VISUAL SEARCH PROBLEMS AS CAUSATIVE FACTOR OF ACCIDENTS AT CROSSROADS

Nobuyuki Uchida ⁽¹⁾, Tsuyoshi Katayama ⁽¹⁾, Dick de Waard ⁽²⁾ and Karel A. Brookhuis ⁽²⁾ Japan Automobile Research Institute ⁽¹⁾ Karima 2530, Tsukuba, Ibaraki, 305-0822, Japan. Telephone: +81 298 56 0874 Fax: +81 298 56 1121 E-mail: nuchida@jari.or.jp Centre for Environmental and Traffic Psychology (COV), University of Groningen ⁽²⁾ Grote Kruisstraat 2/1, 9712 TS Groningen, The Netherlands Telephone: +31 50 363 6772 Fax: +31 50 363 6784

ABSTRACT

In Japan, many fatal accidents involving two vehicles at rural crossroads happen at intersections with good visibility, such as those located in rice field areas. The present study investigated a possible causative factor of these accidents from the point of visual search performance. One possible countermeasure to prevent these accidents was also examined. Two experiments were conducted using the advanced driving simulator of the Centre for Environmental and Traffic Psychology (University of Groningen). In the experiments typical sceneries of rice field intersections were projected on a 165 degrees horizontal screen. It has been found that a vehicle on collision course appears not to move but remains static in the other driver's peripheral visual field. In the first experiment, peripheral vision's detection performance of both a vehicle on collision course, and of a vehicle not on collision course was studied. It was shown that a vehicle that is not on collision course can be easily detected. On the other hand, the detection of a vehicle on collision course was much more delayed especially when the object was further in the peripheral visual field. In the 2nd experiment, the effect of road side fences on the detection of a vehicle on collision course was studied. Fences were set along the roadside of the crossing path, making a vehicle on collision course abruptly appear from behind a fence. It was shown that the detection was earlier with fences compared to the without fences condition.

1. INTRODUCTION

1.1 Rural roads in rice fields

In Japan, along with the development of motorization, many rural roads in rice field areas have been improved with respect to pavement. Some of such roads are used as a by-path in order to avoid the main road with traffic jam. Especially in suburban areas, although some part of rice fields are dotted with houses or buildings which prevent drivers from detecting potential hazard, many intersections have good perspective (Fig. 1). Even if these intersections usually occur every hundred meters, it is seemingly not such a problem to use the road because of their good visibility.



Because of the lack of an appropriate traffic accident classification system about visual condition (e.g. perspective), precise statistics concerning to the intersection accidents in rice fields around suburban areas are not available. However, recent research found evidence that many accidents involving two vehicles at crossroads occur at these intersections with good visibility. Fujita et al. (1998) estimate that the number of this specific type of fatal accidents is more than four hundred in a year. This accounts for about 5% of all total annual fatalities occurring in Japan. An in-depth study which investigated causative factors of this type of accidents reported that 56% of these accidents occurred because of "failed to detect the other vehicle on collision course" (Takubo, 1998). In general, perceptual error or detection failure is one of the dominant causative factors of traffic accidents (Smiley and Brookhuis 1987). In spite of the good visual condition of rural roads in rice fields, perception of crossing traffic seems to be an important causative factor concerning to this type of intersection accidents.

The present study investigated a possible causative factor of these accidents from the point of visual search performance. A possible countermeasure to prevent these accidents was also examined based on the characteristics of peripheral vision.

1.2 Detection of vehicles on the other crossing path

It is considered that detection failure or late detection is related to a conflict between the human visual system and the traffic environment (Rumar, 1990). In the natural environment, visual attention is attracted by moving objects appearing in peripheral vision because of ecological reason (e.g. survive). It is well known that human peripheral vision is sensitive to movement, and motion improves visual performance for stimuli presented in the periphery (Finlay, 1982). Standstill in the peripheral visual field leads to extinction. This type of detection is more or less unconscious, automatic and fast (Rumar, 1990).

However, in our artificial traffic environment, this visual detection system happens to be invalid depending on the situation. In collision situations, when two vehicles approach an intersection on exact collision course, the other vehicle remains at the same angle until a collision. As a result, a vehicle on collision course can be a static object in a drivers' field of view. Even though this object moves against the background, this has no effect on the extinction in the peripheral visual field. In contrast, if the other vehicle is on non-collision course, it has relative horizontal movement in drivers' visual field. The vehicle approaching on collision course rolls closer without any high frequency of movements in peripheral visual field. Apparent growth of the other vehicle image appears just before a collision, because of the non-linearity between the approaching vehicle image size and the observation distance. Furthermore, the direction of the other approaching vehicle on collision course can be far away from the forward direction depending on the relative velocity of each vehicle.

In a recent experiment (Uchida et al., 1999), the detection performance for the vehicle on collision course and on non-collision course were compared. The result was that the detection of a vehicle on collision course is extremely difficult compared to the detection of a vehicle on non-collision course. It was considered that such intersection accidents in rice fields were obvious examples of conflict between the human visual system and the particular traffic situation.

2. EXPERIMENT 1

The first experiment was executed in order to replicate a previous study (Uchida et al., 1999) which was conducted in an indoor-experiment using video clips. The advanced driving simulator of Centre for Environmental and Traffic Psychology (Van Wolffelaar & Van Winsum, 1996) was adopted to present a far more realistic rice field scenery and to investigate the detection performance in two types of traffic situations, approaching a vehicle on collision course and on non-collision course.

2.1 Method

Eighteen subjects participated in the experiment, 7 females and 11 males, aged 20-41 years. All subjects' static visual acuity was above 0.6 (requirement for European standard licensing). All subjects drove the advanced driving simulator of the Centre for Environmental and Traffic Psychology in a typical scenery of rice field intersections that was projected on the rounded wide screen (165 degrees horizontally). Subjects drove the car in auto-cruise control mode at 60 km/h and passed non priority intersections in the test course (Fig. 2). The intersections were located every 300 meters, which is similar to a typical rural road in rice fields in Japan.



FIGURE 2 The test course road network in the first experiment.

The peripheral detection task was adopted as the primary task and every subject was instructed to detect the vehicle approaching on the crossing path without any eye movement in the direction of the target. Three types of target vehicle peripheral appearance conditions were included, corresponding to the previous experiment (Uchida et al., 1999). The details of the three appearance conditions were as follows.

- Collision course condition: The vehicle on the other path remains static in the specific appearance position until arrival at the intersection.
- Non-collision course condition: The vehicle on the other path passes the intersection before the subject arrives.
- Dummy condition: No other vehicle appears on the other crossing path.

The target vehicle always started at the same position, be it left or right, collision or non-collision, appearing at one of 3 eccentricities (30, 45, 60deg). The possibility of appearance of these three conditions was equal and the order was randomized. In order to prevent eye movements, a character was presented in the center of the screen as fixation point. A random alphabet letter was presented every two seconds, and a verbal response was required for a designated character.

The vehicle's detection was indicated by pressing a corresponding button, attached on each side of steering wheel, depending on the appearance side of the target vehicle, left or right. The detection distance, which is the distance from the intersection to subject's vehicle, was taken as a scale of detection performance.

2.2 Results

Figure 3 shows the mean detection distance in the six target vehicle appearance conditions, with both collision and non-collision course condition, as a function of the eccentricity of presented position of the target vehicle on the other path. Also shown in each condition is the standard deviation with vertical bars.

There was a significant difference between the collision and the non-collision course condition (F(1, 17) = 3298, p<0.001). The ability of detecting the vehicle on collision course was clearly inferior to the detection of the vehicle on non-collision course at every appearance eccentricity, and it is consistent with the result of a previous experiment (Uchida et al., 1999). In the collision course condition the detection distance was decreased with increment of appearance eccentricity (The data at left 30 degrees is an exception. The reason is the effect of the pillar in the windscreen as a static visual obstacle covering the other vehicle's appearance). Especially in the case when eccentricity was 60 degrees, the mean detection distance in the collision course condition was around 20m, which

means that the detection of the other vehicle was dangerously delayed. On the other hand, the mean detection distance in non-collision course condition was above 100m in every appearance eccentricity of the other vehicle.



FIGURE 3 Mean distance from subjects' vehicle to the intersection when the target vehicle was detected.

3. EXPERIMENT 2

The results from the first experiment seem to support the assumption that the conspicuity of the crossing traffic has large concern with the intersection accidents in rice fields. Rumar (1990) stated that the increment of target conspicuity may compensate for the following two types of traffic detection errors; cognitive detection error and perceptual detection error. The manipulation to gain the conspicuity of the vehicle on collision course is important for developing preventive measures for the intersection accidents.

As stated before, relative motion improves detection of a moving target in the periphery. However, it has also been suggested that abrupt appearance of a target attracts attention automatically (Theeuwes, 1994; Yantis, 1993). This way of appearance may increase the conspicuity of the other crossing traffic even though the vehicle is on collision course. In the actual traffic environment, one of the possible ways to realise abrupt appearance is to install fences on the road side of crossing path. It will provide abrupt appearance by hiding the other vehicle behind them until appropriate timing.

The second experiment was conducted with the purpose to investigate whether the road side fences are effective in the detection of the crossing vehicle on collision course. If such a road side fence enhances the conspicuity of the target presented in periphery of drivers' visual field, the detection distance will be decreased comparing to the condition without fences.

3.1 Method

The same eighteen subjects as in the first experiment participated in this experiment. All subjects drove the advanced driving simulator in the auto-cruise control mode at 60 km/h and through intersections on the test course like in the first experiment. The peripheral detection task was also adopted as primary task and every subject was instructed to detect the vehicle approaching on the crossing path without any eye movement in the direction of the target. The target vehicle, proceeding on the other path on collision course, appeared at one of two eccentricities (45

degree, left or right), on some of the intersections. A random character was presented in a fixation point, and a verbal response was required in order to prevent any eye movements. The detection distance, which is the distance from the intersection to subjects' vehicle, was again taken as the scale of detection performance.

There were two test course conditions, with-fences and without-fences (the latter is similar to the first experiment). In the with-fences condition the position of fences, the distance from the edge to the intersection, was adjusted depending on the detection performance of each subject, in order to standardize the effect of abrupt appearance. The concrete procedure of the standardization was as follows. The critical point was determined for each subject by means of calculating the mean detection distance in the first experiment (Fig. 4). Based on the critical point, two types of fence pattern were determined, "2 seconds ahead" and "3 seconds ahead". In the "2 seconds ahead" fence pattern, the target vehicle suddenly appeared at 2 seconds before the point when the target reached the critical point (Fig. 5). In the "3 seconds ahead" fence pattern, the target vehicle suddenly appeared at 3 seconds before when the target reached the critical point (Fig. 6). These two pattern of fences were put alternatively along the crossing path of every intersection (Fig. 7).



FIGURE 4 Calculation of "Critical Point".



FIGURE 5 The Fence position in "2 second ahead" fence pattern.



FIGURE 6 The Fence position in "3 second ahead" fence pattern.



FIGURE 7 The test course road network in the second experiment.

3.2 Results

Figure 8 shows the mean detection distance of the target vehicle on collision course in the without-fences and with-fences condition, both "2 seconds ahead" and "3 seconds ahead" fence pattern. Standard deviation of each condition is shown too. There is a significant difference between without-fences and "2 seconds ahead" with-fence condition (F(1, 17) = 16.9, p<0.001), and there is also significant difference between without-fences and "3 seconds ahead" with-fence condition (F(1, 17) = 52.0, p<0.001). In the with-fences condition, both "2 seconds ahead" and "3 seconds ahead" around 10 meters, compared to without-fence condition.

Figure 9 shows the histogram of detection response in the without fence condition. The responses are distributed symmetrically between early and late detection. On the other hand, there were large biases in the histograms of with fence conditions (Fig. 10 & Fig. 11), the probability of detection response was increased to just after the abrupt appearance of the target vehicle from behind the fences.



FIGURE 8 Mean distance from subjects' vehicle to the intersection when the target vehicle was detected.



FIGURE 9 Histogram of detection response (Without Fence).



FIGURE 10 Histogram of detection response (With Fence, 2 second ahead).



FIGURE 11 Histogram of detection response (With Fence, 3 second ahead).

4. DISCUSSION

Rumar (1990) stated that detection failure and late detection fall into two main categories; cognitive detection error and perceptual detection error. The former may result from lapses of cognitive expectation, and concerns the drivers' voluntary direction of attention in a conscious, planned and controlled way. The latter may result from difficulties with perceptual thresholds concerning the nature of the stimulus which attracts attention automatically (e.g. motion). The result of the first experiment shows that the latter problem concerning the conspicuity of other traffic is the main causative factor of intersection accidents in rice fields. However, most of the measures imposed to prevent rice fields intersection accidents are only meant to enhance drivers' awareness and search for the hazardous traffic on other path consciously, by means of traffic regulation signs (e.g. Stop sign). Although it has been shown that drivers are able to learn and develop the efficiency of visual scanning (Moray, 1990), voluntary scanning based on experience and expectation does not always reveal less frequent and less imminent traffic information (Summala, 1996). It is necessary to enhance the conspicuity of the vehicle on collision course as a preventive measure for intersection accidents, because the increment of target conspicuity compensates for traffic detection errors, both cognitive detection error and perceptual detection error (Rumar, 1990).

The second experiment shows that road side fences, which provide abrupt appearance by hiding the other vehicle until appropriate timing, can enhance the conspicuity and help the detection of vehicles on collision course. This measure seems to be cost-effective and able to combine with current measures (e.g. Stop sign). Further investigation will be necessary condition to investigate the efficient position of the fence (the distance between the edge to the intersection) and properties (e.g. width or length) for practical use. As it is shown that elderly drivers have a higher risk of getting involved in a fatal accident at rice field intersections compared with other age groups (Uchida et al., 1999), it is also important to investigate the efficiency of the measure for elderly drivers.

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