RESEARCH ON RELATIONSHIP BETWEEN COGNITIVE IMPAIRMENT AND DRIVING BEHAVIOR OF STARTING/STOPPING FOR ELDERLY DRIVER

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Abstract

Recently in Japan, traffic accidents caused by elderly drivers have attracted public attention. Elderly drivers are judged whether they can continue driving based on the cognitive test results at the renewal of their driver's license. However, it has not been to lead to the reduction of accidents. Therefore, it is important to understand the relationship between cognitive impairment and driving behavior for elderly drivers. In this study, we analysis on the relationship between cognitive impairment and driving behavior for elderly drivers. The driving ability is evaluated using the data of driving behavior during starting/stopping. Regression models that explain the relations between cognitive impairment of an elderly driver and driving ability were estimated.

Keywords: elderly driver, driving ability, cognitive impairment

1 Introduction

Recently in Japan, traffic accidents caused by elderly drivers have become a serious social problem. Traffic accidents caused by elderly drivers are believed by age-related in cognitive impairment. It has a great effect on driving ability and leads to the occurrence of driving accidents. Elderly drivers are obliged to undergo a cognitive test at the time of renewal of his/her driving license. Thus, they are judged whether they can continue driving based on the results of cognitive tests.

However, even if elderly drivers pass the cognitive test, a traffic accident will occur due to cognitive impairment. This is because the relationship between the degree of cognitive impairment and the occurrence of traffic accidents for elderly drivers has not yet been clarified. Therefore, performing a cognitive test has not been obtained great effect.

There are many previous studies that focus on the relationship between driving ability and cognitive impairment for elderly drivers from an engineering point of view. For example, Myers et al [1] focused on the relationship between road driving tests and cognitive tests by elderly drivers. As a result, it was clarified that the results of the cognitive test and the driving ability are proportional. Wadley et al [2] and Griffith et al [3] conducted driving experiments by an elderly driver of MCI. They focused on the driving behavior when going straight. These previous studies have shown the possibility of discriminating MCI using lane deviance, steering stability, and vehicle speed changes. In addition, Frittelli et al [4] showed that elderly drivers of MCI have less time to follow vehicles in front. Beratis et al [5] focused on the driving behavior when changing lanes. It was shown that when the cognitive impairment of elderly drivers declines, driving operations of lane change tend to be delayed.

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We have reviewed previous studies on driving ability and cognitive impairment for elderly drivers. However, it became clear that quantitative analysis has not yet been performed. The reason is that it is necessary to set clear criteria when evaluating driving ability. Thus, in this study, we analyze the relationships between driving ability and the cognitive impairment of elderly drivers. Regression models that explain the relations between cognitive impairment of an elderly driver and driving ability were estimated.

2 Data

2.1 Outline of observation experiment

Table 1 shows the outline of the driving experiment. In this study, 56 drivers aged 65 and over living in Kanazawa City, Ishikawa Prefecture were the participants. The driving behavior of the elderly driver was observed for 2 weeks.
The flow of the driving experiments is shown. First, we obtained confirmation of consent to participate in the experiment to start it. Next, we conducted a hearing survey of the participants. In this hearing survey, the participants' age, gender, visual acuity, and the presence or absence of eye diseases were investigated. Next, a cognitive test was performed. Finally, an observation device was installed in the participant's vehicle to observe the driving behavior.
Table 2 shows the attribution of participants. There is almost no gender bias and it became clear that most of them were in their 70s. In addition, most of the subjects had visual acuity of 14/20 or higher, but it was revealed that they had eye diseases.

Table 1 Outline of experiment.

Target person	Citizens living in Kanazawa city who are aged 65 and over and who drive daily.
Number of persons tested	56 persons
Observation period	2 weeks
Procedure of the experiment	1. Obtain the consent of the participant. 2. Perform a hearing survey to the participant 3. Perform the cognitive test 4. Perform the observation survey for driving behavior.
Items of the hearing survey	Sex, Age, Eyesight, Presence or absence of eye diseases

Table 2 Attribution of participants(N=56)

Sex	Male: 41.07 %, Female: 58.92 %
Age	60s: 26.79 %, 70s: 66.07 %, 80s: 7.14 %
Eyesight	Under 6/20: 1.79 %, Between 6/20 ≈ 14/20: 12.50 %, Over 14/20: 85.71 %
Presence of eye diseases	Cataract: 50.00 %, Glaucoma: 16.07 %, Other eye diseases: 23.21 %

2.2 Outline of cognitive test

In this study, participants were tested for MMSE, Pareidolia, TMT-A, and TMT-B. MMSE is composed of 11 questions that covered orientation, registration, attention, calculation, recall, language, and visuospatial perception. scores range of MMSE from 0 to 30; scores less than 24 are indicative of cognitive impairment. It was clarified that when the MMSE score is 24 points or less, it has a great influence on driving ability.
Pareidolia is a test to find the phenomenon (hallucination) in which the shape of stains and clouds on the wall looks like a human face or an animal. From the results of this test, it is

possible to detect whether or not it is Lewy body dementias. In the case of driving, it is related to the oversight of road signs.
TMT has been widely used as a test of executive function and visual perceptual and visual–motor tracking. TMT is given in two parts. Trail Making Test Part A (TMT-A) requires participants to connect a series of consecutively numbered circles and involves visual scanning, number recognition, numeric sequencing, and motor speed. Trail Making Test Part B (TMT-B) requires participants to connect a series of numbered and lettered circles, alternating between the two sequences. The results of TMT showed the possibility of making a judgment on safe/dangerous driving.
Figure 1 shows the results of the cognitive test. Figure 1 (a) shows the results of the MMSE. If the MMSE result is 23 points or less, there is a risk of dementia. However, there was not it in the participants of this study. Figure 1 (b) shows the results of Pareidolia. This score does not have a reference value. Therefore, it can be said that the lower the number of correct answers, the more Lewy body dementias possibilities. However, it became clear that most of the participants answered all the questions correctly. Figures 1 (c)-(d) show the results of TMT-A and TMT-B. It can be said that the cognitive impairment of TMT-A and TMT-B declines when the calculation time is long.

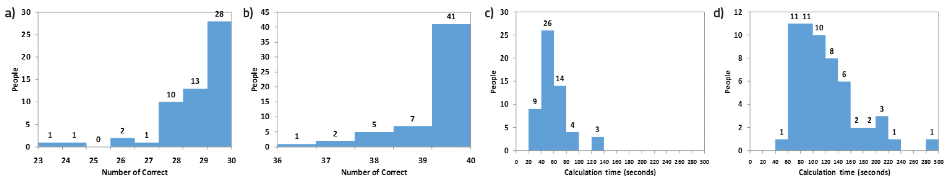

Figure 1 Result of cognitive test (N=56)

2.3 Observation device and observation method

Table 3 shows the outline of the observation device. The driving behavior was observed using the Qstarz GT BL-1000 GT. This observation device measures the vehicle speed, acceleration of the three-axis, azimuth, and location information every 0.1s. The acceleration for X-axis is the left-right acceleration of the vehicle. The right side when viewed from the driver is positive. The acceleration for Y-axis is the acceleration of the front and rear of the vehicle. The front is positive when viewed from the driver. The flow of observing the driving behavior is described. When starting operation, the driving behavior is observed by turning on the power of the observation device. When the operation is finished, the observation of the driving behavior is stopped by turning off the power of the observation device.
Figure 3 shows the driving situation of the participants during the survey period. Figure 3 (a) shows the number of driving days per week. It was revealed that all the participants were driving over three days a week. Figure 3 (b) shows the average driving minutes per day. It was found that most participants had less than an hour of driving minutes per day.

Table 3 Overview of observation device

Using device	Acceleration censor (Q-starz International Co,Ltd. (QstarzGT BL-1000GT)
Observation item	Vehicle speed/km/h/3-axis acceleration/G/Azimuth/deg/Location information /latitude/longitude
Observation interval	These data are measured at 10 Hz (0.1 seconds).
Observation procedure of driving behavior	1. Turn on the switch of the observation device before starting the driving. 2. Turn off the switch of the observation device after the driving is completed.

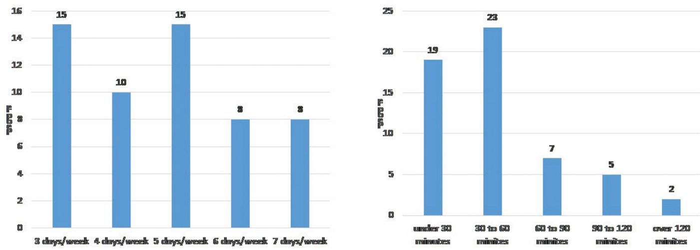

Figure 2 Driving situation of participants (N=56)

3 Production of analysis data

3.1 Extraction of driving behavior of starting/stopping for driver

In this section, the driving behavior of starting and stopping is extracted from the observation device. In this study, the driving behavior of starting and stopping is extracted from the speed of the vehicle. For the starting driving behavior, the driving behavior of the vehicle with a speed of 0 km/h to 20 km/h is extracted. On the other hand, the driving behavior of the stop extracts the driving behavior of the vehicle at a speed of 20 km/h to 0 km/h.

3.2 Index of driving ability evaluation

This section describes the evaluation of driving ability using the driving behavior of starting/stopping. In this study, we considered the driving behavior of starting and stopping due to cognitive impairment from two perspective.

One focuses on the incidence of sudden braking. A high rate of sudden braking means that a traffic accident is likely to occur. In this study, drivers with a high incidence of sudden braking were considered to correlate with cognitive impairment. Therefore, the driving behavior in which the acceleration in the Y-axis direction exceeds the absolute value of 0.25 G is counted as sudden braking. The sudden braking occurrence rate is obtained by dividing the number of starting/stopping driving behaviors in which sudden braking has occurred by the number of starting/stopping driving behaviors performed on that day.

Moreover, we focus on the value of acceleration in the Y-axis direction observed in the driving behavior of starting/stopping. A large value of acceleration in the Y-axis direction means that the effect of an accident is large. In this study, drivers with large acceleration values were considered to correlate with cognitive impairment. Thus, we focus on the maximum and minimum values for acceleration in the Y-axis direction.

Table 4 shows an example of evaluation of driving ability using the driving behavior of starting and stopping. Calculate the average value and standard deviation during the survey period from the rate of sudden braking of starting/stopping for each driving day. Furthermore, the average value and standard deviation during the survey period are calculated from the maximum and minimum values of acceleration in the Y-axis direction of starting and stopping for each operation day(See the red frame in the figure). A high average value means a large rate of sudden braking and a large value of acceleration in the Y-axis direction. Therefore, it means dangerous driving. On the other hand, if the standard deviation is high, the occurrence rate of sudden braking and the value of acceleration in the Y-axis direction fluctuate greatly from the day. Therefore, it means that daily driving is not stable.

Table 4 Calculation example of driving ability evaluation

Observation date	Ratio of sudden staring [%]	Ratio of sudden stopping [%]	Maximum acceleration for Y-axis when starting (G)	Minimum acceleration for Y-axis when starting (G)	Maximum acceleration for Y-axis when stopping (G)	Minimum acceleration for Y-axis when stopping (G)
4/6/2020	17.24	14.81	0.37	-0.39	0.22	-0.17
4/8/20220	9.09	12.50	0.35	-0.31	0.41	-0.40
4/9/2020	14.29	16.67	0.27	-0.27	0.26	-0.26
4/10/2020	15.38	6.45	0.28	-0.46	0.41	-0.30
4/11/2020	0.00	6.25	0.13	-0.23	0.23	-0.16
4/12/2020	14.29	6.67	0.13	-0.25	0.32	-0.15
Average	11.71	10.56	0.25	-0.32	0.31	-0.24
Standard deviation	6.35	4.69	0.10	0.09	0.08	0.09

4 Model estimation

4.1 Analysis method

In this study, we build a model that estimates cognitive impairment from the driving ability of elderly drivers. Therefore, we will clarify the effect of information on starting/stopping driving behavior and driver on the cognitive test. It is important to know what variables reproduce the results of the cognitive impairment test. Therefore, we use multiple regression analysis, which can grasp significant variables, as the analysis method.

The variables to be set in the model are described. The result of the cognitive test is set in the objective variable. The driving ability evaluation obtained from the starting/stopping driving behavior and the information about the driver are used as explanatory variables.

4.2 Estimation result

Table 5 shows the estimation results of multiple regression analysis. The explanatory variable was selected by the stepwise increase/decrease method with the rejection area set to 0.2. Significant explanatory variables for each cognitive impairment test are described. In the estimation result of MMSE, the parameter of the positive sign is a factor that enhances cognitive impairment. As a result, it was revealed that the driver who has many driving days per week, has a lot of driving time per day, has a high average rate of sudden braking when stopping, and has a high average maximum acceleration for Y-axis has a good. From this, it became revealed that the above variables explain the degree of impairment of intelligence function that can be measured by the MMSE.

In the estimation result of Pareidolia, the parameter of the positive sign is a factor that enhances cognitive impairment. As a result, It was revealed that the driver who has glaucoma, has a large standard deviation of the ratio of sudden braking when starting, and has a large standard deviation of minimum acceleration for Y-axis has a good. From this, it was revealed

that the degree of Lewy body dementias that can be measured by Pareidolia is explained by the above variables.
In the estimation result of TMT-A, the parameter of the negative sign is a factor that enhances cognitive impairment. As a result, It was revealed that the driver who is older, has glaucoma, has another eye disease, has a large standard deviation of minimum acceleration for Y-axis when stopping has a long calculation time for TMT-A. In the estimation result of TMT-B, the parameter of the negative sign is a factor that enhances cognitive impairment. It was revealed that the driver who is older, has a large standard deviation of minimum acceleration for Y-axis when starting has a long calculation time for TMT-B. From this, it was clarified that the possibility that an elderly driver who can measure with TMT-A and TMT-B judges safe and dangerous driving is explained by the above variables.
Moreover, focus on the adjusted coefficient of determination. In conclusion, the TMT-B model proved to be relatively good. Therefore, it was revealed that the driving ability of starting/stopping behavior can be measured by TMT-B. Moreover, the possibility that an elderly driver can judge safe/dangerous driving can be high.

Table 5 Estimation result

Object variable	MMSE		Pareidolia		TMT-A		TMT-B	
Explanatory variable	Estimate	t value	Estimate	t value	Estimate	t value	Estimate	t value
Age					8.16	3.02	23.90	4.85
Cataract			-0.49	4.04				
Glaucoma			0.23	1.93	3.60	1.35		
Other eye diseases			-0.15	1.31	5.68	2.16		
Driving day/week	0.45	2.25						
Driving time/day	0.29	1.51						
Average ratio of sudden starting			-0.58	2.45				
Standard devitation ratio of sudden starting			0.48	2.33				
Average ratio of sudden stopping	0.38	1.88	-0.23	1.71				
Standard devitation ratio of sudden stopping					-4.10	1.56	-8.27	1.65
Avarage of maximum accelation for Y-axis when starting	0.29	1.52						
Standard devitation of minimum accelation for Y-axis when starting			0.24	2.12			14.88	2.74
Avarage of maximum accelation for Y-axis when stopping							-19.59	3.54
Avarage of minimum accelation for Y-axis when stopping			-0.67	2.35				
Standard devitation of minimum accelation for Y-axis when stopping			-0.75	3.02	4.48	1.67		
Intercept	28.98	157.60	39.52	370.27	58.87	23.25	119.72	25.04
Ajusted R-squared	0.14		0.27		0.27		0.42	
Multiple correlation coefficient	0.20		0.39		0.33		0.46	
Number of samples	56		56		56		56	
AIC	201.45		144.73		496.04		566.35	

5 Conclusions

In this study, we examined the relationship between cognitive impairment and driving behavior. The cognitive impairment of elderly drivers was tested by the MMSE, Pareidolia, TMT-A, TMT-B. Driving behavior data was collected using an accelerometer through observation experiments. We focused on starting/stopping driving behavior. To evaluate the driving ability, the rate of sudden braking at the start and stop of each day was calculated. In addition, the maximum / minimum acceleration of the Y-axis of the starting/stopping behavior for each day was also calculated. The average and standard deviation within the observation period were calculated from the evaluation of these driving abilities.

In this study, we constructed a model that estimates cognitive impairment from the created evaluation of driving ability. As a result, it was confirmed that there is a weak but causal relationship between the driving behavior of elderly drivers and cognitive impairment.

In conclusion, it was clarified that the visual processing ability and attention distribution of cognitive impairment are related to the starting/stopping behavior of elderly drivers.

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