

A STUDY ON THE CHARACTERISTICS OF DRIVER'S EYE-MOVEMENT AT THE ROAD SECTION WITH SHORT SIGHT DISTANCE

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Abstract: When traffic accident occurs at the road section with short sight distance caused by the fog or snowfall, this traffic accident would expand to the multiple crashes because the backward driver has difficulty to recognize the traffic accident. There is the need to decrease the traffic accidents at the road section with short sight distance, because multiple crashes influence serious disadvantage to the social services. In this study, the survey of using the eye-mark recorder is conducted to understand the characteristics of the point of regard by the driver's attribute. By comparing the situation that the sight distance is short and the other car overpass at the right side, it is also found that the viewpoint of each attribute is different. Expert driver could see this car, while the novice driver would not. It could be considered that this characteristic comes from the difference of the variance of the viewpoint.

Key Words: traffic accident, short sight distance, eye-mark recorder

1. INTRODUCTION

It becomes comfortable to drive the expressway in the snowfall season, because the snow removal operations have conducted adequately to correspond to the snowfall and snowstorm. However, the possibility of traffic accidents caused by the skid is still high because of the over speed for the road condition or the use of tire for non-snowfall period in the snowfall season. In addition, this increases the possibility to expand the multiple crashes due to delay of detecting the traffic accident occurrence under the situation of the obscure visibility. The damage by the multiple crashes is thought to be serious because of the involvement of the large number of vehicles in one accident. And also, the influence by the multiple crashes to the social activity would be large because of the longer closure of the expressway. Therefore, it is important to set up the countermeasures to decrease the multiple crashes.

In this paper, characteristics of the multiple crash occurrences are shown, and the driver's point of regard in the obscure visibility situation is focused to clarify the differences of the driver's point of regard by the driver's attributes in order to consider the countermeasures to decrease the multiple crashes.

2. CHARACTERISTICS OF THE MULTIPLE CRASHES

Spatial relationship between the location of the multiple accidents and the location of frequent occurrence of accident is analyzed before understanding the characteristics of multiple crashes. All records of traffic accidents that had been occurred for the period of 1995-2001 years in Tohoku Expressway are used as the data for analysis. The locations where more than 5 accidents occurred in the same kilo post are defined as the point of frequent occurrence of accident, and the accidents that more than 5 vehicles were involved in one accident are defined as the multiple crashes. Figure 1 shows the relationship between the frequent occurrence of traffic accident and multiple crashes. From this figure, it is understood that the share of the Area-C, that shows the number of locations where the multiple crashes is existed and the frequent occurrence of traffic accident is not existed, is twice as much as the share of the Area-B, that shows the number of locations where the both multiple crashes and the frequent occurrence of traffic accident are existed. This means that the location of multiple crashes is not same as the locations of frequent occurrence of traffic accident.

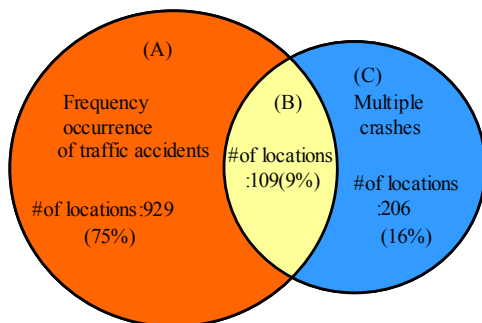


Figure 1. Relationship between the frequent occurrence of traffic accident and the multiple crashes

In order to understand the characteristics of the relationships between two types of locations clearly, accident data are divided into two groups by the season (snowfall and non-snowfall). Figure 2 and 3 shows the relationship between the frequent occurrence of traffic accident and multiple crashes by the season (snowfall and non-snowfall). It is found that the share of Area-F and Area-I are different in almost 1.5 times, while the share of the Area-D and Area-G, Area-E and Area-H are almost same. This shows important feature that the multiple crashes in the snowfall season might occur the location where traffic accident does not occur frequently. Moreover, this might show the hazardous situation that slight traffic accident would bring the multiple crashes in the snowfall season.

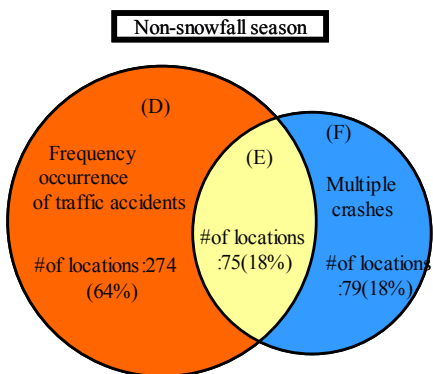


Figure 2. Relationship between accidents in the non-snowfall season

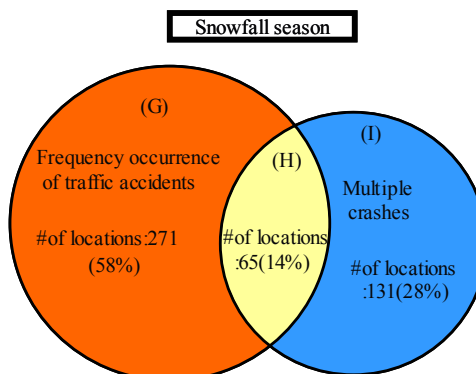


Figure 3. Relationship between accidents in the snowfall season

Figure 4 shows the relationship between the season for the frequently occurrence of traffic accidents, and Figure 5 shows the relationship between the season for the location of multiple crashes. By comparing these figures, it is found that the shares of overlapped area (Area-K and Area-N) are almost same in a smaller amount. This shows the characteristics that the location of both multiple crashes and frequently occurrence of traffic accident are different by the season. Therefore, these might exist the seasonal factor to be occurred both the frequently occurrence of traffic accident and the multiple crashes. By comparing the non-overlap areas (Area-J and Area-L in the frequently occurrence of traffic accident, and Area-M and Area-O in the multiple crashes), it is clarified that the share of Area-M and Area-O differs in almost twice while the share of Area-J and Area-L is almost same. This means that the level of danger for frequently occurrence of traffic accident would be same for each season, and there might exist some important factor that brings the multiple crashes in snowfall season. Therefore, it is important to find the factors that would bring the multiple crashes in order to provide the safe condition of expressway in the snowfall season.

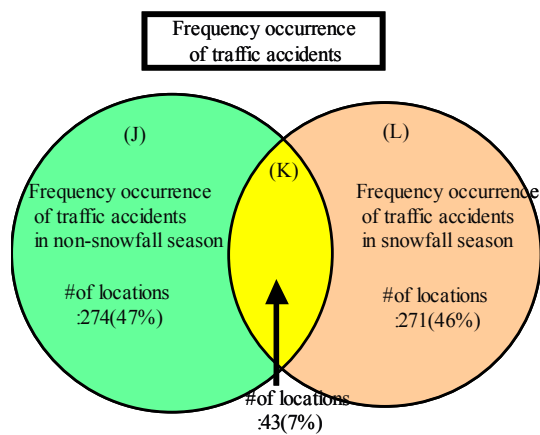


Figure 4. Relationship between season in the black spot

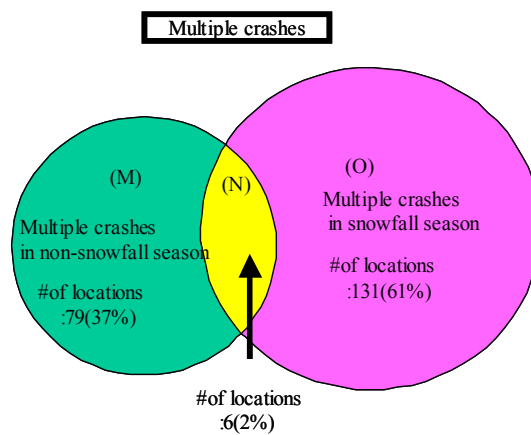


Figure 5. Relationship between season in the multiple crashes

3. THE VIEWPOINT OF ANALYSIS FOR THE TRAFFIC ACCIDENT IN THE SNOWY REGION

In order to avoid the multiple crashes in the obscure visibility situation, many countermeasures are considered, such as, to reserve the longer headway distance, to keep the legal speed or to run in a slower speed, and to understand the surrounding traffic situation. By considering from the various point of view, the perspective to understanding the surrounding traffic situation are chosen for the analysis in this paper. It could be said that to reserve the longer headway distance and to keep the legal speed is a problem of the driver's themselves, and it is able to solve this problem by changing the driver's mind. However, it would take longer time to change driver's attitude and it might be hard to introduce these countermeasures to all drivers, these countermeasures are not taken into consideration. It is required to establish the countermeasures to help the driver so as to understand the surrounding traffic conditions because drivers have much difficulty in setting their eyes in the obscure visibility situation. Therefore, point of regard of the drivers is focused to understand the characteristics in the obscure visibility situation in this paper. In order to establish the effective countermeasures to avoid the traffic accident, it might be important to understand the point of regard of the drivers. Because, it could be thought that understanding the drivers' point of regard would contribute to find the cause of traffic accident by the drivers' aspect in the obscure visibility situation that drivers could get few information for driving. After

understanding the drivers' point of regard, it could be able to consider the standards in installing the objects that helps drivers to run in safe.

The aim of this study is to propose the measures that contribute to establish the countermeasures in order to prevent the multiple crashes by the result of the analysis of the driver's point of regard, such as the difference of the location of the point of regard by changing the sight distance of driver's visibility in each driver's attribute. There exists similar research to understand the drivers' point of regard in the obscure visibility situation (Fukazawa 1995). In this research, special vehicle were utilized to understand the drivers' point of regard. However, it could be thought that main purpose of this research is to develop this special vehicle, because only one subject was used to understand the driver's point of regard. It might be hard to clarify the characteristics of the driver's point of regard by the small number of subject. It is important to use large number of subjects to get a general knowledge. By utilizing the large number of subjects, it could be able to compare the characteristics of the point of regard by drivers' attribute. This is the difference compared to the former research. In this study, 10 subjects are used to obtain the data. By dividing into two groups, it could be able to compare the characteristics each other. In this study, one of the reasons to occur the traffic accident might be the difference of the skill of driving in the snowfall season. The drivers that are not used to drive in the snowfall season might have high possibility to make traffic accident. It could be thought that drivers' point of regard would explain this feature. It could be thought that expert drivers tend to see many areas, while novice drivers tend to see partially, for example.

4. OUTLINE OF THE DATA

Study area for acquisition the data is selected to understand the influencing factors toward the driver in the obscure visibility situation. It is better to chose the location where the multiple crashes had occurred in the past, because it is found that the locations of the multiple crashes are not necessarily the locations of the frequently occurrence of traffic accident from the result of Chapter 2. The sections between the Taiwa I.C. and the Furukawa I.C. and between the Taiwa I.C. and Tsukidate I.C. are selected for the research area (Figure 6). There are two lanes for each direction, and the number of traffic volume is about 30,000 vehicles per day. In this section, serious multiple crashes that 64 vehicles were involved occurred in December 2000.

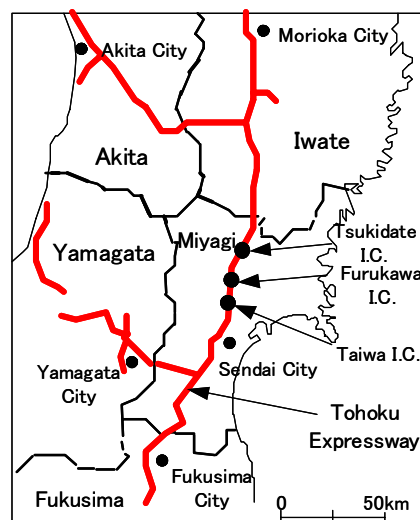


Figure 6. Outline of the study area

4.1 Outline of the video data

Table 1 shows the outline of the video data that is used in this research. This video image was taken in 2001. Video camera was set in the passenger's seat of the vehicle, and road traffic condition from the view of passenger seat was recorded. Only the data of passenger car is used for this research, because the number of case for the view of trucks is not highly recorded compared to that of passenger car. And this would bring higher difficulty in understanding the characteristics of the point of regard by changing the driver's visibility. However the data that vehicle run in the left side lane are used in this research, because the driving time in the right side lane is quite short compared to that in the left side lane. The data of visibility in the both left and right lane are obtained because driver made lane change actions several time in this video image.

Table 1. Outline of the video data

Types of the vehicle	Passanger car		Truck	
Date	6th Marth,2001	4th Marth,2001	7th Marth,2001	31th Marth,2001
Time	13:00~14:00	12:40~14:00	15:30~16:00	19:50~20:50
Section	Taiwa I.C. ~Furukawa I.C.	Tukidate I.C. ~Furukawa I.C.	Taiwa I.C. ~Furukawa I.C.	Taiwa I.C. ~Furukawa I.C.
Weather	Fine	Rainy	Fine	Snowy
Sight distance	Clear	50m,100m,200m, 300m,400m,500m, more than 500m	Clear	More than 500m

4.2 Profile of the video data

Figure 7 shows the still image of each view by changing the sight distance from the driver. These still images were examined to consider the supposed point of regard in each video image. As a result, it could be thought that the point of regard might change from the far in the center to the near in the left side lane by changing the sight distance to short. This would mean that driver might stare the objects that driver could see clearly in the obscure visibility situation. From this analysis the relationship between the point of regard and sight distance are considered, however the result of the characteristics based on the still image does not include the numerical relationships. Therefore, eye-mark recorder was used to understand the characteristics of the point of regard in detail.

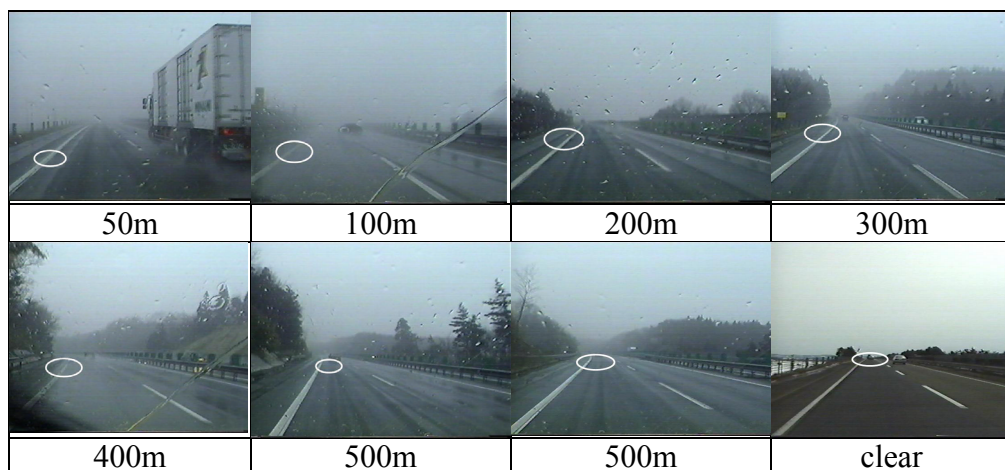


Figure 7. Profile of the video data by sight distance

4.3 Outline of the survey using the eye-mark recorder

Eye-mark recorder, that could measure the driver's point of regard in detail, was used to understand the characteristics of the point of regard in the obscure visibility situation. Table 2 shows the outline of the survey using the eye-mark recorder. In this survey, subjects have to put the eye-mark recorder and see the screen that the aspect of the road traffic condition from the driver's position is shown by the video image. Experiment time to get the data of the point of regard in each subjects was set to 30 minutes in order to avoid the decrease of concentration or the fatigue caused by the longer experiment time for the survey. Time period of each sight distance was set between the 60 seconds and 90 seconds. Video image was edited to show the obscure visibility situation and the clean visibility situation alternately in order to avoid the habitude situation to the video image. All subjects see the same video image so that it is able to compare the point of regard by the driver's characteristics easily.

Table 2. Outline of the survey using the eye-mark recorder

Date	November 19, 2001
Number of subjects	10
Place	Akita University
Contents	subjects see the screen wearing the eye-mark recorder

4.4 Area setting

In order to show the location where subjects tend to regard selectively, area of the video image is divided into several parts in this study. The characteristics of subjects would be clarified by counting the share of these parts. Figure 8 shows the areas divided into 5 parts based on the papers presented before. The result of this paper says that 1) driver tend to stare the roadside line in the left side in the obscure visibility situation, 2) driver tend to see the taillight at the obscure visibility situation in the night, 3) driver mainly see the front area of the lane, 4) driver confirms the vehicle overtake in the right lane.

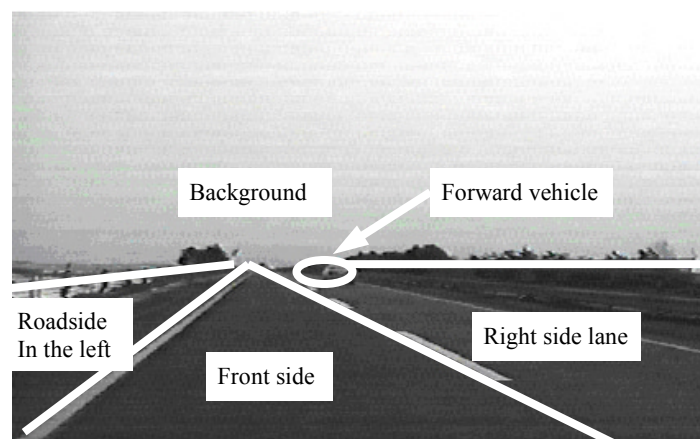


Figure 8. Area divided into 5 parts

4.5 Classification of the subjects by the attribute

There are 10 subjects selected randomly in this research. In this paper, subjects are classified into 2 groups (expert driver and novice driver), because it is easy to say that the driving career influences to the traffic accident without mentioning especially for the obscure visibility situation in the snowfall season. Expert driver is defined as follows;

- owns a vehicle
- drives more than 1 years

Novice driver is defined as follows;

- not owns a vehicle
- drives once in a while
- owns a car, however driving experience is less than 1 year

4.6 Method to analyze

Up to now, classification of the subjects and the area setting were done. There are many points of view to analyze using this database. In this paper, 1) relationship between the sight distance and the location of the point of regard, 2) relationship between the sight distance and the variance of the point of regard, and 3) variance of the point of regard in the specific condition are analyzed.

5. RELATIONSHIP BETWEEN THE SIGHT DISTANCE AND THE LOCATION OF THE POINT OF REGARD FOR THE DRIVER

To consider how much does the subject tend to see these 5 areas, there are two kinds of analysis, such as to use the share and the use of the order of the share in order to understand the relationship between the sight distance and the point of regard of the subjects. It might be better to use the order of the share of 5 areas than to use the shares of it directly in order to show the result of the characteristics of the point of regard clearly. Therefore, the order of the share of 5 areas by changing the sight distance are analyzed by the driver's attribute such as the expert and the novice driver in this study.

5.1 Characteristics of the expert driver

Figure 9 shows the relationship between the sight distance and the location of the subject's point of regard by the order of the share of 5 areas in the entire expert drivers. Vertical axis in this figure shows the order of the share, and "1st" means the area that subjects see most. Horizontal axis shows the sight distance in the ascending order. It is found that the expert drivers tend to see the "background" more by shortening the sight distance. There are any areas to show the same trend such as increasing the ratio of the point of regard by the shortening the sight distance. Main viewpoint of regard would shift from the "forward vehicle" to the "background" gradually by changing the sight distance from clear to obscure, while the share of seeing the "forward vehicle" is higher in the case of clear visibility. Expert drivers tend to see the "forward vehicle" in the clear visibility because expert driver could see the whole area. It could be thought that expert driver see the "background" to keep the safe situation, because it is hard to see the whole areas and to understand the traffic condition as well in the obscure visibility.

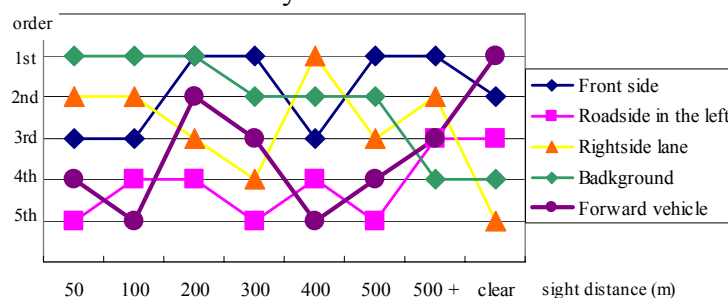


Figure 9. Characteristics of the point of regard in expert drivers

5.2 Characteristics of the novice driver

Figure 10 shows the relationship between the sight distance and the location of the subject's point of regard by the order of the share of 5 areas in the entire novice drivers. It is found that the share of confirming the "front side" is high in novice drivers by shortening the sight distance. There does not exist the same areas that increase their order by shortening the sight distance. It also found that novice drivers tend to see the "roadside in the left" most in the clear visibility situation. Main viewpoint of regard changes from the "roadside in the left" to the "front side" in the novice drivers as the sight distance shortens. This means that novice drivers tend to see the roadside line and the snow protecting fence forehead in the clear visibility situation. However, novice drivers feel the sense of anxiety to see the point of unclear, because it is hard to understand the whole road traffic conditions in the case of obscure visibility situation. And this might bring novice driver to see the "front side" ahead.

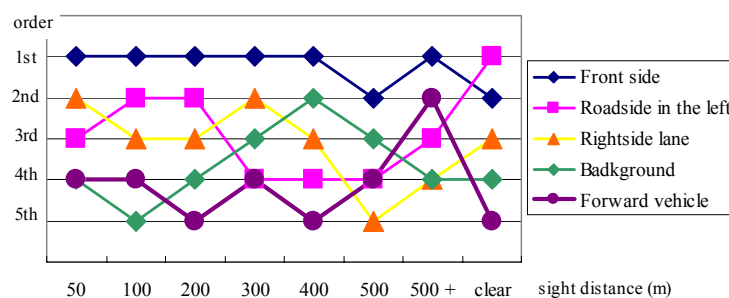


Figure 10. Characteristics of the point of regard in novice drivers

5.3 Comparison between the novice and expert drivers

From the result of former sections, it is found that expert drivers tend to see the "background" to understand the whole road conditions, and novice drivers tend to see the "front side" just ahead, as the visibility obscures. If the driver only sees around the vehicle, they would have much difficulty in understanding the whole road traffic conditions in the case of obscure visibility situation. Therefore, the possibility to be the multiple crashes would increase accompanied by the delay to understand the situation forehead, such as traffic accident. It is important manner to see the whole area to prevent a multiple crashes as the expert drivers do. The manner of seeing around of the vehicles in the case of obscure visibility situation might be brought by the difficulty in understanding the road geometry. Therefore, in order to urge the drivers to see the whole area in the case of obscure visibility situation, it is important to introduce the countermeasures to show the driver the road geometry clearly. The installment of the delineator, that is installed on the roadside and gives the way to the driver, is an one important countermeasure to guide the driver's point of regard.

6. RELATIONSHIP BETWEEN THE SIGHT DISTANCE AND THE VARIANCE OF THE POINT OF REGARD

From the analysis of the relationship between the sight distance and the location of the point of regard, the characteristics of the viewpoint of regard are clarified by the driver's attribute such as expert and novice drivers. However, the similarity of the point of regard in each driver's attribute is not analyzed deeply. There is a need to analyze the variation of the driver's point of regard. In this study, variance are calculated by the share of the 5 areas mentioned before in each sight distance for each driver's attribute such as expert and novice

drivers.

6.1 Characteristics of expert drivers

Figure 11 shows the variance of the expert driver in each sight distance. By comparing the variance of each area, it is confirmed that the variance of the “front side”, “right side lane” and “background” is large, while the variance of “roadside in the left” and “forward vehicle” is small. This means that the share of confirming the “roadside in the left” and “forward vehicle” is almost same score within the subjects, whenever the sight distance changes variously.

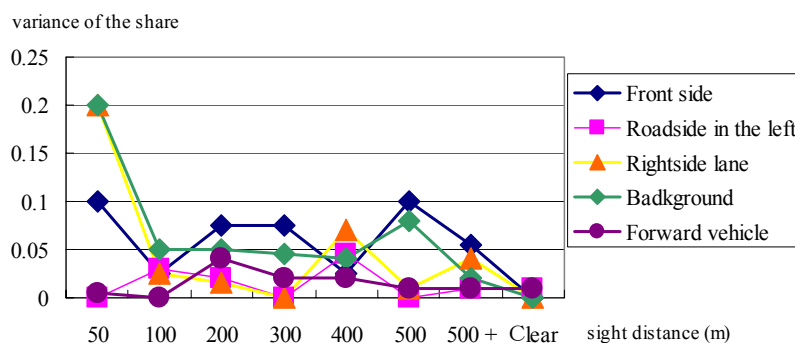


Figure 11. Variance of the point of regard in expert drivers

6.2 Characteristics of the novice drivers

Figure 12 shows the variance of the novice driver in each sight distance. By comparing the variance of each area, it is found that the variance of the “front side”, “roadside in the left” and “background” is large, while the variance of “right side lane” and “forward vehicle” is small. This means that the share of the “right side lane” and “forward vehicle” is almost same in the subjects, whenever the sight distance would change variously.

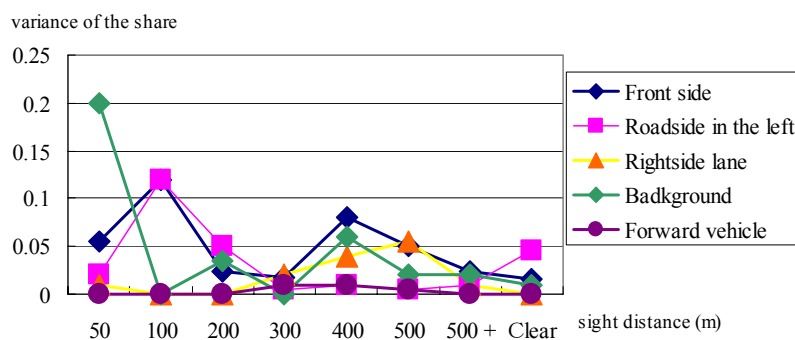


Figure 12. Variance of the point of regard in novice drivers

6.3 Comparison between the expert and novice drivers

By comparing the variance of both expert and novice drivers in each sight distance, it is found that the score of the variance tend to decrease, as the sight distance longer. This means that there are few differences of the characteristics of the point of regard in the clear visibility situation for both expert and novice drivers. Score of variance is longer in novice drivers than that of expert drivers. This shows that there are significant differences within the novice drivers because of the inexperience to drive a vehicle in the obscure visibility situation.

Therefore, it is important to guide the viewpoint of regard to decrease the difference within the novice drivers in order to prevent the multiple crashes.

7. ANALYSIS OF THE CHARACTERISTICS OF THE DRIVER'S POINT OF REGARD

In this chapter, the analysis of the characteristics of the driver's point of regard at the situation when experimental vehicle is overtaken by the other vehicle are conducted to understand the influence of the change of the external environment. Figure 13 shows the transition of the expert driver's point of regard by time frame in the case that sight distance is equal to 100m. From this figure, the share of the subjects who glance the vehicle overtake in the right lane are calculated by the driver's attribute and by the sight distance to clarify the difference. Figure 14 shows the share of the subjects who glance the vehicle overtake it in the right lane in each sight distance. It is found that the share would increase as sight distance decreases from the 500m to 200m in expert drivers, while the share of the novice driver decrease in the same situation. It is an interesting result that both expert and novice drivers do not see the vehicle overtakes it in the right lane in the obscure visibility situation. To understand this result, the characteristics of the driver's point of regard at the case the experimental vehicle is overtaken by the vehicle running in the right lane are analyzed. To clarify the differences of the point of regard in each driver's attribute, order of the share are used to understand the trend easily.

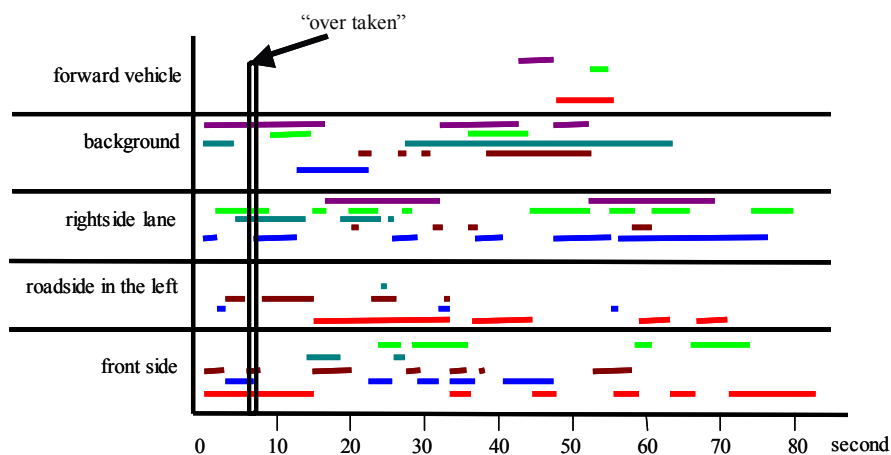


Figure 13. Transition of the point of regard in expert drivers

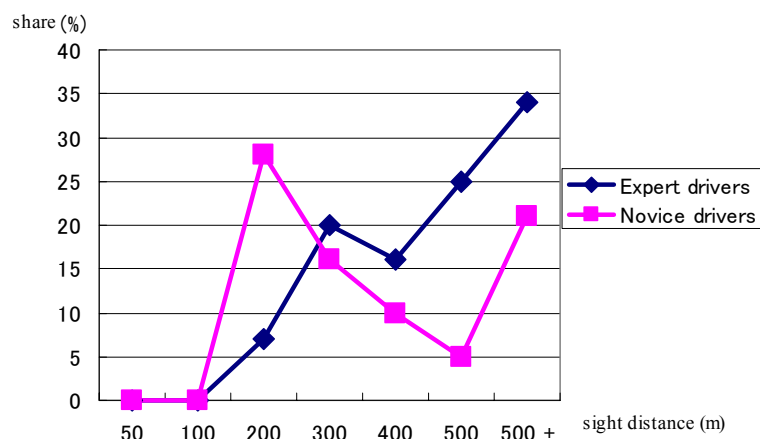


Figure 14. Share of the glance to the vehicle in each drivers

7.1 Characteristics of the expert drivers

Figure 15 shows the order of the share in each sight distance when experimental vehicle was overtaken by other vehicle running in the right lane. Vertical axis shows the order of the share and horizontal axis shows the sight distance. It is found that expert drivers see the “right side lane” mainly in the case of obscure visibility situation. From this output, it could be said that expert driver tend to see around the centerline when their vehicles is overtaken by the vehicle running in the right lane in the obscure visibility situation. In order to clarify this characteristic, this figure is compared with the usual condition mentioned in the chapter 5. Figure 16, that is same as Figure 9 in chapter 5, shows the relationship between the sight distance and the location of the subject’s point of regard by the order of the share of 5 areas in the entire expert drivers. By comparing these figures, it is found that the order of seeing “background” is almost same except the obscure visibility situation. This might be thought that expert drivers see the centerline in the condition that experimental vehicle is overtaken by the other vehicle, while expert driver see the “background” in the usual condition in the case of obscure visibility situation. This might be caused by the psychological factor to avoid the traffic accident with the vehicle overtaking in the right lane.

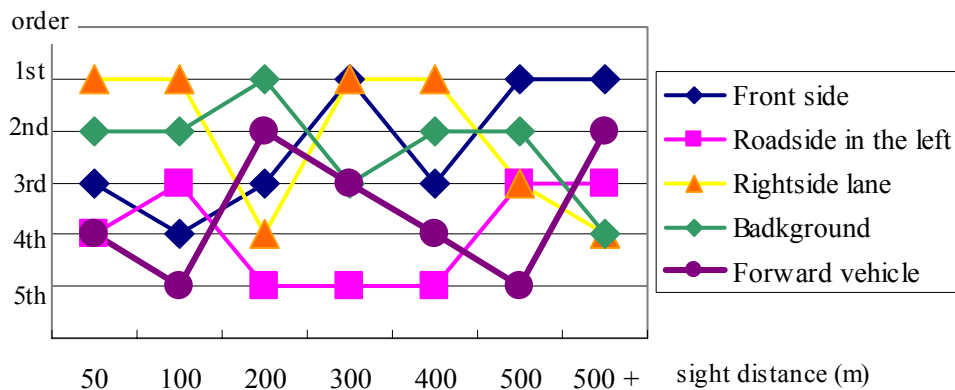


Figure 15. Order of the point of regard to the vehicle in expert drivers

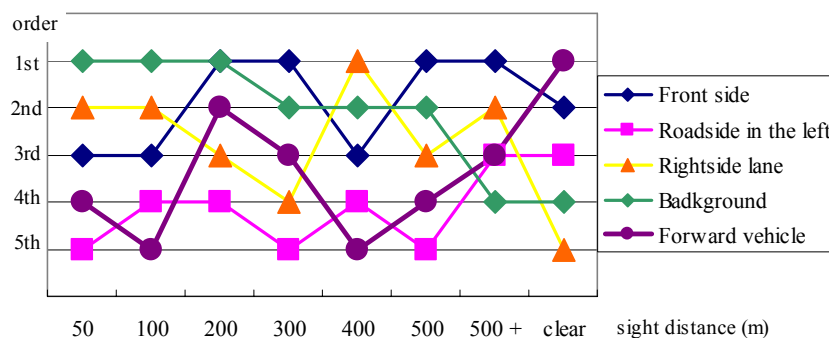


Figure 16. Characteristics of the point of regard in expert drivers

7.2 Characteristics of the novice drivers

Figure 17 shows the order of the share in each sight distance when experimental vehicles was overtaken by the other vehicle running in the right lane. It is found that novice drivers see the “front side” ahead mainly in the case of obscure visibility situation. The location of the point of regard would not change for the novice drivers, because novice driver tend to see the “front side” in the case of having the longer sight distance. In order to clarify this characteristic, this figure is compared with the usual condition mentioned in the chapter 5.

Figure 18, that is same as Figure 10 in Chapter 5, shows the relationship between the sight distance and the location of the subject's point of regard by the order of the share of 5 areas in the entire novice drivers. By comparing these figures, it is found that the order of the area of "front side" is almost same not only in the longer sight distance but also in the obscure visibility situation for the novice drivers. Therefore, it could be considered that novice driver might have difficulty in collecting the information about the traffic conditions.

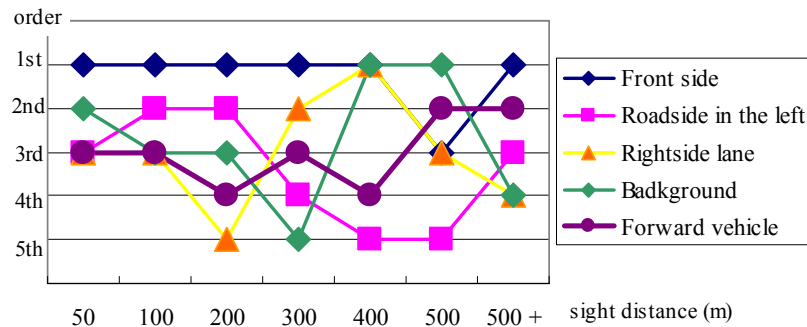


Figure 17. Order of the point of regard to the vehicle in novice drivers

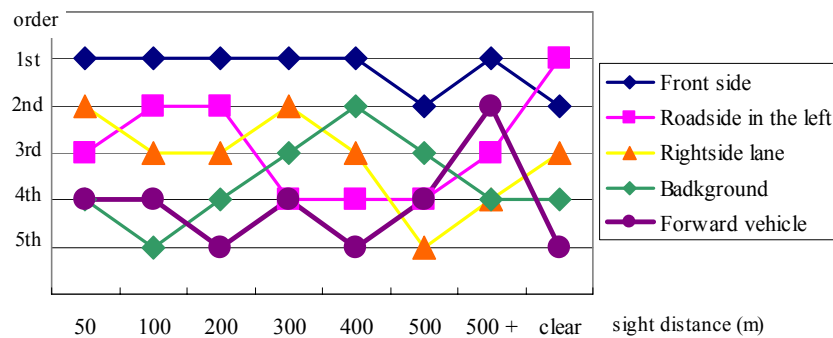


Figure 18. Characteristics of the point of regard in novice drivers

7.3 Comparison between the expert and novice drivers

By comparing the characteristics of expert drivers (Figure 15) and of novice drivers (Figure 17), it is found that novice driver would not change their attitude of the point of regard, while expert drivers change their location of the point of regard in response to the vehicle that overtakes in the right lane. There are many items that influences to the driver in the expressway, such as the sign to show the direction and the sign to show the running speed. It is important to understand the spatial position each other in the obscure visibility situation in order to avoid the multiple crashes. Driving the vehicle without recognizing of the surrounding environment might bring the traffic accident and the multiple crashes sometimes. Therefore, it is important to act as expert drivers do, such as to see the whole area unevenly.

8. CONCLUSION

In this paper, the relationship between the location of the frequently occurrence of traffic accident and the multiple crashes are analyzed. From this analysis, it is found that the location of the multiple crashes has different characteristic from that of the frequently occurrence of traffic accident. This result means that there exists same special factor to occur the multiple crashes. By conducting the survey using the eye-mark recorder, it is able

to understand the characteristics of the driver's point of regard by the driver's attribute and the sight distance. From this analysis, many important findings are obtained as follows;

- expert drivers tend to see the background in the case of obscure visibility situation in order to understand the surrounding conditions as a whole
- novice drivers tend to see the road ahead in the case of obscure visibility situation because of the difficulty in paying attention to the other area
- the characteristics of the point of regard tend to similar in each drivers by increasing the sight distance.

In this research, video data of the obscure/clear visibility situation are used to understand the driver's point of regard, because it is danger to use eye-mark recorder directly in the case of obscure visibility situation. However, there exists some accident such as the point of regard stick out from the screen, because subjects sit down the chair and just see the screen by way of driving the vehicle. This might bet the future challenge to introduce a situation that subjects feel as driving in real.

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