Distance Perception in Driving

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DISTANCE PERCEPTION IN DRIVING

By
OTA HIRO (太田博雄)[1]
(*Tohoku Institute of Technology*)

This experiment was conducted to examine the underlying mechanism of drivers' underestimation of distance between the drivers' cars and cars ahead as observed by Rockwell in 1966.

Three kinds of experiments were conducted using five subjects.

Condition 1: Subjects were asked to drive their car behind an equipment car on the road. While driving, they were asked to estimate the objective distance from their car to the equipment car ahead at various speeds.

Condition 2: Subjects sitting in the passenger seat were asked to estimate the objective distance between their car and the car ahead at various speeds.

Condition 3: Subjects were asked to observe a videotape consisting of three TV monitors' displays of a driving scene as if they were the driver and to estimate the objective distance between their car and the car ahead.

In each of the three conditions described above, the relationship between subjective distance and objective distance was analyzed at three driving speeds: 0 km/h, less than 80 km/h and more than 80 km/h. The main findings were as follows;

1. The relationship between objective distance and estimated distance was shown to be linear.
2. The higher the driving speed, the lower was the slope of the function, i.e., when drivers drove at higher speeds they underestimated the distance between cars compared with estimations made at lower speeds.
3. There were no differences in estimation between the three observation conditions, which means that the movement of the retinal image could be said to be the most crucial factor in the underestimation of distances when following cars ahead.

Key words: distance perception, driving, sensory cues, TV observation, Driving speed.

INTRODUCTION

In the experiments conducted by Gugerty, L. (1996), subjects locate cars ahead at a closer location than the actual one when asked to recall car locations on the recall grid showing the road after observing an animated driving scene on the simulator. Although the response road extended from 9 lengths behind to 17 lengths ahead, all the cars were within 13.5 length.

What does this result mean? Is it just an artifact produced by the experimental method used or some significant reflection of drivers' perceptual characteristics associated with driving on the road?

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1. Tohoku Institute of Technology, Futatsuzawa 6, Taihaku-ku, Sendai 982, Japan.

Rockwell (1972) found that the higher the speed at which drivers drive their cars, the shorter the subjective distance drivers perceive between their car and the car ahead. He did not discuss the mechanism of this phenomena but focused only on the individual differences and the inaccuracies found in the drivers' judgement of distance.

The aim of this experiment is to examine and understand the mechanism of drivers' underestimation of distance in driving.

Many sensory cues arise while driving a car: visual, auditory, kinesthetic, vestibular and other cues. Which sensory cue is responsible for producing phenomena? There may be one crucial underlying sensory cue or a combination of several cues which lead to the phenomena of distance underestimation in driving. As well, there could be an ecological explanation. According to Gibson, J.J. (1950) perception fundamentally plays the role of enabling the organism to "get along with" the environment. Gibson views organisms as involved in constant active exploration of their environment, encountering objects in a variety of ways. Osaka (1982) also states the importance of studying perception from an ecological viewpoint and mentioned that the visual world perceived by subjects who are moving is very different from that perceived by subjects who are standing still. He stated that researchers of perception must consider perception to be a process of adjustment to environment.

Three hypotheses were established in consideration of the ideas outlined and the experiments were conducted to verify which hypothesis was right;

Hypothesis 1: The reason for drivers' underestimation of distance between their cars and the cars ahead might arise from anxiety, because driving at high speeds is known to increase tension levels in drivers. It might lead to drivers taking longer distances between their cars and the cars ahead. Underestimation of distance in driving may be an adjustment mechanism for avoiding accidents.

Hypothesis 2: Many sensory cues received during physical movement might be important factors in underestimating distances between cars. Not only visual cues but also other sensory cues, e.g., proprioceptive, kinestheic, vestibular cues..., might influence the judgement of distance.

Hypothesis 3: The important cue is visual, especially the movement of the retinal image.

METHOD

Three kinds of experiments were conducted.

Condition 1: Subjects are asked to drive their car behind the equipment car on the course shown in Fig. 1. As they drive they are asked to estimate the objective distances from their car to the equipment car ahead at various speeds. It can be said that the subjects in this experiment tend to be active in movement because they must determine how to maneuver their car.

Condition 2: Subjects in the passenger seat are asked to estimate the objective distance between their car and the car ahead at various speeds. They merely remain seated in the passenger seat during driving, and in that sense they are passive in their movement.

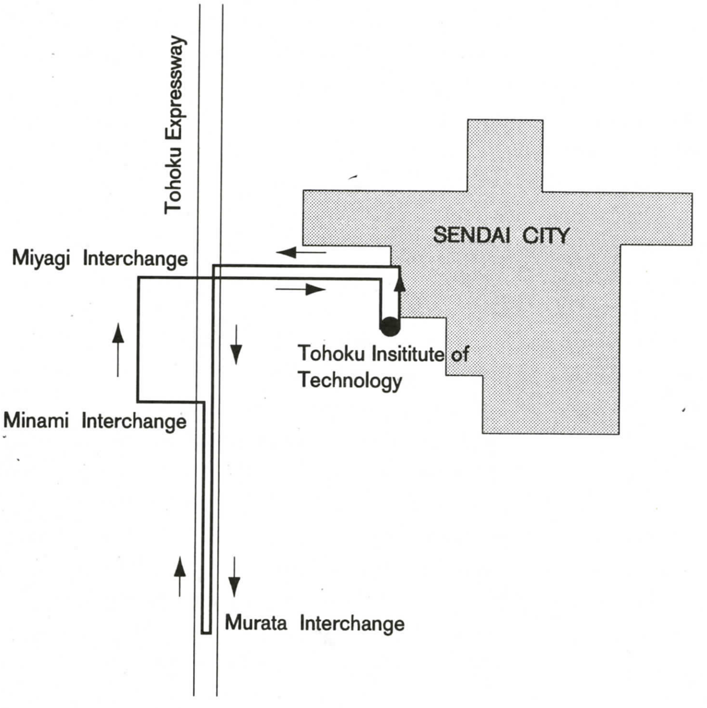

Fig. 1. The driving course.

Condition 3: Subjects are asked to observe the videotape consisting of three TV monitors showing a driving scene as if they are the driver and estimate the objective distances between their car and the car ahead (Fig. 2).

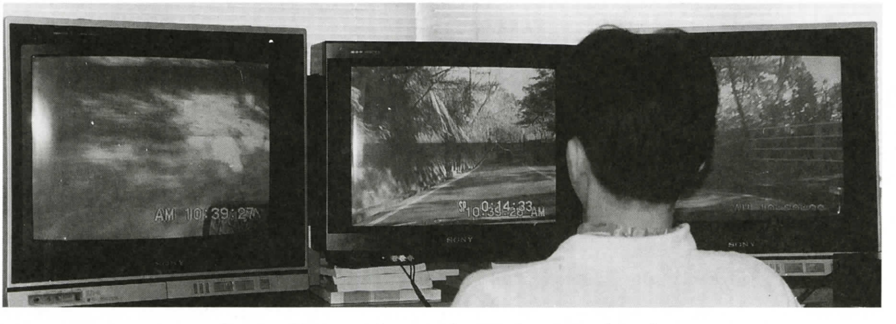

Fig. 2. The scene shown in the TV observation (photo).

The experiments are designed to examine the hypotheses in the following way;

If subjects underestimate distance only under Condition 1, it could be concluded that the act of driving causes subjects to underestimate distance. If subjects underestimate distances also under the second observation condition, one must abandon the hypothesis that observation as a driver is requisite for the underestimation of distance. If subjects tendency to underestimate is obtained also under the third condition, one must conclude that the visual cues are the most important factor. In condition 3, motor, vestibular and muscular sensations are not present, even when the visual cues for estimating distance are the same as in other observation situations.

Five subjects participated in each experiment condition. The order of the subjects' participation in each experiment was designed to reduce any influence that might have been derived from the order of the experiments (Table 1). In Condition 1, after a short practice in driving the equipped car, a Subaru 2000cc with five manual gears, subjects were asked to follow the leading car, a Honda Civic 1300cc, driven by the author's có-worker. The driving course is shown in Fig. 1; the course included local roads and an expressway. The speed limits of the local roads are 50 km/h and that of the expressway is between 80 to 100 km/h. Subjects were asked to estimate objective distances between their car and the car ahead at various speeds at various points along the road while driving for about 1 hour. Before and after the driving experiments subjects were asked to estimate the distance between their car and the car ahead at 0 km/h, at a standstill. In Condition 2, subjects sat on the passengers seat and asked to estimate the objective distance between the subjects car and the car ahead while the experimenter drove on the same driving course. For the experimental material used for Condition 3, the author drove on the same roads and videotaped the car ahead at various speeds and with various distance headways.

Table 1. Order of experimental conditions in each subject.

Condition	Driver	Passenger	TV
UR	1	3	2
YA	2	3	1
MA	3	2	1
IT	2	1	3
OU	1	2	3

Results

Driving speeds were categorized into three kinds of speed for understanding the effect of speed upon distance perception; 0 km/h, less than 80 km/h, more than 80 km/h. The relationship between subjective distance and objective distance in each speed condition is shown to be linear. The slope of the function of each speed condition in each subject is shown in Table 2.

Table 2. Comparison of slopes of functions between objective distance and estimated distance in each observation condition at each driving speed.

		Driver				Passenger				TV observation		
	(km/h)	0	<80	>80	(km/h)	0	<80	>80	(km/h)	0	<80	>80
UR		0.63	0.54	0.37		0.82	0.51	0.61		0.80	0.63	0.54
YA		1.50	1.41	0.75		1.50	0.93	1.26		2.83	1.78	1.19
MA		0.35	0.29	0.30		0.64	0.38	0.31		1.08	0.31	0.36
IT		0.79	0.65	0.41		1.15	0.74	0.84		0.91	0.50	0.53
OU		0.77	0.48	0.27		0.83	0.69	0.46		0.55	0.46	0.41
means		0.81	0.67	0.42		0.99	0.65	0.70		1.23	0.74	0.61
(SD)		(0.38)	(0.39)	(0.17)		(0.30)	(0.19)	(0.33)		(0.82)	(0.53)	(0.30)

The higher the driving speed is, the lower the slope of function is; when drivers drive at higher speeds they underestimate the distance compared with that estimated at lower speeds. Drivers' ability to discern distance headway changes deteriorates while driving at high speeds.

The degree of underestimation of distance under static conditions is smaller than that seen under mobile conditions.

Figure 3 shows the results for one of the five subjects (Condition 1, in the drivers' position). We can see that at 0 km/h this subject estimates 50 m as 38 m, at less than 80 km/h as 35 m and at more than 80 km/h 27 m. We can also see that in the static condition this subject estimates the change of distance headway from 50 m to 70 m as 38 m to 55 m (difference; 17 m), at less than 80 km/h as 35 m to 45 m (difference : 10 m), at more than 80 km/h as 27 m to 32 m (difference : 5 m).

Table 3 and Fig. 4 show the rate of change of subjective distance in each of the three speed conditions under each observation condition compared with the objective distance calculated by the following formula; rate of changes = [(subjective distance) - (objective distance)] / (objective distace) × 100

A minus figure signifies the underestimation of objective distances. The higher the driving speed is, the bigger the degree of underestimation is. There are no differences between the three observation conditions even though it seems that the figures of the observation condition as a driver are lower than other two observation conditions. This result is achieved because the individual differences are quite substantial.

Discussion

What is the reason for drivers' underestimation of distance between their cars and the cars ahead in driving?

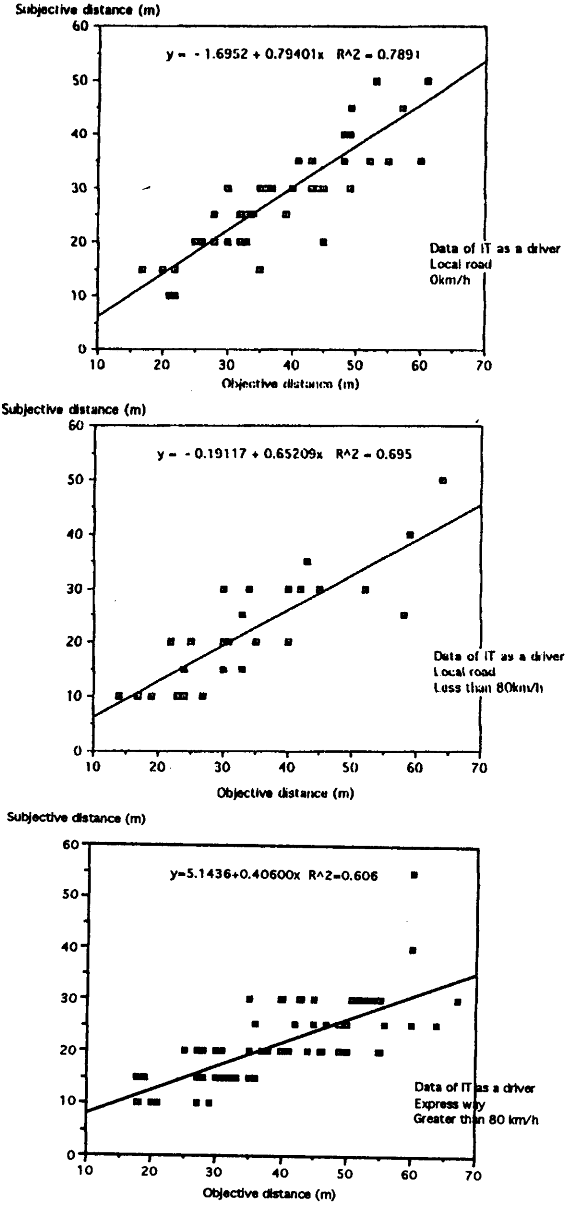

Fig. 3. Observation as a driver (sub. IT).

Table 3. rate of changes = [(subjective distance) - (objective distance)]/(objective distace) × 100 (Minus figures mean underestimation)

speed	driver	passenger	observation
0 km/h	−14.7(39.0)	6.6(49.0)	3.2(50.1)
0−80 km/h	−23.1(28.0)	−17.3(33.0)	0.9(61.5)
80 km/h−	−30.8(22.8)	−20.0(27.9)	−20.6(13.6)

( ) stadard deviation

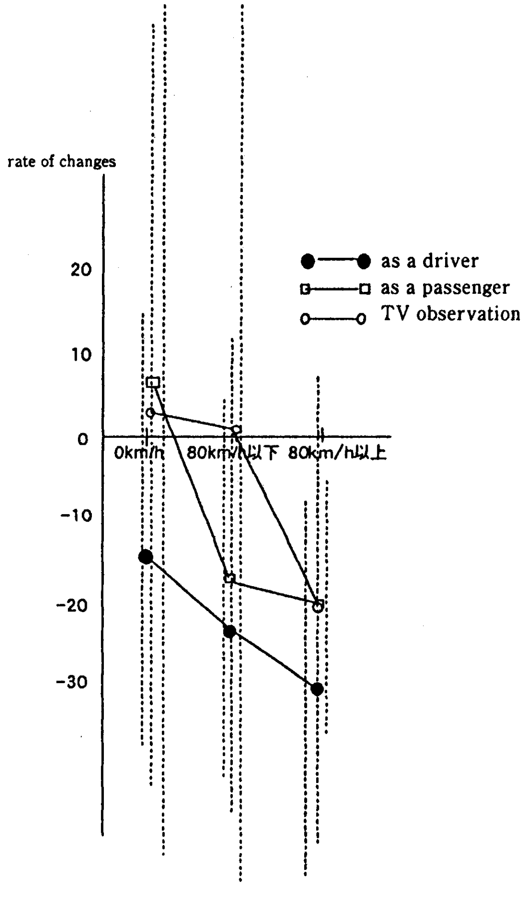

Fig. 4. Rate of changes = [(subjective distance) - (objective distance)]/(objective distace) × 100 (Minus figures mean underestimation).

As we can see from the results described above (Fig. 3), there are ultimately no differences between the three observation conditions, i.e., observation as a driver, observation as a passenger and observation of TV. This result means that the movement of the retinal image can be said to be the most crucial factor in the underestimation of distances when we follow cars ahead.

The results of Gugerty, L. (1996), mentioned at the beginning of this paper, can be said to show a indirect evidence of shrinkage of perceptual distance headway. The observation of computer graphics also seems to produce the same effect on distance headway perception.

The hypothesis which might explain these results can be considered from various viewpoints. The following hypothesis might be one of them; Looking at "divided illusion (Fig. 5)", we underestimate the size of the lefthand part of the figure which is not filled with lines. We underestimate not only space but also time elapsed when the amount of presented information decreases. Orstein (1969) mentioned that we feel the time elapsed to be longer when the degree of stimulation and complexity increases during the period. Subjects feel the time elapsed to be longer when they remember experiences, as compared with a situation which contains fewer or no memories. This suggests that time perception can be related either to memory or to information processing.

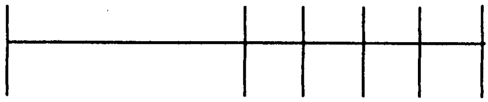

Fig. 5. Divided Illusion (Oppel).

The degree of stimulation which subjects perceive is reduced when driving at high speed. In another words, the amount of information which subjects can process is at the highest level when they stop to observe their physical environment (in the stationary condition). And when the subjects are mobile, the degree of stimulation which they can look at or the amount of information which they can process decreases, because retinal images are in motion and the observers can't see scenery well (Fig. 6).

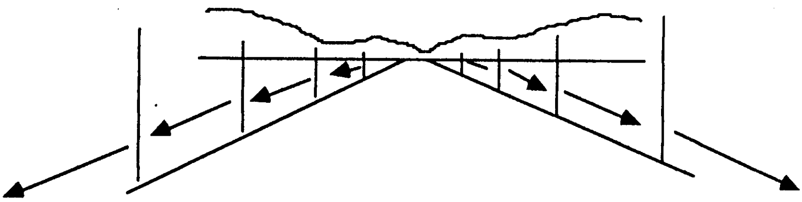

Fig. 6. Retinal image in driving.

The findings of Cavallo et al. (1996) might support this hypothesis. She asked her subjects to estimate time-to-collision (TTC, i.e., the time it will take to reach the obstacle); sixteen male and female subjects are presented with computer-generated images on a large screen (48 degrees) showing approaches to a stationary vehicle on a straight section of road. The stimulation stops a few seconds before fictional impact and the subject is required to press a button when he/she expects the collision to take place. They tested the effects of road environment characteristics on TTC estimation, including five modalities with only the vehicle-obstacle presented, and a gradual enrichment of the visual scene by adding the roadside, safety posts and texture on the cariageway. Results show that road environment characteristics have a significant effect on TTC judgements; the enrichment of the environment increases safety margins. These results allow us to infer that the higher the degree of enrichment of information in the visual field, the longer the estimated distance from the observer.

Problems for drivers regarding distance perception in driving.

The mechanism of drivers' underestimation of distance headway while driving should be investigated further by applying more organized experiments. However the results of this paper may provide some practical information to drivers.

Drivers should know about the fact that distance perception in driving differs from that experienced under non-driving conditions, i.e., stationary conditions. That the slope of curve which shows the relationship between physical distance and subjective distance between drivers and cars ahead is less than 1.0 while subjects are driving means that the degree of change of the subjective distance is lower than that of the objective distance. The higher speed at which drivers drive their cars, the worse the ability to differentiate changes in physical distance. It is obvious that such deterioration in distance perceptual ability at high speeds in driving can lead to dangerous driving situations.

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