Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Analysis on Characteristics of Dangerous Driving Events via Recorded Data of Drive-Recorder

Keonhee Min[a] Akira Ando[b]

[a]*Nikken Sekkei Research Institute, 3-7-1 Kanda Ogawamachi Chiyoda ku ,Tokyo 101-0051 Japan*
[b]*Nikken Sekkei Research Institute, 3-7-1 Kanda Ogawamachi Chiyoda ku ,Tokyo 101-0051 Japan*

Abstract

In this research, from the viewpoint of improving traffic safety policies, we focus on clarifying the characteristics of dangerous driving events (stop sign violation, traffic light violation, pedestrian disturbance, excessive speed etc.) which are thought to be closely related to traffic accidents. Conventional studies on traffic safety focused mainly on improvement of road structure etc. and aimed at extraction of dangerous places or spots from probe data, meanwhile this research focuses on dangerous driving behaviors which are initial but hidden cause of traffic accident. In addition, analysis of whole set of data which includes both of Video and GPS data during whole travel hours stored in drive recorders of 175 participants, which is unprecedented.
As a result, it was shown that the dangerous driving has a certain occurrence tendency, which is attributed to the individual characteristics of the driver, the driving place, and the driving hours. The results of this research can be expected to contribute to effective driving safety enlightenment campaigns for reducing traffic accidents. We also investigate relationship between cognitive impairment and dangerous driving of elderly drivers to bring new findings to future traffic safety policies.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: Drive Recorder, Traffic Violation, Elderly Driver, GPS, Cognitive Impairment

1. Introduction

Japanese National Police Agency data shows that the number of traffic accidents in Japan in 2015 was 536,899, with the number of fatalities 4,117 and injuries 666,023. Compared to the previous year, the number of accidents decreased by 36,943 (6.4%) and the number of injuries by 45,351 (6.4%) , marking 11 consecutive years of decrease in number of accidents and injuries , and in addition the number of fatalities decreased to less than 1/4 of the highest number in 1971.

However, for the first time in 15 years, the number of fatalities increased compared to the previous year, by 4 people (0.1%), and the goal stipulated that " the number of fatalities due to traffic accidents shall be decreased to less than 3,000 by 2015" in the 9th Traffic Safety Basic Plan could not be achieved.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

Nonetheless, recent decrease in the number of traffic accidents and fatalities can be considered as result of improved safety performance of automobile, improvement of dangerous road conditions including intersections, and strengthening enforcement for traffic violation.

On the other hand, Japan is experiencing the unprecedented rapid population aging, the fatality ratio of elderly people aged 65 or older (hereinafter, "the elderly ")is approximately 6 times higher than for other age groups, and steadily growing year by year and recording the highest number so far . As a traffic accident involving the elderly tends to result in large accidents, Japanese Authorities urges elderly drivers to voluntarily return their driver's licenses and cognitive test for the elderly aged 75 and older who seeks renewal of driver's license became obligatory under the revised Road Traffic Law in 2017.

However, many of traffic accident involving the elderly caused by mild cognitive impairment (MCI) which is difficult to detect with current mandatory cognitive test and more effective measure based on understanding of relation between cognitive functions and driving skills is required to prevent the traffic accident of elderly drivers.
I n addition, a lot of attention is also being given to horrible accidents involving children on community roads, etc.

Although in the past it has been possible to reduce the number of traffic accidents and fatalities through the efforts of road administration and traffic safety administration as stated before, there are limits to the effectiveness of such past efforts alone for further reducing traffic accidents in the future, and it is required that drastic changes in public awareness toward reducing traffic accidents and tangible efforts for promoting public dissemination and edification are necessary.

In particular, a previous study pointed out that for a person who caused traffic accidents, there is a certain positive correlation between the occurrence of accident and the number of their past traffic law violations [1)]. In other words, it can be said that there is strong implication that more frequent traffic violation leads to the higher possibility of traffic accident. From this point, traffic safety promotion aimed at residents and companies accompanied by efforts to reduce traffic violations would be the most effective measure

Therefore, in this research, we investigate the characteristics of dangerous driving to obtain knowledge for the future traffic safety promotion activities

In this research, we extract full-time video driving data from drive recorders with GPS data and accelerometer data (speed, acceleration data)

As stated above, a series of fatal traffic accidents caused by the elderly drivers that involve group of children on a way to school or pedestrians has become serious social issue in recent Japan. And it is important to understand characteristics of driving behavior of elderly drivers and to suggest traffic safety policies considering that characteristics not only for Japan but for highly populated countries such as ASEAN countries India and China where similar issue is expected in near future.

Therefore, this research aims to investigate not only characteristics of dangerous driving event of drivers in general But also relation between driving characteristics and cognitive functions of elderly drivers and offer some suggestion for future traffic safety policy.

2. A Review of Previous Studies and Purpose of This Research

2.1. A Review of Previous Studies

There are extensive studies on traffic safety policies and measures, and they mainly focused on identifying a hazardous road spots. Common methodology in identifying a hazardous road spots is to use the traffic accident data by police agency to estimate dangerous locations and implement countermeasures. However, this method has its own limitation since traffic accidents themselves are rare occurrences, it takes time to acquire sufficient data to implement countermeasures and such countermeasures are limited to after-the-fact measures, and it is not possible to implement preventive measures at locations where there is a potential for accidents to occur. Moreover, another problem that has been pointed out is that such traffic accident location data is not well organized and is not shared among stakeholders.

Because of this, in recent years methods utilizing the GPS data that can be obtained from the car navigation systems to detect sudden changes in speed or acceleration/deceleration and estimate locations where dangerous driving events occur have become more common . Yada et al.2) analyzed the relation between probe data and road sections with frequent traffic accidents, and showed the tendency that traffic accidents were more frequent in sections where rapid

deceleration occurred. Meanwhile, Yamamoto et al.3) also used Nagoya-area taxi probe data to analyze the relationship between the road sections with frequent traffic accidents and road sections with rapid deceleration.

In addition, some of progress has been made in researches on traffic accident prone spots by utilizing drive recorder installed in taxis and trucks. Miura et al.4) extracted the GPS data and video data from drive recorders installed in taxis to identify hazardous spots and analyze the occurrence factors to occurrence of dangerous situations. However, these methods use the rapid deceleration events detected by accelerometer in the drive recorder as the trigger to record the events, and observation only can be made at the point when rapid deceleration events occur. Imanaga et al.5) are developing a method that utilizes event triggered drive recorders installed in taxis to detect rapid deceleration situations from accelerometer and automatically identify dangerous locations. Furthermore, Matsunuma et al.6) have reported a demonstration experiment in which drive recorders are installed in public service vehicles and the accelerometer data from drive recorder are used to identify dangerous driving, and the results are used for the driver safety training program for public service vehicle drivers.

As described above, features of previous research show that they mainly focus on the use of GPS and accelerometer for the detection of specific events.

2.2. The Purpose of Research

The purpose of this research is to clarify the occurrence characteristics of dangerous driving events or traffic violations which potentially leads to traffic accidents (hereinafter, "dangerous driving") and obtain data which can be effectively used as the basis for traffic safety promotion and public edification for safe driving.

First, unlike previous studies which focused on identifying hazardous spots, we aims to capture "dangerous driving events" that are precursors to near-miss incidents or actual accidents. In particular, there are few studies on the occurrence characteristics of dangerous driving events, and the knowledge gained from this research is expected to be effective not only for citizen awareness edification, but also for effective implementation of enforcement.

Second, we utilize full recorded video data from drive recorder. In previous studies, only with the occurrence of sudden deceleration events, the recording data was extracted and identification of hazardous spots were possible, but when the focus is placed on the occurrence characteristics of dangerous driving as in this research, this kind of logic cannot be applied. (In other words, dangerous driving is also being performed even in places where sudden deceleration phenomena are not occurring. In addition, from the start the purpose is to clarify the driving tendencies (dangerous driving occurrence characteristics) of daily drivers) Because of this, in this research, full video data of the drive recorder were visually examined exhaustively to capture dangerous driving events and understand its characteristics. Through this unprecedented approach we expect to gain new insight for traffic safety.

Third, we also aim to show dangerous driving characteristics of elderly drivers and discuss its cause. Especially it is meaningful to offer the new insight for rapidly unfolding aging society in global scale.

3. Methodology

3.1. Overview

Residents of Aichi Prefecture who drives for at least 3hours a day and more than 3days a week) participate in research as subject. Each participants were provided a drive recorder for one week and instructed to install the drive recorder in their private car and drive as usual during a monitoring period.

As a result, total number of participants was 175 people (Table 1). Although Age and Gender of Participants varied, Number of male and elderly driver were somewhat dominant among the groups.

For the research purpose, drive recorder setting was changed so that a unit records not only when event occurred, but records full driving time period. Storage space for maximum of 11hours of record was secured.

Under this condition, an average of 8.7 hours/week of image data and GPS data, accelerometer data per a driver could be obtained.

Table 1. Age Groups and Gender distribution of Participants

Age group	20	30	40	50	60	70	80	Total
Female	9	3	11	8	11	2	0	44
	20.5%	6.8%	25.0%	18.2%	25.0%	4.5%	0.0%	100%
Male	13	13	17	24	37	26	1	131
	9.9%	9.9%	13.0%	18.3%	28.2%	19.8%	0.8%	100%
Total	22	16	28	32	48	28	1	175
	12.6%	9.1%	16.0%	18.3%	27.4%	16.0%	0.6%	100%

3.2. Definition of Dangerous driving event

In this research, "dangerous driving event" is defined as shown in Table 2. Most of them are also defined as traffic violation by the Road Traffic Law of Japan. We identified “dangerous driving event” and places where events occurred from recorded video data of participants. By matching event occurrence time with GPS log data, We could visualize geographical distribution of dangerous driving events.

For speeding, sudden deceleration/acceleration were identified using GPS data and accelerometer data.

Table 2. Definition of Dangerous Driving Events

Check item classification		Judgement items
Traffic light	Traffic light violation	Red light violation, Yellow light violation, accelerating at the change of Traffic light, snap decided start.
	Stopping at intersections having traffic lights	Stopping past the stop line, stopping on the crosswalk
Driving on community roads	Stop sign violation	Not stopping, stopping past the stop line, not doing a 2-stage stop
	Not slowing down at Stop sign or with low visibility	
Right or Left Turn		Too wide turn, Too steep turn, Turn with inappropriate speed
Passing through a crosswalk	Method for passing through a crosswalk (including at intersections with traffic lights)	Interfering with crossing pedestrians, not decelerating or going at low speed.
	Decelerating and going through at low speed even without presence of pedestrians.	
Consideration of pedestrians, bicycles, etc.	Maintaining a safe lateral distance.	Insufficient distance from pedestrians, distance from bicycles, or distance from parked cars
	Going too fast when passing.by	Going too fast when passing by pedestrians, bicycles, or parked cars.
Common	Driving while protruding into the opposite lane in areas where such protrusion is prohibited.	
	Exceeding speed limit（※）	
	Inappropriate vehicle separation distance	
	Interfering with pedestrians or vehicles when entering and leaving road for facilities off of the road.	
	Sudden braking（※）	
	Sudden start（※）	

4. Occurrence characteristics of dangerous driving events

4.1. Overview

The driving routes travelled by all participants are shown in Figure 1. Since GPS logs are extracted from one week long records of 175 participants, routes cover a wide range of Aichi prefecture area.

In addition, a total of 4,021 dangerous driving events was identified from the data of all participants. Among these cases, Among these cases, the most common event classification was ① Stop sign violation (N=2,728 ; 67.8% of total events), followed by ② interfering with pedestrians (consists of lack of consideration for pedestrians or bicycles = 396 cases 9.8%; interfering with pedestrians on crosswalk = 78 cases, 1.9%), ③ traffic light violation (consists of ignoring traffic light (red) = 53 cases, 1.3%; ignoring traffic light (yellow) = 139 cases, 3.5%), and ④ speeding (284 cases, 7.1%).

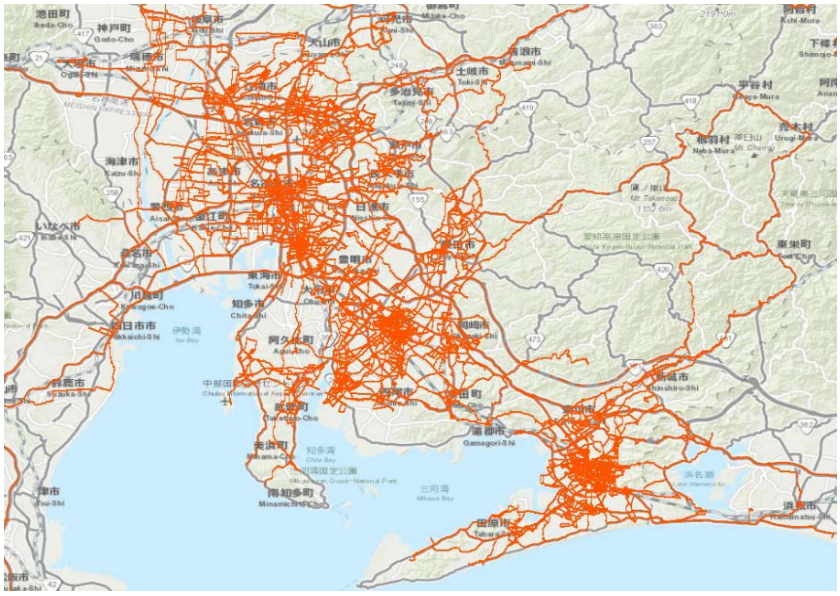
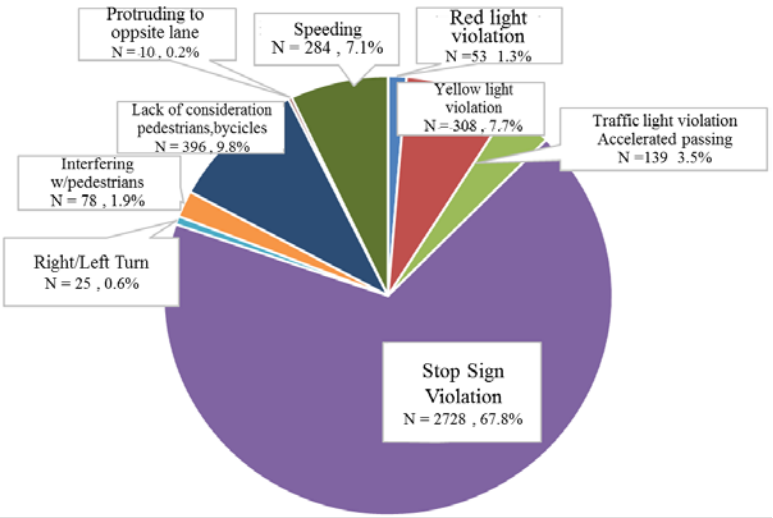


Fig. 1 Visualization of GPS log(Orange lines indicates routes travelled by participants)

the most frequent dangerous driving is stop sign violation (2,728 cases; 67.8%), followed by interfering with pedestrians (consist of : lack of consideration for pedestrianthe most common phenomenon was ① failure to stop for a moment (2,728 cases; 67.8%), followed by ② interfering with pedestrians (consist of : lack of consideration for pedestrian

Fig. 2 Number of Dangerous Driving Events (N=3661)



4.2. Characteristics of dangerous driving events by attributes of participants

Dangerous driving occurrence characteristics by driver attributes were analyzed focusing on 4 types of dangerous driving events which are the most frequent occurrence phenomena as mentioned above. For this survey, each

participants is asked to fill in about driver's license holding year and the driving purpose during the monitoring period in a diary format, so that data was also used in the following analysis.

(1) General trends of dangerous driving and individual attributes

In order to analyze the general trends of dangerous driving events (e. g., ignoring of traffic lights, failure to stop for a moment, interfering with pedestrians, speeding, etc.) and individual attributes (e. g., residential area, age, sex, driving history, driving time, driving purpose), uncorrelated testing between all of these items was performed. For the results, the items where the null hypothesis that each dangerous driving phenomenon and individual characteristic were uncorrelated which could be rejected at significance levels of 5% and 1% are shown in Table 3.

- Looking at the total number of occurrences of dangerous driving, there is a high statistical superiority relationship with age and driving history. From the sign conditions, it can be thought that as the age and driving experience decreases, the frequency of occurrence of dangerous driving increases.
- As for traffic light violation, it is shown that younger drivers and those who often drive (those with long driving hours) tend to ignore traffic light more often.
- Stop sign violation is shown to be influenced by distance from residence, not by individual attributes.
- Interfering with pedestrians showed significance for sex, with women being more likely to take the risk than men.
- It was shown that speeding occurred more frequently with young drivers and those who drive cars a lot.

Detailed analysis results for the above will be discussed later.

Table 3. Correlation factors and coefficient of Dangerous driving events and attributes of participants

Dangerous driving events	Correlation factor ①	Correlation factor ②
Total number of violations	Age (-0.162※)	Driving history (-0.182※)
Cases of traffic light violation	Age (-0.158※)	Driving time per week (0.190※)
Cases of stop sign violation	Area of residence(0.174※)	—
Cases of interfering with pedestrians	Sex (0.172※)	—
Cases of excessive speeding	Age (-0.161※)	Driving time per week (0.238※※)

※※: 1% significance; ※: 5% significance

(2) Characteristics by age groups

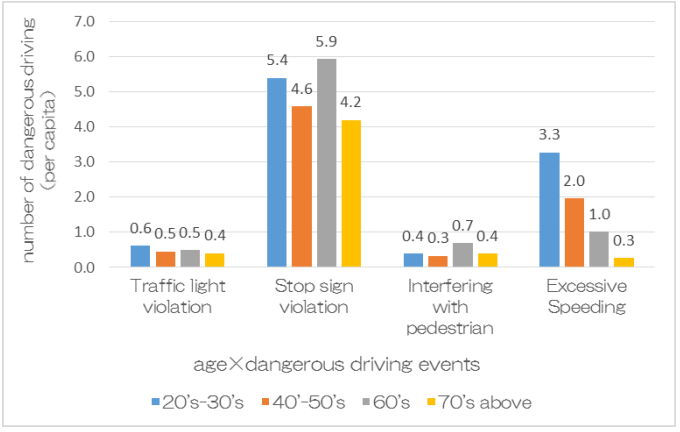


Fig. 3 Number of dangerous driving events occurrences by age groups

Looking at the number of occurrences of dangerous driving per person per day (= Number of occurrences / (Number of people who performed that dangerous driving x 7 days)), it is shown that the occurrence tendency was relatively higher for drivers in their 20s to 30s or in their 60s than for other age groups.

For speeding, age group characteristics were clearly shown, with the tendency to speed increasing as the age decreased.

As shown above, the occurrence characteristics of dangerous driving are different according to the age group.

(3) Characteristics by driver's license holding year

As for license holding year of drivers, it was shown stop sign violation and speeding are clearly higher for drivers with less than 5 years since obtaining a license compared to other groups. In addition, the same group showed a higher tendency toward ignoring traffic lights as well.

Based on this point, it is shown that number of dangerous driving event such as stop sign violation, speeding, ignoring traffic lights, etc. is much higher among inexperienced drivers whose license holding years are relatively short.

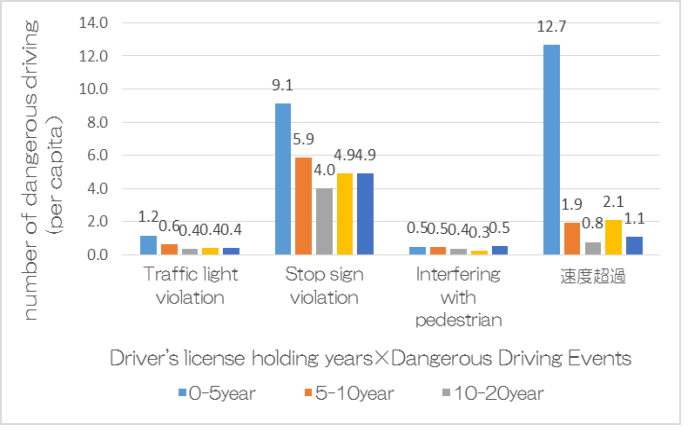


Fig. 4 Number of dangerous driving occurrences (per person per day) by license holding year

(4) Characteristics by purpose of driving

If we look at the purpose for driving, failure to stop for a moment and speeding tended to be higher during commuting. The classification of "Other" includes personal purposes such as hobbies, entertainment, etc., and it is assumed that the high occurrence frequency for this classification is greatly influenced by the higher age groups.

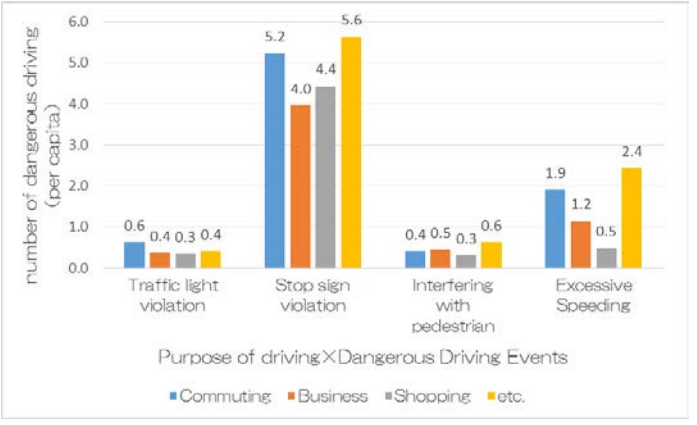


Fig. 5 Number of dangerous driving occurrences (per person per day) by license holding year

It is conceivable that the reason for that is that the ratio of elderly among the participants this time is high, and many such elderly are not employed, so that even on weekdays, the purpose of driving being not commuting but traveling for personal reasons (e. g., golf, meeting friends, volunteering, etc.) is high and many cases of dangerous driving at such times are included.

4.3. Occurrence characteristics by geographical distribution and time

As for major dangerous driving events, we investigate the dangerous driving occurrence characteristics for location and time by linking the GPS data captured by the drive recorder with the occurrence location.

(1) Stop Sign Violation

Since stop sign violation tended to occur more frequently near the driver's home, geographical relationship between the distance from home and frequency was shown. (See Figure 6.)

As a result, it is shown that many stop sign violation events occurred within 500 m distance from the driver's home. On the other hand, an objection to this point regarding this tendency would be that the occurrence ratio is high because the driver drive near their home more often naturally. .

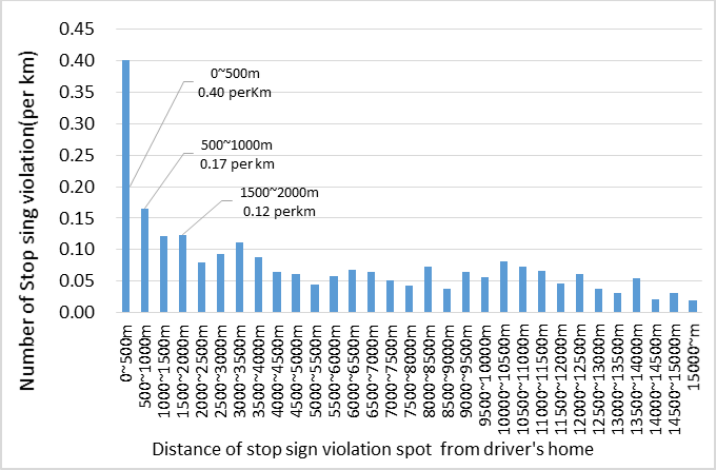


Fig. 6 Number of stop sign violation per km by distance from driver's home

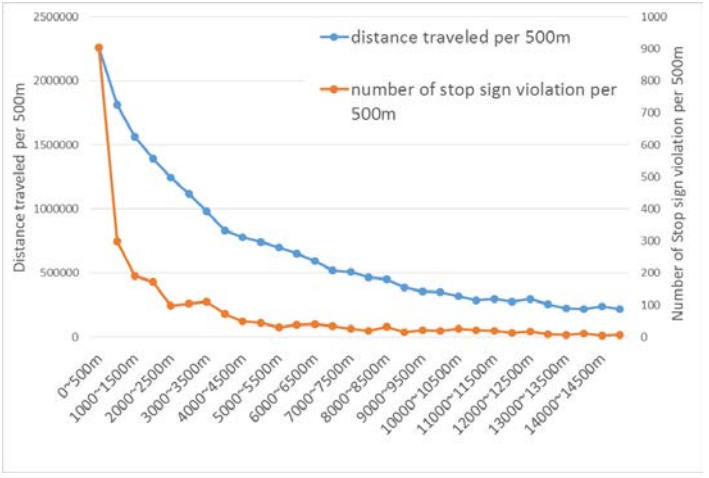


Fig. 7 Number of stop sign violation per 500m and distance traveled per 500m from driver's home

Therefore, although the vertical axis of Figure 6 uses the normalized value (= Cases of failure to stop for a moment / kilometers traveled weekly by distance zone), it can be seen that the number of cases occurring within 500 m of the driver's home is still high. Furthermore, Figure 7 shows the relationship between the number of cases of failure to stop for a moment by each distance zone area centered on the home and the meters traveled, but when independence testing between these two groups (that the occurrence of failure to stop for a moment was not related to whether the number of meters traveled was high or low), the result was $p = 0.000 < 0.01$ indicating that the

independence of both sides is significant. From this point also, it was shown that "having a lot of opportunities for travel is not related" and a lot of failure to stop for a moment occurred near the driver's home.

From the above, it can be predicted that near the driver's home, the familiarity and sense of security of the driver results in a tendency for many cases of failure to stop for a moment to occur.

Furthermore, a remarkable point in this analysis result is that the analysis results from this research are consistent with the analysis of traffic accident occurrence characteristics conducted by the Ministry of Land, Infrastructure, Transport and Tourism [7], which pointed out that "Many traffic accidents occur within 500 m from home". In other words, although many traffic accidents occur within 500 m from the driver's home, it can be hypothesized that this is also caused by the high number of cases of failure to stop for a moment.

Next, the time occurrence characteristics for failure to stop for a moment will be discussed in detail (see Figure 8). From this, it was shown that failure to stop temporarily tends to occur more often in the morning and evening time periods.

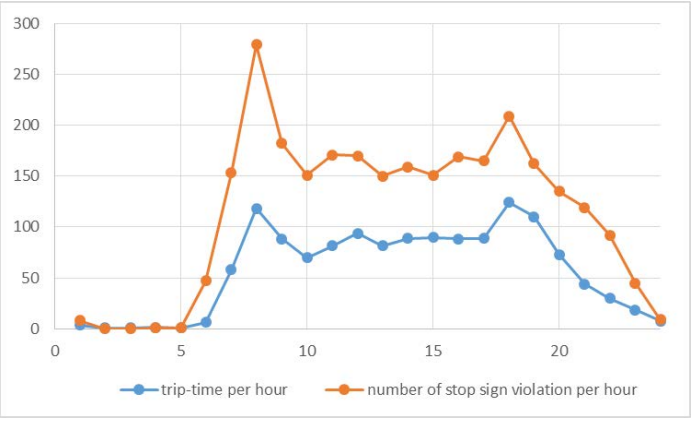


Fig. 8 Trip-time per hour and number of stop sing violation per hour

However, for this point as well, the objection that "the occurrence ratio (captured ratio) is naturally higher for the morning and evening time periods because of the higher traffic volume at those times" can be anticipated. Therefore, we conducted an independence test on the monitor's number of travel trips by time period and the number of occurrences of failure to stop for a moment by time period. The result was $p = 0.0071 < 0.01$ (significance level of 1%), and the hypothesis that the two phenomena are the same phenomenon could be rejected. In the graph of Figure 8 as well, the occurrence ratio of failure to stop for a moment in the morning and evening shows a peak ratio higher than the ratio of the number of trips by time period for those periods, and it can be inferred that there is mutual independence.

In other words, it can be inferred that the fact that failure to stop for a moment occurs more often in the morning and evening hours does not relate to the high number of trips during those time periods, but that the dangerous driving phenomenon of failure to stop for a moment is because the driver is in a hurry during the morning and evening periods.

Regarding these time period characteristics as well, since the results are consistent with the point "There are many traffic accidents in the 8 o'clock and 17 o'clock time periods" shown in a past study[8], it can be said that this suggests that rehabilitating such dangerous driving behavior would lead to a reduction in traffic accidents.

(2) Traffic lights violation

For Traffic light violation as well, analyses of occurrences per kilometer traveled from home (Figure 9) and occurrences per time period (Figure 10) were performed.

For the distance from home, although it can be thought that it would occur more frequently in places relative close to home (within about 4 to 5 km), clear tendencies like those for failure to stop for a moment were not found.

For the time period, as with failure to stop for a moment, a tendency for the phenomena to occur frequently in

the morning and evening time periods was shown. However, for this point too, as before since the objection that the high number of trips per time period taken by the monitor is the cause can be anticipated, we conducted independence testing for the number of trips by time period and the number of cases of ingoring traffic lights by time period.

The results were p=0.391>0.05, and it was impossible to dismiss the fact that the two groups are the same. Therefore, for ignoring traffic lights, since the traffic volume is high in the morning and evening, the interpretation that the phenomenon is also likely to be captured is valid.

However, it is a fact that ignoring traffic lights occurs often in the morning and evening periods, appealing this point through enforcement and disseminating materials for citizen edification will be effective.

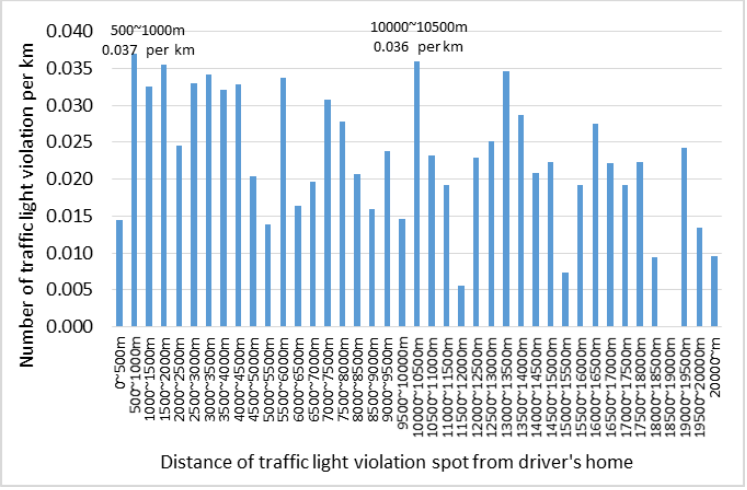


Fig. 9 Number of traffic light violation per km by distance from driver's home

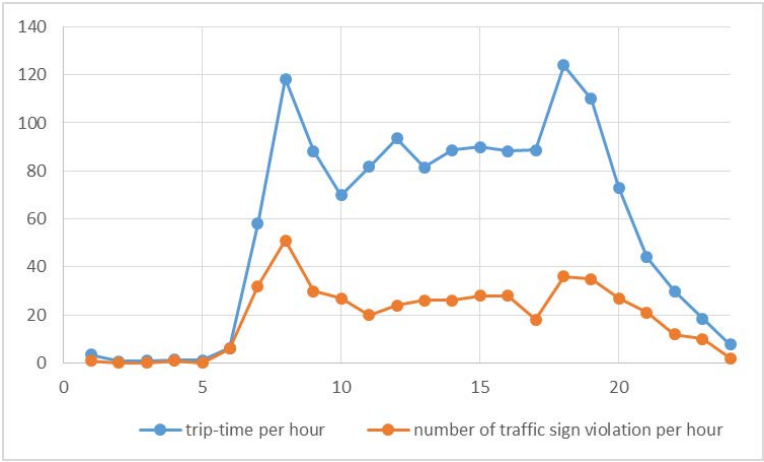


Fig. 10 Trip-time per hour and Number of traffic light violation per hour

(3) Interfering with pedestrians

As for interfering with pedestrians, it, in addition to the peak hours of the morning and evening, it also occurs frequently in the periods from 11 to 12 o'clock and 15 to 17 o'clock when many pedestrians appear.

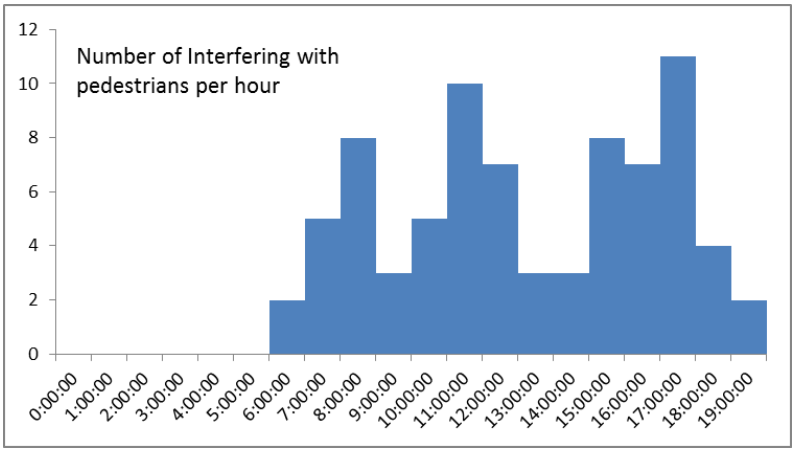


Fig. 11 Number of Interfering with pedestrians occurrence per hour

Next, plotting of pedestrian interference on a map are shown in Figure 12.
Figure 12 shows a map of the places where pedestrian interference occurred, but from this it can be seen that there is a tendency for the phenomenon to occur frequently in places where there are many people such as around stations, around living areas, etc.

Therefore, when the places where pedestrian interference occurred were counted focuing on road classifications (Table 4), the place with the highest occurrence frequency was not main roads (2- or 4-lane roads) but single-lane roads, and it is thought that it is occuring in back street district roads and community roads. As a ratio, in fact this is where more than 80% occurs.

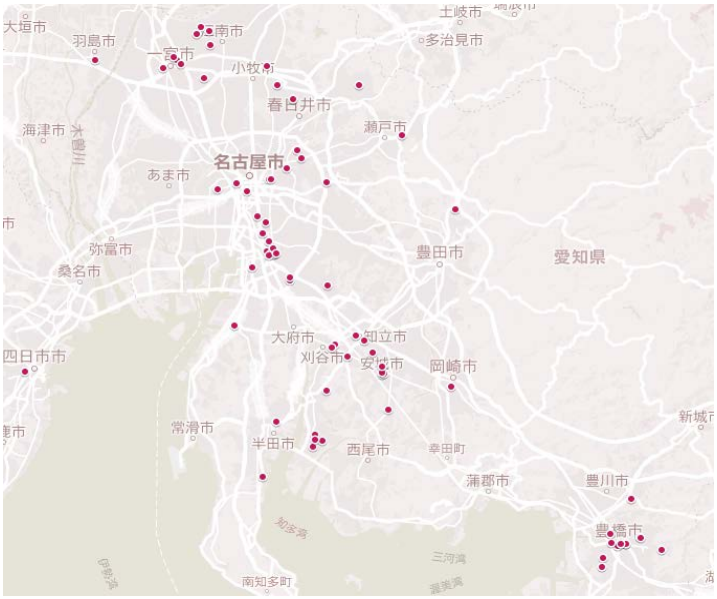


Fig. 12 Spot where interfering with pedestrians occurs near Nagoya city

Furthermore, since from the drive recorder images it could be seen that the places where pedestrian interference occurred were often around stations or places where children or students are involved, in order to quantitatively verify this point, as a result of counting the number of places where pedestrian interference occurred within 500 m walking distance from stations and schools using GIS, it was found that there are 46 schools and 29 stations. In other words, it was shown that there is a higher risk of pedestrian interference occurring on roads used by students around

schools than around stations.

From the above, for the occurrence characteristics of pedestrian interference, it was shown to occur frequently mainly on community roads or in back street districts around stations, and also that the risk to children and students around schools is high.

Table 4. Definition of Dangerous Driving Events

	4 lanes or more	2 lanes	Single lane	Total
Occurrences	3 cases	12 cases	63 cases	78 cases
Ratio	3.8%	15.4%	80.8%	100.0%

(4) Speeding

Looking at the occurrence trends for speeding by time period, it can be seen that the morning commuting time period is remarkably higher. It is conceivable that this is caused by rushing when commuting.

Also, the locations where speeding occurred organized by the road administrator classification are shown in Table As a result, of the 284 total occurrences, the number of occurrences on prefectural roads and municipal roads was overwhelming at 157, but since this is influenced by the extended roadway length (in other words, it is natural that the number of checked incidents would be higher on roads with long extended lengths), the normalized number of speeding occurrences (= Number of speeding occurrences by road classification / Extended distance of that road) determined using the extended road distance by road administrator in Aichi Prefecture as listed in the 2010 Road Traffic Census [9] were calculated and compared.

The resulting values were 0.152 for expressways, 0.048 for national highways, and 0.043 for prefectural roads and municipal roads, and the possibility of speeding occurring increased as the road standards became higher. Although this is easy to imagine in general, it can be said that it was possible to confirm this again using this data. In addition, regarding farming and forestry roads, since the area of residence of the participants was an urban area, even though the number of participants who travel on such roads was not very high, since the extended road length within the prefecture is long, the participants who traveled on farming and forestry roads, it is thought that the probability of speeding on such roads was high.

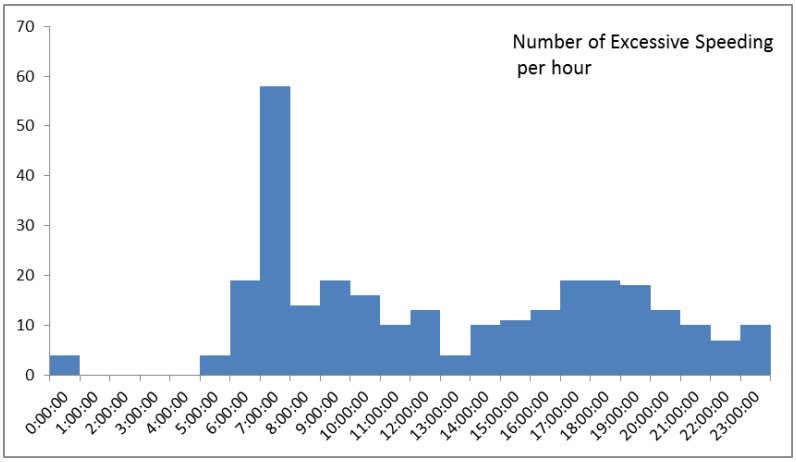


Fig. 11 Number of excessive speeding occurrence per hour

Table 5. Number of speeding occurrences by road administrator classification

Road classification	Number of occurrences	Extended road length in prefecture	Normalized value
Expressways	30	194.5km	0.152
National highways	57	1171.3 km	0.048
Prefectural roads + municipal roads	157	3632.3 km	0.043
Community roads	29	Unknown	-
Farming/forestry roads	11	2582 km	0.004

5. *Analysis* on characteristics and causes of dangerous driving events of elderly drivers

5.1. Characteristics of dangerous driving events of elderly drivers

5.1.1. Overview of data

In this chapter, we aim at understanding at characteristics of dangerous driving events of elderly drivers and discussing their causes.

To analyze data properly, it is required to obtain sufficient amount of data. Therefore, we recruited new participants from Aichi prefecture, and acquire new data set that consists of elderly drivers aged 65 and above (N=92, 46%) and non-elderly drivers. (N=104, 53%), roughly same proportion for both age groups (Table6.)

Table 6. Age Groups and Gender distribution of Participants

Age Group	20's	30's	40's	50's	60's	70's	80's	65 and above
Female	1	2	12	11	8	12	2	20
	1%	1%	6%	6%	4%	6%	1%	10%
Male	14	8	15	28	36	41	8	72
	7%	4%	8%	14%	18%	21%	4%	36%
Total	15	10	27	39	44	53	10	92
	8%	5%	14%	20%	22%	27%	5%	46%

5.1.2. Characteristics of dangerous driving event of elderly drivers

In this section, for further analysis, we selected dangerous driving events that are thought to be more serious violations compared to others (e.g. red light violation, wrong-way driving, interfering with pedestrian and speeding), and stop sign violation which is most frequent events as subjects, and compared occurrence characteristics of these driving events between elderly drivers group and non-elderly drivers group.

Specifically, for each driving events, we compare number of occurrence (per capita), and statistically tested their differences between two age groups (elderly-non elderly). Since probability distribution of dangerous driving event occurrence is not supposed to be normal distribution. We conducted non-parametric Wilcoxon test on number of occurrence (per capita) for each driving events between two age groups. The results is shown in Table7

Table7. The Number of Dangerous driving event occurrence (per capita) for elderly drivers and non-elderly drivers

Dangerous driving events	Non-elderly Drivers(per capita)	Elderly drivers（per capita）	Wilcoxon test (p-Value)
Red light violation	0.29	0.48	0.024
Yellow light violation	1.18	1.11	0.631
Stop sign violation	5.41	8.97	0.002
Interfering with pedestrian	0.14	0.32	0.029
Speeding	1.04	0.73	0.144
Wrong-way driving	0	0.10	-

As for red light violation, the number of occurrence (per capita) for non-elderly drivers (0.29), and elderly drivers, (0.48) implies that elderly drivers tends to ignore red light more frequently than non-elderly drivers. And also Wilcoxon test result with p-value = 0.024(<0.05) shows occurrence characteristics of red light violation between two age groups is significantly different. In other words, it can be said that elderly drivers tends to ignore red light more frequently than non-elderly drivers.

As for yellow light violation, the number of occurrence (per capita) for non-elderly drivers (1.18), and elderly drivers, (1.11) shows that non-elderly drivers tends to ignore yellow light slightly more frequently than non-elderly drivers. However, Wilcoxon test result with p-value = 0.631 shows there is no significant difference between two groups.

As for stop sign violation, the number of occurrence (per capita) for non-elderly drivers (5.41), and elderly drivers, (8.97) shows that elderly drivers tends to violate stop sign more frequently than non-elderly drivers. And also Wilcoxon test result with p-value = 0.0002(<0.01) shows occurrence characteristics of stop sign violation between two age groups is significantly different. In other words, it can be said that elderly drivers tends to ignore stop sign more frequently than non-elderly drivers.

As for interfering with pedestrian, the number of occurrence (per capita) for non-elderly drivers (0.32), and elderly drivers, (0.14) shows that elderly drivers tends to interfere with pedestrian on cross walk more frequently than non-elderly drivers while driving. And also Wilcoxon test result with p-value = 0.029(<0.05) shows occurrence characteristics between two age groups is significantly different. In other words, it can be said that elderly drivers tends to interfere with pedestrian more frequently than non-elderly drivers.

As for speeding, the number of occurrence (per capita) for non-elderly drivers (1.04), and elderly drivers, (0.73) implies that non-elderly drivers tends to conduct speed violation more frequently then elderly drivers while driving. However, Wilcoxon test result (with p-value = 0.144) shows there is no significant difference between two groups.

As for wrong-way driving, the number of occurrence (per capita) for elderly drivers is 0.10, however, there is no wrong-way driving among non-elderly drivers. Therefore, it is shown that wrong-way driving may be unique event for elderly drivers.

5.1.3. Cognitive Impairment and Dangerous driving events

Recently, relationship between dangerous driving behavior and dementia begins to recognized widely in Japan

As stated above, Japanese National Police Agency made cognitive test for the elderly aged 75 and older who seeks renewal of driver's license obligatory under the revised Road Traffic Law in 2017.

It is well-accepted fact that individual with cognitive impairment has tendency to show dangerous driving behavior. However, relation between specific cognitive impairment and specific dangerous driving behavior is not clear.

On the other hand, the Research Institute on Support and Development for Safe Driving by the Elderly created "The Cognitive Impairment Early Detection Checklist 30" (hereinafter, "checklist")under the supervision of Dr. Urakami (MD, Prof .at Tottori Univ.) for early detection of Mild Cognitive Impairment (MCI)related Driving behavior and alarming individual about his/her driving (Table.8)

In this research, using the checklist, we aims at clarifying the characteristics of dangerous driving of elderly driver who shows MCI symptoms and bring the new insight for further traffic safety measure and countermeasure on cognitive impairment.

As stated above, the checklist focuses on MCI which leads to change in driver's behavior in particular and advocates the concept of "Driver's Cognitive Impairment"

The Checklist classifies its 30 items into five groups which represent certain cognitive function, such as Forgetfulness (memory impairment) group (7 items), Impaired Orientation group (4 items) which is related to impairment on temporal or positional orientation, Impaired Judgement group (5 items) which is related to disturbance in thinking or decision making, Spatial Perception group(6 items) which related measuring distance between oneself and objects, and Decrease in Attention, Concentration or Motivation group (8 items) (Table 8)

Table8 Cognitive Impairment Early Detection Checklist (Excerpt)

Item No	Item	Related Cognitive group
1	I sometimes have to search my car keys or driving license.	Forgetfulness (Memory Impairment)
2	Car stereo and car navigation system operations that I could handle before are now impossible	Forgetfulness (Memory Impairment)
10	When I go out by car, sometimes I return by a different mode of transportation	Forgetfulness (Memory Impairment)
22	I go to destination at the wrong date and time more frequently	Forgetfulness (Memory Impairment)
6	Sometimes I forget where I parked my car in the parking lot	Impaired Orientation
16	It's become harder to perceive the speed and distance of oncoming cars and others	Impaired Judgement
18	Driving Highway has become frightening(or I have become less proficient)	Spatial Perception Impairment
19	Merging has become more frightening(or I have become less proficient)	Spatial Perception Impairment
20	I scrape my car on walls or fences when parking more often.	Spatial Perception Impairment
27	It's gotten harder for me to converse with passenger while driving	Decrease in Attention, Concentration or Motivation
23	My driving has gotten erratic, with more sudden starts, braking and steering(or people tell me this)	Decrease in Attention, Concentration or Motivation
28	The dirt on my car doesn't bother me as much, and I don't wash the car very often now	Decrease in Attention, Concentration or Motivation

Table9 below shows results from the check lists that total of 92 participants who are aged 65 or above filled in. Each checked items are counted up and aggregated by related cognitive groups

As a result, Attention, Concentration or Motivations group is most checked (47), meaning more than half of participants has checked. Spatial perception impairment group follows by 44checked items and forgetfulness by 24 checked items

Table9. Number of Checked / Unchecked by 5 Groups

Checked / Unchecked	**Forgetfulness (Memory Impairment)**	**Impaired Orientation**	**Impaired Judgement**	**Spatial Perception Impairment**	**Attention, Concentration or Motivation**
Number of unchecked	68	73	75	48	45
Number of checked	24	19	17	44	47
Average number of checked (per capita)	1.2	1.2	1.2	1.6	1.9

To understand the relationship between cognitive impairment characteristics and dangerous driving events, we conducted correlation analysis between checklist results (total number of checked items by 5groups) and the number of dangerous driving events occurrence. (Table 10)

Table10. Result of Correlation Analysis （Number of Checked by 5 Groups and Number of Dangerous Driving Events occurrence）

Test of Non-Correlation (P-Value: * P<0.05, ** P<0.01)	Forgetfulness (Memory Impairment)	Impaired Orientation	Impaired Judgement	Spaitial Perception Impairment	Decrease in Attention, Concetration or Motivation	Red Light Violation	Stop Sign Violation	Rail Road Crossing Violation	Interfering with Pedstrian	Wrong-way driving	Protruding into the opposite lane	Unsteady Steering	Sudden Braking
Forgetfulness(Memory Impairment)	-	0.3055	P < 0.001	0.0011	P < 0.001	P < 0.001	0.8008	0.1495	0.9703	P < 0.001	0.8331	0.2622	0.5287
Impaired Orientation		-	0.9267	0.2681	0.8188	0.2446	0.3821	0.4223	0.9373	0.2217	0.0517	—	0.8132
Impaired Judgement	**		-	P < 0.001	P < 0.001	0.0124	0.6794	0.4483	0.617	P < 0.001	0.9345	0.8531	0.4016
Spaitial Perception Impairment	**		**	-	P < 0.001	0.0116	0.5597	0.9809	0.7942	0.0016	0.5917	0.491	0.7722
Decrease in Attention, Concetration or Motivation	**		**	**	-	P < 0.001	0.6006	0.9129	0.7613	P < 0.001	0.2239	0.42	0.9532
Red Light Violation	**		*	*	**	-	0.26	0.0042	0.8546	0.0022	0.9656	0.1747	0.0049
Stop Sign Violation							-	P < 0.001	0.7522	0.8214	0.5649	P < 0.001	0.2101
Rail Road Crossing Violation						**	**	-	0.2522	0.3594	0.4689	P < 0.001	0.0161
Interfering with Pedstrian									-	0.704	0.3071	0.4903	0.5749
wrong-way driving	**		**	**	**	**				-	0.3968	0.7609	0.667
Protruding into the opposite lane											-	0.7323	0.6345
Unsteady Steering							**	**				-	0.0073
Sudden Braking						**		*				**	-

As for red light violation and wrong-way driving which are highly dangerous traffic violations, shows significant correlation with forgetfulness, impaired judgement, spatial perception impairment and decrease in attention, concentration or motivation. In other words, it is shown that an elderly drivers who has cognitive impairment related these three groups has high risk to ignore the red light or drive opposite direction.

On the other hand, there is no significant correlation with other dangerous driving events and cognitive impairments. However, it is notable that rail road crossing violation, unsteady steering, and sudden deceleration has significant correlation with red light violation which is correlated with several cognitive impairment groups. It can be inferred that cognitive impairment may affect these types of dangerous driving events somehow.

As shown above, we could show that cognitive impairment and dangerous driving events such as red light violation and wrong-way driving are correlated. It is obvious that these traffic violation can leads to serious traffic accident more than any other dangerous driving behavior. And also if cognitive impairment can be main factor of dangerous driving events. New and effective approach on the traffic safety policy is required (e.g. suggesting elderly driver to voluntarily return their driver's licenses strongly). In fact, survey conducted by ministry of land, infrastructure and transport of Japan also shows that elderly drivers aged 75 and above consists of largest portion of accident caused by wrong-way driving and fatality rate in these accident is 40 times higher than in accidents caused by other traffic violation.

6. Conclusion and outlook

6.1. Conclusion

The purpose of this research was to clarify the occurrence characteristics of dangerous driving, for which it was not possible to obtain sufficient research knowledge from conventional sources, from the aspects of individual characteristics of drivers, occurrence locations, time periods, etc. with the intention of reducing traffic accidents.

According to a past study [10], nationwide Aichi Prefecture has high occurrences of failure to stop for a moment and ignoring traffic lights, but for other violations the occurrences were not particularly remarkable. On the other hand, the number of fatal traffic accidents in Aichi Prefecture is the highest in the nation, and in particular the number of traffic accidents in which pedestrians are the victim is also high in comparison with the national average.

It has been pointed out that the cause of this is the occurrence of failure to stop for a moment and traffic disruptions of pedestrians [11].

Under such circumstances, through this research the following knowledge regarding dangerous driving occurrence characteristics could be obtained:

(1) For dangerous driving that has the risk of leading to traffic accidents, there were many cases of failure to stop for a moment, ignoring traffic lights, pedestrian interference, and speeding.
(2) Dangerous driving varied according to sex/age and driving history (number of years since acquiring driver's license), purpose of driving, etc. Failure to stop for a moment was high for young drivers and the elderly, and speeding was high for young drivers. In addition, for people with short driving histories, there were many cases of failure to stop for a moment and speeding. Furthermore, it was found that dangerous driving such as failure to stop temporarily, speeding, ignoring traffic lights, etc. were more likely to occur even during commuting.
(3) Failure to stop for a moment occurred frequently within 500 m of home, and it was also proven to occur frequently in the morning and evening periods. Since this is phenomena that coincides with locations and times where traffic accidents are likely to occur, as shown in existing studies, elimination of such dangerous driving can be expected to lead to reductions in traffic accidents.
(4) Ignoring of traffic lights was also frequent in the morning and evening, but it was not possible to reject this as a subordinate phenomenon caused by the high traffic volumes during those time periods.
(5) Pedestrian interference tended to occur during periods when there are many pedestrians or in back street districts or on community roads near stations, and in addition on community roads there is concern about the danger to students near schools.
(6) The occurrence of speeding was particularly remarkable during the morning commuting time period, and there

was a tendency for it to be likely to occur on roads such as expressways which are easy to drive on and have l ower traffic volume and fewer intersections.

As described above, the results of this research are consistent with reports on traffic violation occurrence characteristics and fatal accident causes in Aichi Prefecture shown in past surveys, and it is thought that the reliability is high. Also, as mentioned above, although there are reports that the occurrence of traffic accidents is frequently within 500 m of home even when viewed nationwide, the results from this research regarding the fact that there were many failures to stop momentarily were also consistent with that point, and it is believed that the results of this research were able to capture the general phenomena of dangerous driving characteristics.

(7)As for dangerous driving events of elderly drivers, Compared to non-elderly drivers, dangerous drive events such as red light violation, wrong-way driving and interfering with pedestrian prone to occur by elderly drivers. And these dangerous driving events are significantly correlated to cognitive impairment (MCI). In other word,

(8)Cognitive impairment of elderly drivers may increase number of traffic violation that can lead to serious traffic accident.

As shown above, in this research, we could show new insight for the characteristics of dangerous driving events of elderly drivers which have been ignored.

These findings are also expected to be useful basic information for dissemination and education of citizens and in future driver safety education together with plans for implementation of enforcement measures.

6.2. Future Outlook

In this research, although it was possible to grasp an overview of dangerous driving occurrence trends, it will be necessary to more specifically grasp the causes of dangerous driving occurrence in the future to develop useful awareness-raising methods for drivers in the future. For that purpose, it is thought that it will be necessary to capture and analyze in detail the driver's psychological state, driving environment, etc. at the time that dangerous driving was performed.

References

1) Nobuhiro Yano: Traffic Violation Histories of Drivers Who Caused Traffic Accidents, The Japanese Psychological Association, 73rd Conference, pp1336，2009.
2) Junichi Yada，Yuta Ozaki，Masayuki Yabu: Research on Hazardous Location Extraction Methods Utilizing Probe Data, Civil Engineering Society, 49th Civil Engineering Studies Research/Lecture Collection，Vol. 49，CD-R，2014.6
3) Toshiyuki Yamamoto，鄧磊，Takayuki Morikawa，Hirokuni Morikawa，Yoshiya Morimoto: Analysis on the Possibility of Extracting Intersections With Multiple Traffic Accident Risks Using Probe Data, Civil Engineering Society, 33rd Civil Engineering Research Presentations Conference CD-ROM 2006 6
4) Koji Miura，Yasuhiro Hirohata，Kojiro Matsuo: Study on the Extraction of Dangerous Situations And Hazardous Situations Of Traffic Accidents Using Drive Recorders, Civil Engineering Society, 38th Civil Engineering Studies Research/Lecture Collection, 2008.
5) Hisashi Imanaga，Osamu Takatori: Types of Complications Recorded by Event-Record-Type Drive Recorders And the Possibility of Automatic Extraction, Civil Engineering Society, 42nd Civil Engineering Studies Research/Lecture Collection, 2010
6) Tsuyoshi Matsunuma，Koichi Ariga，Yoshiyuki Naito，Jun Tanaka，Hidenori Goto: Traffic Safety Measures on Community Roads Using Drive Recorders, Civil Engineering Society, 51th Civil Engineering Studies Research/Lecture Collection, 2015
7) Ministry of Land, Infrastructure, Transport and Tourism: Committee for Studying Physical Devices, etc. on Community Roads, Material 1: Environment Around Community Roads, 2015，http://www.mlit.go.jp/road/ir/ir-council/life_road/doc01.html
8) Institute for Traffic Accident Research and Data Analysis: ITARDA INFORMATION Special Edition: "Traffic

Accidents that Occur in the Evening" No.62，pp3，2006
9) FY 2010 National Roads/Streets Traffic Information Survey, Traffic Survey Tables: Aichi Prefecture, pp1，2010
10) International Association of Traffic and Safety Sciences: Basic Research Report on Traffic Safety and Traffic Enforcement, pp4-pp13, March 2011
11) Aichi Prefecture: Regarding Fatal Traffic Accident Trends in FY 2014, https://www.pref.aichi.jp/uploaded/attachment/51050.pdf