trial. We measured the frequency of disappearance, based on the total number of mouse presses, and the cumulative disappearance time, calculated as the sum of the durations between a mouse press and the next release during 30 sec. Participants were given five practice trials at the beginning of the experiment.

**RESULTS AND DISCUSSION**

Table 1 shows the mean frequency of disappearances and the cumulative mean disappearance time for each condition. Paired t-tests revealed that the frequency of disappearance was higher in the movie condition than in the static frame condition ($t(8) = 6.14$, $p < .01$) and that the cumulative disappearance time was longer in the movie condition than in the static frame condition ($t(8) = 3.90$, $p < .01$). Since the perceptual disappearance of the critical stimulus occurred longer and more frequently with the movie than with the static frame, it is likely that the perceptual disappearance is attributable not to Troxler fading but to MIB induced by the optical flow pattern. Because the movie of driving scenes was recorded in a real driving situation, the findings of Experiment 1 suggest that the perceptual disappearance may occur in real world driving situations due to MIB.

It is important to note that the results of Experiment 1 illustrate how often perceptual disappearance might actually occur in real driving situations. The cumulative disappearance time was about 6 sec, which accounts for 20% of a single trial. A previous study found that the proportion of the cumulative disappearance time ranged from about 20% to 40% of a trial (Bonneh et al., 2001). Our results are comparable to the previous MIB study, suggesting that kinetic information in natural scenes (optical flow patterns) could induce MIB to the same degree as the kinetic information associated with artificial

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<th>Condition</th>
<th>Frequency of Disappearance</th>
<th>Cumulative Disappearance Time&lt;sup&gt;a&lt;/sup&gt;</th>
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<td><strong>Experiment 1</strong></td>
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<td>Movie</td>
<td>6.24</td>
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<td>Static Frame</td>
<td>2.51</td>
<td>1.14</td>
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<td><strong>Experiment 2</strong></td>
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<tr>
<td>Fixed</td>
<td>5.08</td>
<td>1.78</td>
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<td>Moving</td>
<td>3.36</td>
<td>2.03</td>
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<sup>a</sup> seconds
stimuli, such as translating or rotating dots and a rotating array of crosses. Of course, it should be noted that generalization of the results is not easy because of differences in the conditions of a real driving situation and a laboratory situation (e.g., greater arousal level and task difficulty in a real driving situation).

The results of Experiment 1 suggest that participants perceived the disappearance of the critical stimulus within the useful field of view (UFoV), which is the visual area from which one can extract useful information without eye or head movements (Ball, Beard, Roenker, Miller, & Griggs, 1988). Crundall, Underwood, and Chapman (1999) suggested that UFoV in driving situations is within 7 deg of the fixation point. Thus, the critical stimulus in this experiment (5 deg from the fixation point) was contained within the UFoV for driving situations. The results of Experiment 1 therefore suggest that drivers might miss objects within the visual area from which they normally extract useful visual information.

**Experiment 2**

The results of Experiment 1 suggest that perceptual disappearance due to MIB can occur in real driving situations. In light of this possibility, it is important to explore the limiting factors of the effect within driving situations. Although Bonneh et al. (2001) claimed that saccadic eye movement disrupted the persistence of MIB, it is unclear how effective saccadic eye movement was in suppressing MIB because the data were not provided in Bonneh et al. (2001). Furthermore, it is unclear whether saccadic eye movements prevent the occurrence of MIB, in addition to disrupting the persistence of MIB. Therefore, Experiment 2 was designed to explore the effect of saccadic eye movements on perceptual disappearance in driving situations.

The task in Experiment 2 was identical to that in Experiment 1. In half of the trials, however, the position of the fixation point was periodically changed along the horizontal axis. In the remaining half of the trials, the fixation point was stable at the center of the display. If the perceptual disappearance effect is diminished in the former condition, this is evidence that eye movements are an important factor in suppressing the perceptual disappearance of objects in natural driving situations.

**Method**

*Participants*

Nine undergraduate students participated in Experiment 2. None had participated in Experiment 1.

*Apparatus and Stimuli*

All stimuli were the same as those used in Experiment 1 except that static frames of the movie were not used.

*Procedure*

The procedure was almost identical to that of Experiment 1, with the following changes. Each trial
began with the presentation of the fixation point at the center of the display. Two seconds after the onset of the fixation point, the movie and the critical stimulus were presented until the end of the trial. In half of the trials (the fixed condition), the fixation point was always presented at the center of the display during the trial. In the other half of the trials (the moving condition), the fixation point was presented at the center of the display for 2 sec and then randomly presented either 1 deg left or right of the center of the display for 2 sec; then the fixation point returned to the center of the display. This displacement of the fixation point was repeated throughout the trial. In both conditions, participants were encouraged to fixate on the fixation point. Thus, participants were periodically induced to saccade toward the fixation point in the moving condition, whereas in the fixed condition, they fixated on the center of the display throughout the trial. Participants performed five practice trials at the beginning of the experiment and then performed the ten trials of each condition in a random order.

**RESULTS AND DISCUSSION**

Table 1 shows the mean frequency of disappearances and the cumulative mean disappearance time for each stimulus condition. Paired t-tests showed that the frequency of disappearance was significantly lower in the moving condition than in the fixed condition ($t(8) = 6.10, p < .01$) and that the cumulative disappearance time was significantly shorter in the moving condition than in the fixed condition ($t(8) = 7.87, p < .01$). Saccadic eye movements reduced the frequency of disappearance and the cumulative disappearance time by almost half. These results suggest that saccadic eye movements may be an important factor in disruption of MIB in real driving situations.

To investigate whether eye movements shortened the perceptual disappearance, we calculated the mean disappearance duration (the interval between the button press and the release) for each condition. A t-test ($t(8) = 4.46, p < .01$) indicated that the disappearance duration was shorter in the moving condition ($M = 0.98$ sec, $SE = 0.11$) than in the fixed condition ($M = 1.80$ sec, $SE = 0.21$). This result suggests that eye movements disrupted the persistence of the perceptual disappearance. Together with the frequency of disappearance data, these results support the notion that eye movements do play a significant role in both suppressing the perceptual disappearance effect and limiting its persistence.

The decrease of perceptual disappearance in the moving condition may have been due to the change in location of the fixation point rather than to saccadic eye movements. Kawabe, Yamada, and Miura (2007) demonstrated that a transient signal such as an abrupt onset of a small object disrupted the persistence of MIB. In the present study, a transient signal induced by the location change of the fixation point might have disrupted the persistence of MIB. However, Kawabe et al. (2007) showed that the transient signal disrupted MIB only when it was presented near the critical stimulus (approximately less than 1 deg). Therefore, it is plausible that the decrease of MIB in the moving condition is attributable to eye movements rather than the change in location of the fixation point.
The purpose of this study was to investigate whether visual objects could disappear from visual awareness due to MIB in simulated driving situations and to identify any factors that might prevent the disappearance of the perceptual object. In Experiment 1, the perceptual disappearance occurred more often and longer when participants observed a movie of driving scenes than when they observed a static frame of the movie. In Experiment 2, the perceptual disappearance effect occurred less often and for shorter durations when participants periodically made saccades than when they maintained fixation at the center of the display. Furthermore, in both experiments, perceptual disappearance frequently occurred in simulated driving situations (on about 20–25% of trials). In light of these findings, we suggest that the perceptual disappearance of visual objects in simulated driving scenes may frequently occur due to MIB and that the eye movements are potentially an important factor associated with this disappearance. Since participants were exposed to similar perspectives in real driving situations, these conclusions may generalize to real-world driving situations.

It may be argued that perceptual disappearance does not occur in real driving situations because drivers rarely maintain fixation at one spatial location. However, previous studies have shown that novice drivers (Chapman & Underwood, 1998) and fatigued drivers (Schleicher, Galley, Briest, & Galley, 2008) do tend to fixate at one spatial location. Furthermore, other studies have revealed that drivers are likely to have this tendency when they are engaged in cognitive tasks, such as spatial imagery tasks (Recarte & Nunes, 2000), and are intentionally following cars ahead (Crundall, Shenton, & Underwood, 2004). Therefore, the present study suggests that, at least in specific situations, perceptual disappearance may frequently occur in real driving situations.

It may also be argued that a visual object such as a car would not disappear in real driving situations because of its size. Although the physical size of a car is considerably larger than the red small disk used in the present study, its retinal size is not so large in real driving situations. When one car (about 1.5 m in width) is traveling ahead of another car at an inter-vehicular distance of 100 m (the appropriate inter-vehicular distance when two cars are traveling on a highway at 100 km/h), the retinal size of the leading car is relatively small for the driver of the car in the rear, about 0.9 deg in visual angle. Previous studies have reported that MIB occurred for an object of about 1 deg in size (Hsu et al., 2006; Schölvinck & Rees, 2010). Therefore, conclusions from the present study may generalize to real-world driving situations. Future research should investigate whether a moving but retinally stable car actually disappears from the driver’s awareness.

REFERENCES


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