Senior Drivers' Driving Behavior and Characteristics on Expressways

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Abstract: To investigate the difference between senior drivers and younger drivers' physiological function in expressway driving, we collected the relevant data of the two groups over a 2 hours' drive spanning a 140km stretch of the Tomei Expressway. Then we interviewed those drivers and measured their physiological function before, during and after their drive. It was found that senior drivers did have more driving stress and fatigue than younger drivers during their drives on the expressway although they had less self-awareness of their driving stress and fatigue levels than younger drivers.

Keywords: Senior Driver, Physiological function, Self-recognition, Expressway Driving, Driving Fatigue, Driving Tension

1. INTRODUCTION

Although the volume of traffic fatalities and injuries has been reduced in recent years, the number of senior drivers causing accidents has increased, along with a rise in the proportion of senior drivers vs. younger drivers involved in accidents. In our review of traffic accidents, where the vehicle at fault was a passenger car, the number of senior drivers involved was shown to have skyrocketed. Specifically, the total number of accidents in 2010 dropped 55% from 2000. Furthermore the number of car accidents caused by non-senior drivers (aged 15-64 years) declined to 28% of all traffic accidents involving fatalities or injuries. In comparison, in the same 10-year period the percentage of senior driver-caused accidents grew from 15% to 22.3% (Cabinet office GOJ, 2011).

Meanwhile, it is expected that the number of accidents caused by senior drivers will jump as the Baby Boom Generation reach the senior age bracket. Currently there is scant opportunity for drivers to obtain additional safety training once they receive their license. It is therefore recommended that safety content specifically focused on expressway driving be added to the training curriculum already required for license renewal for drivers 70 years of age and above.

In approaching this issue, we found that there have been relatively few studies on the physical and mental condition of senior drivers during extended expressway driving (Kimura et al., 1991; Tanaka et al., 1994; Kawai et al., 2003). While the ability of these drivers to negotiate ordinary roads has been more fully studied, we learned that very little has been done

to understand what is happening as this increasingly large cohort of motorists utilize the nation's expressways (Matsuura et al., 1992; Akamatsu et al., 2005; Uno, 2003).

With the final objective of making a textbook for this proposed curriculum in mind, we carried out various measures and analyses to reveal the capabilities of the average senior driver. In this report, we show the results of our research on senior and younger drivers' physiological functions and whether there are measureable differences between the abilities and fatigue states of senior and younger drivers during extended expressway use.

2. EXPERIMENTAL METHOD

As part of our study, we asked senior and younger drivers to drive on the Tomei Expressway between Oi-Matsuda Interchange (IC) and Numazu IC (Figure 1). The first driving route constituted a 51.6 km round trip from Oi-Matsuda IC to Gotenba IC, and the second driving route constituted a 90.8 km round trip from Oi-Matsuda IC to Numazu IC, a total of 141.4 km of continuous driving. Both routes together took about two hours.

The items measured before driving were static and dynamic vision, visual acuity, deep vision, auditory reaction time (selective reaction), flicker value, driving awareness (questionnaire survey), and the investigation of subjective fatigue symptoms (questionnaire survey).

The items measured during and post driving were fixation and eye movement, degree of neck rotation (video image analysis), flicker value, subjective body fatigue (questionnaire survey), the investigation of subjective fatigue symptoms (questionnaire survey), mental capacity assessment (ability to identify one sound out of three sounds), reaction time (video image analysis), degree of awareness of driving characteristics, vehicle behavior (video image and GPS data analysis), and the characteristics of the exterior environment while driving (video image and GPS data analysis).

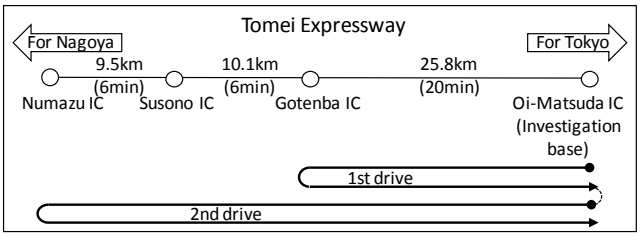

Figure 1. Routes for 1st and 2nd drives

The subjects were 21 senior drivers (over 70 years of age) and 21 younger drivers (under 39 years of age). The basic characteristics of subjects are shown in Table 1.

Before starting, we explained to the subjects the contents of the survey, the safety assurance, their right to suspend the test at any time, and the protection of their personal information. Thereafter we obtained their agreement in writing to participate in the survey.

Table 1. Basic statistics of subjects

Group	Young age group (21)		Senior age group (21)	
Average age	Male (16)	30.3	Male (19)	72.6
	Female (5)	26.5	Female (2)	71.5

3. RESULTS OF SURVEY

3.1 Feelings of Tension and Apprehension

We also provided a questionnaire to both the younger group (21 persons) and senior group (21 persons), a total of 42 people, that asked for an indication of any tension or apprehensiveness in response to changes in driving conditions, the driving environment and driving methods. The survey results are shown in Table 2.

1) Both the senior and younger group became tense when asked to accelerate up to a specific speed, and the younger group indicated that they felt it was even more dangerous than the senior group.
2) Compared to the younger group, the senior group felt more danger at a specific speed, and during uphill driving, and became tenser when overtaking another car.
3) Looking at the responses of "no feelings of tension or danger" in detail, more senior group members said they felt no tenseness or danger in the 1st and 2nd drives than the younger group members.
4) The senior group did not become tense and felt little danger as expressed by subjective symptoms.

Table 2. Stress and risk felt by drivers in different driving conditions

[1] : post 1st drive [2] : post 2nd drive			Feeling no stress and no risk				Feeling stress and risk			
			Younger drivers		Senior drivers		Younger drivers		Senior drivers	
			Number [1] / [2]	Ave. Index [1] / [2]	Number [1] / [2]	Ave. Index [1] / [2]	Number [1] / [2]	Ave. Index [1] / [2]	Number [1] / [2]	Ave. Index [1] / [2]
Feeling stress	Acc./Dec.	Accelerating	12/14	-2.25/-2.07	15/14	-2.33/-2.43	9/7	1.56/1.43	6/7	1.67/1.29
		Steady drive	13/16	-2.31/-2.06	14/17	-2.50/-2.00	8/5	1.63/1.60	7/4	1.43/1.25
		Decelerating	12/15	-2.08/-2.07	18/19	-2.50/-2.21	9/6	1.22/1.50	3/2	1.33/1.50
	Alignment	Straight	16/14	-2.19/-1.79	17/15	-2.41/-2.47	5/7	1.20/1.43	4/6	1.50/1.17
		Right curve	11/14	-2.00/-1.86	15/18	-2.53/-2.39	10/7	1.60/1.57	6/3	1.17/1.00
		Left curve	12/13	-1.83/-1.85	16/17	-2.44/-2.47	9/8	1.78/1.38	5/4	1.00/1.00
		Upslope	18/20	-2.00/-1.90	18/19	-2.67/-2.32	3/1	2.00/1.00	3/2	1.00/1.00
		Downslope	10/16	-1.75/-1.85	15/16	-2.60/-2.44	9/8	1.78/1.50	6/5	1.50/1.20
	Tunnel	Entrance	10/16	-2.20/-1.94	11/14	-2.45/-2.36	11/5	1.27/1.80	10/7	1.20/1.71
		Inside	12/15	-2.00/-1.87	11/14	-2.27/-2.43	9/6	1.44/1.67	10/7	1.50/1.71
		Exit	12/13	-2.08/-2.00	15/15	-2.47/-2.40	9/8	1.22/1.88	6/6	1.33/1.33
		Overtaking	9/7	-2.00/-1.71	11/13	-2.18/-2.46	12/14	1.58/1.57	10/8	1.80/1.88
Feeling risk	Acc./Dec.	Accelerating	17/19	-2.41/-2.05	19/16	-2.58/-2.38	4/2	1.25/2.00	2/5	1.00/1.00
		Steady drive	16/17	-2.31/-1.94	18/19	-2.67/-2.32	5/4	1.00/1.75	3/2	1.00/1.00
		Decelerating	16/17	-2.25/-1.88	19/19	-2.68/-2.32	5/4	1.60/1.50	2/2	1.00/2.00
	Alignment	Straight	17/16	-2.24/-2.13	20/16	-2.50/-2.44	4/5	1.50/1.00	1/5	1.00/1.20
		Right curve	11/14	-2.09/-1.86	17/17	-2.47/-2.35	10/7	1.60/1.29	4/4	1.00/1.25
		Left curve	15/13	-1.93/-1.92	18/19	-2.67/-2.37	6/8	1.50/1.38	3/2	1.00/1.00
		Upslope	16/18	-1.94/-2.00	19/19	-2.53/-2.37	5/3	1.40/1.33	2/2	1.00/2.00
		Downslope	13/12	-1.77/-1.83	18/19	-2.67/-2.26	8/9	2.00/1.33	3/2	1.00/1.50

Indexes : Stress and risk levels were categorized on a scale of one to three when stress and risk was experienced and minus one to minus three when stress and risk were not experienced

3.2 Self-awareness of Fatigue Before, During, and After Driving

The self-awareness of fatigue for both the younger and senior age groups before, during, and after driving was assessed. The drivers described their degree of fatigue on a scale of 6, such as +3, +2, +1 when drivers were aware of fatigue and, -1, -2, -3 when drivers were unaware of fatigue. After that, we totalized these indexes for both groups and found the following tendencies (Table 3).

1) The senior and younger drivers showed the same tendencies in stress levels when driving

on the expressway such as shown in (1), (2), (3), (4).

2) In terms of self-awareness of fatigue post driving, more senior drivers did not feel fatigue than the younger drivers.

Table 3. Fatigue felt by drivers after driving

[1] : post 1st drive [2] : post 2nd drive	Feeling no fatigue				Feeling fatigue			
	Younger drivers		Senior drivers		Younger drivers		Senior drivers	
	No. [1] / [2]	Av. Index [1] / [2]	No. [1] / [2]	Av. Index [1] / [2]	No. [1] / [2]	Av. Index [1] / [2]	No. [1] / [2]	Av. Index [1] / [2]
(1) Driving without relaxation	8/10	-1.75/-1.90	6/10	-2.17/-2.20	13/11	2.23/1.92	15/11	2.20/2.36
(2) Feeling stress	6/11	-2.00/-1.82	6/8	-2.17/-2.13	15/10	1.80/1.90	15/13	2.27/1.92
(3) Driving carefully	9/10	-2.44/-2.00	12/11	-2.33/-1.82	12/11	1.50/1.36	9/10	1.44/1.30
(4) Driving with headache	4/6	-1.50/-1.17	6/4	-2.33/-1.50	17/15	1.76/1.93	15/17	2.27/1.65
(5) Want to have a rest	10/5	-1.90/-2.20	16/16	-2.56/-2.19	11/16	1.73/1.88	5/5	1.60/1.80
(6) Feeling heavy-eyed	13/9	-2.15/-1.89	20/18	-2.75/-2.39	8/12	1.25/1.42	1/3	3.00/1.33
(7) Feeling sluggish	13/13	-2.69/-1.77	21/18	-2.81/-2.44	8/8	1.38/1.25	0/3	- /1.67
(8) Feeling disoriented	15/13	-2.40/-2.31	20/18	-2.70/-2.67	6/8	1.33/1.63	1/3	1.00/1.67

Index : Fatigue levels were categorized on a scale of one to three when fatigue was experienced and minus one to minus three when fatigue was not experienced.

3.3 Nature of Driving Fatigue and Points of Fatigue in the Body

We asked both groups of drivers whether they felt fatigue before, during, or after driving at 18 different points in their bodies. The results are as follows.

1) Senior drivers reported feeling less fatigue than younger drivers.
2) The senior drivers reported less points of fatigue than the younger drivers before, during, or after driving.

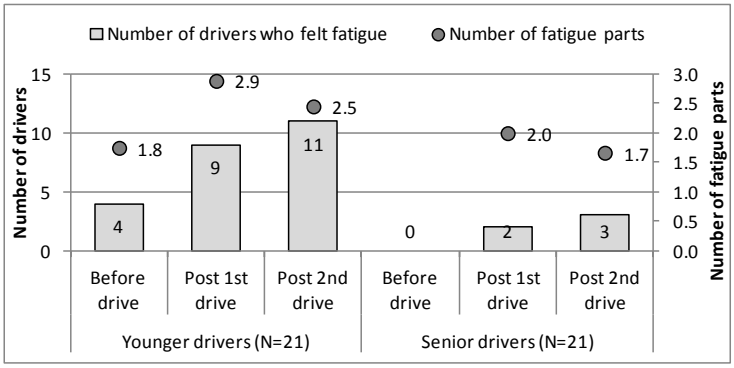

Figure 2. Number of drivers who felt fatigue and the number of fatigue points

3.4 Effects on Flicker Values during Extended Driving

The flicker values after the first drive and after the second drive were compared with the pre-drive values, and the results from calculating the increasing rates and decreasing rates for the group with increasing flicker values ("increasing group") and the group with decreasing flicker values ("decreasing group") accordingly are shown below.

1) The number of persons with decreasing flicker values was larger in the senior age group than in the younger age group. The simple averages combining both the increasing group and decreasing group for each age group show that the amount of decrease was larger for the senior age group than the younger age group.
2) In the senior age group, a more significant decrease was seen following the second drive than following the first drive. The decrease exceeded the -5% value that is considered the

maximum daily allowable decrease, and decreased to almost the overall maximum allowable limit of -10% (Hashimoto, 1973).

3) This suggests that cerebral cortex activity decreased significantly as a result of expressway driving which lasted approximately 2 hours or more. Therefore this indicates that senior drivers require a break every 1 – 2 hours.

Table 4. Progress of flicker value compared to before driving

		Younger drivers (1) / (2)	Senior drivers (1) / (2)
All drivers	Average (%)	1.41 / -0.30	-0.85 / -2.22
	Standard deviation	4.32 / 6.44	7.86 / 9.23
Increase group	Number of samples	14 / 10	8 / 8
	Average (%)	3.79 / 5.22	6.89 / 7.48
	Standard deviation	2.46 / 4.14	4.24 / 5.64
	Maximum (%)	8.87 / 15.23	14.19 / 19.12
	Minimum (%)	0.27 / 1.85	1.67 / 1.05
Decease group	Number of samples	7 / 11	13 / 13
	Average (%)	-3.35 / -5.33	-5.61 / -8.19
	Standard deviation	3.07 / 3.02	5.29 / 4.69
	Maximum	-0.48 / -1.55	-0.63 / -1.09
	Minimum	-7.92 / -11.75	-21.86 / -16.92

Note : (1) Post 1st drive, (2) Post 2nd drive

3.5 Relationship of Sympathetic Nervous System Activity and Driving Behavior

A number of existing studies have made clear that the heart rate response, affected both directly and indirectly, with various daily activities including driving, is deeply related to the autonomic nervous system activity. According to one recent study (JSNR, 2007), it is clear that the ratio of low frequency to high frequency (referred to as LF/HF ratio) reflects the activity of the sympathetic nervous system (as part of the autonomic nervous system controlling the functioning of the circulatory system and internal organs). Therefore, we calculated and analyzed the LF/HF ratio of the motorists' heart rate during expressway driving and investigated as to whether each driver's sympathetic nerve activity adjusted normally, and to what extent, to psychosomatic activity adjusted normally. Then we wanted to ascertain the conditions of the sympathetic nerve activity. (Number of examinees: younger age group 16, senior age group 17.)

During the round-trip test drives between Oi-Matsuda and Numazu, we classified and analyzed the evaluation of the LF/HF ratio of each examinee of the younger age group and senior age group. We found that they fell into three categories as associated with changes in driving conditions on the expressway: (1) under 10 LF/HF -- non-tense sympathetic nervous system type; (2) 11-29 LF/HF -- slightly tense driving type; and (3) over 30 LF/HF -- strongly tense driving type.

3.5.1 Average LF/HF Ratio (Sympathetic Nervous System Stress Level) When Driving

Figure 3 shows that many seniors generally drove under conditions that caused strong sympathetic nervous system stress. So after assessing the driving survey, we could presume that senior drivers often had higher sympathetic nervous system stress levels caused by driving conditions.

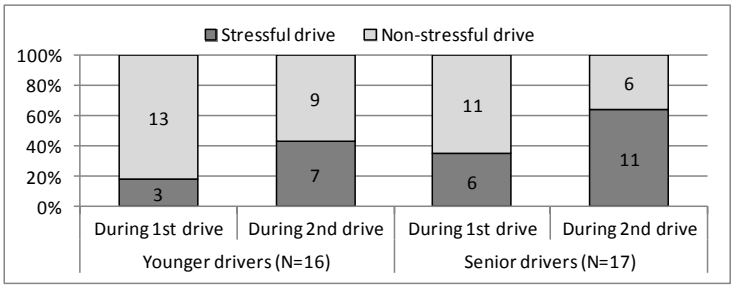

Figure 3. Driving stress population number (sympathetic nervous level)

3.5.2 Case Study of Senior Driver's Response to Extended Expressway Diving

As an example of a typical senior driver, we selected a 73-year-old male. He drives a passenger car for leisure purposes and to conduct shopping trips three or four times a week. He has been driving for 52 years, more recently averaging 7,000 km a year. He is healthy, but has bad dynamic visual acuity. For the driving test, he drove about two hours from 0:58 pm to 3:00 pm on the Tomei Expressway.

The autonomic nervous system incidents for this case are shown as a rise in the LF/HF ratio on the graph below (Figure 4). The following statements are listed in descending order of the LF/HF ratio and include driving actions not detailed in Figure 4.

1) He overtook a passenger car on a left hand curve in a high traffic flow situation. (LF/HF ratio 60)
2) He passed a big bus on a right hand curve. (LF/HF ratio 49)
3) He drove into a tunnel and on a downhill left hand curve. (LF/HF ratio 45)
4) He drove into a tunnel and after traveling for a time on a right hand curve inside the tunnel, two cars overtook his vehicle and rapidly veered back into his lane. He made a sudden braking action to avoid a rear-end collision, since there were many vehicles in the inner lane. (LF/HF ratio 42)

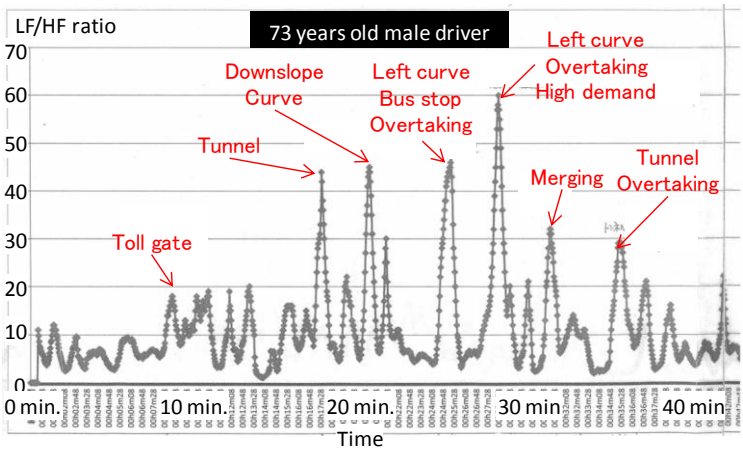

Figure 4. An example of a profile of the LF/HF ratio (73years old male driver)

Both senior and younger drivers were prone to high stress during high-speed driving in curves and tunnels, and in situations where they had to be especially careful of other cars.

4. CONCLUSIONS

In this questionnaire survey, senior drivers showed a tendency towards not recognizing stress and fatigue by themselves, compared with younger drivers. In the physiological function survey, the senior drivers' physiological functions had a greater tendency to show stress and fatigue when compared with younger drivers.

In this way, we found that senior drivers are aware of the decline of their physiological function. However without exception the senior drivers did not understand the full meaning of it. Therefore we could determine that it is very important for senior drivers to recognize their own physiological function through driving tests, driver education and additional driving instruction at training facilities.

We also determined that drivers with physical fatigue are not always aware of the extent of their driving fatigue, and that those who suffer from driving stress are not themselves aware of the stress. It is also necessary for senior drivers to recognize their self-condition not only through self-awareness but also by obtaining knowledge on physiological functions and to take actions such as taking periodic rests etc. to recover from driving fatigue.

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