



SELECTED PROCEEDINGS

SENIOR DRIVERS' SELF-RECOGNITION AND PHYSIOLOGICAL FUNCTION IN EXPRESSWAY DRIVING

HIDEKI TAKAHASHI, CENTRAL NIPPON EXPRESSWAY COMPANY LIMITED
JIAN XING, NIPPON EXPRESSWAY RESEARCH INSTITUTE COMPANY LIMITED
SHOICHI HIRAI, NIPPON EXPRESSWAY RESEARCH INSTITUTE COMPANY LIMITED
TAKAO OKUBO, NIPPON UNIVERSITY
HIROYUKI KONDA, CENTRAL NIPPON HIGHWAY ENGINEERING NAGOYA COMPANY LIMITED

This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere.
Details on the full paper can be obtained from the author.

ISBN: 978-85-285-0232-9

13th World Conference
on Transport Research

www.wctr2013rio.com

15-18
JULY
2013
Rio de Janeiro, Brazil

unicast

SENIOR DRIVERS' SELF-RECOGNITION AND PHYSIOLOGICAL FUNCTION IN EXPRESSWAY DRIVING

Hideki Takahashi¹, Jian Xing², Shoichi Hirai², Takao Okubo³, Hiroyuki Konda⁵

¹*Central Nippon Expressway Company Limited*

²*Nippon Expressway Research Institute Company Limited*

³*Nippon University*

⁵*Central Nippon Highway Engineering Nagoya Company Limited*

Email for correspondence: h.takahashi.al@c-nexco.co.jp

ABSTRACT

Although year-by-year the number of traffic fatalities and injuries in Japan has recently been decreasing, the proportion of road accidents caused by senior drivers has risen over time, now accounting for 22.3% of all accidents. Since the number of older drivers is forecast to increase rapidly as part of an accelerating demographic trend, it is important and necessary to improve the motoring skills of these drivers through a new focus on their education and training.

In this study we surveyed and analyzed the self-recognition and physiological function of senior drivers in respect to expressway driving and we want to make clear how to improve the training courses provided to drivers as they reach an older age.

As the study proceeded we found that not all senior drivers are aware of the decline of their reaction time, stamina, awareness, and other physiological functions; that some senior drivers with physical infirmities do not realize their fatigue state; and that some with driving tension are not adequately aware of the increased stress. Therefore we came to understand that it is very important for senior drivers to recognize their own physiological function through physical driving tests and driving education at driver training facilities. It is also necessary for senior drivers to recognize their personal condition not only through self-recognition but also by understanding physiological function to help them recover from driving fatigue by taking periodic rests and other measures.

Keywords: senior driver, self-recognition, physiological function, expressway driving, driver training, driving fatigue, driving stress, subjective symptoms.

INTRODUCTION

Even as 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 older drivers vs. younger drivers involved in accidents. In our review of traffic accidents in which the vehicle of the driver responsible was a passenger car, the number of senior drivers involved was shown to have skyrocketed. Specifically, the number of accidents in total dropped to 55% in 2010 compared to 2000, and the number of car accidents caused by non-senior drivers (aged 15-64 years) declined to 28% of all traffic accidents involving deaths 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 Government of Japan, 2011).

Meanwhile, while 15.7% of the 81 million automobile license holders in Japan were over 65 years of age in 2010, by 2020 it is expected that the proportion of senior drivers will have doubled to 33% of all license holders as members of the Baby Boom Generation reach senior age (National Police Agency, 2011).

Currently there is scant opportunity for drivers to obtain additional safety training once they receive their license. It is therefore recommended that as part of the special training course for license renewal already required for drivers 70 years old or above, safety content specifically focused on expressway driving in respect to older drivers' abilities be added to the training curriculum.

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. 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.

With the end objective of making a textbook for this proposed curriculum, 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 in these ways:

- 1) Characteristics of older drivers as they use the expressways and their attitudes toward expressway driving, based on group interviews and questionnaire-type surveys.
- 2) 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.

LITERATURE REVIEW

It is well known that aging results in a range of changes in sensory, cognitive and motor skills that may affect driving skill and susceptibility to injury (Oxley et al., 2003). Even in healthy older adults, aging brings about eventual deteriorations in the ability to gather appropriate and

accurate information through sight, hearing and balance; to move correctly or effectively; and to make successful, timely decisions (Lang et al. 2013). These reductions vary markedly between individuals, and the rate of decline of a particular ability is not necessarily accompanied by similar declines in others. These three classes of ability can be labeled sensory, motor and cognitive, and decline in them affects the ability to drive safely. Several traffic related studies have given an overview of the specific sensory, cognitive, and motor skills that deteriorate with age. The most important functional changes that accompany normal aging relate to visual and perceptual abilities, cognitive abilities and physical abilities (SafetyNet, 2009).

The road safety of senior drivers is to a large extent determined by two factors: functional limitations and physical vulnerability. Both factors contribute to the relatively high fatality rate as a result of crashes among older road users. Functional limitations can increase crash risk, whereas a higher physical vulnerability increases injury severity. Functional limitations and age related disorders do not automatically lead to unsafe traffic behavior. Other characteristics of senior road users can prevent safety problems. Among these are the insight into one's own physical status and functional limitations, awareness of the impact of aging on driving performance, self-awareness of the impact of declining functional performance and health issues on driving skill, driving experience, and compensation behavior such as driving when the roads are less busy or when it is daytime and dry (SafetyNet, 2009; Oxley et al., 2003, Lang et al. 2013).

Relating to the driving behavior of Japanese senior drivers, limited studies have been conducted on ordinary roads (Matsumura et al., 1992; Akamatsu et al., 2005; Uno, 2003) and on expressways (Kimura et al., 1991; Tanaka et al., 1994; Kawai et al., 2003). Nagahama (1998) conducted an experimental study on senior drivers' dynamic visual acuity. Hashimoto (1973) described the relationship between fatigue and monotony of driving. Nishiyama (1985) conducted a study on senior driver's driving behavior. Nevertheless, there are still many points relating to senior drivers' status and their driving behavior to be made clear. In order to reduce senior driver related traffic crashes on Japanese expressways, it is considered important to make clear their self-recognition and self-assessment of driving skill and physical status and functional limitations, and physiological function while driving on expressways. This is what the study intends to reply.

GROUP INTERVIEW SURVEY

Outline of survey

We conducted group interviews aimed at ascertaining driving and physiological characteristics of senior motorists and used what we learned to develop a questionnaire for later individual surveys. We carried out 10 group interviews in total on 61 drivers 65 years of age and older. An outline of the group interviews is shown in Table 1 and the age structure of the participants is shown in Fig. 1.

Senior drivers' self-recognition and physiological function in expressway driving
(Takahashi, Xing, Okubo, Hirai, Konda)

Table 1 Outline of group interview survey

Item	Content
Subject of investigation	Persons over 65 years old (mainly 70 or above) who drive on expressways
Region of investigation	Kanagawa Prefecture
Period	October – November, 2010
Sample size	61 persons (54 males, 7 females)
Method of investigation	Group interview survey (2 hours); each group comprising 6 or 7 participants
Items of investigation	<ul style="list-style-type: none"> • Reasons expressways are used • Nature of driving on expressway • Self-recognition of physiological function • Awareness during expressway driving • Awareness of driving rules • Frightening incidents experienced • Need for driving training

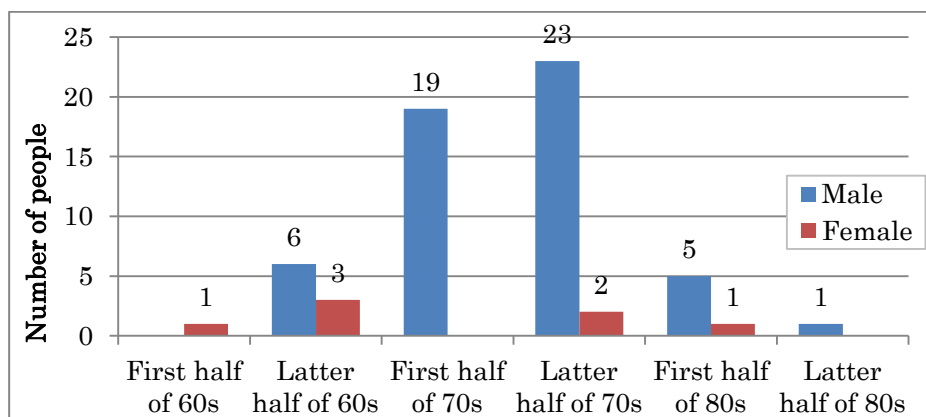


Fig.1 Age breakdown of interview subjects

Results of survey

Driving frequency

Of the survey participants, 80% indicated they drove their cars 2-3 times a week. Over all, 85% reported that they drive on expressways, but said the frequency of their expressway use had been decreasing over time.

Driving purpose

The purposes given for driving were many and varied, but the daily main purpose was to carry out largely local-area activities such as shopping, going to appointments, circle activities with friends, dining out, farm work, etc., and to pick up and drop off family members at clinics, hospitals, and train stations. They tended to have limited driving routes and purposes, such as using the same route both going and returning, typically keeping within an

Senior drivers' self-recognition and physiological function in expressway driving

(Takahashi, Xing, Okubo, Hirai, Konda)

approximately 20-km radius. Reasons given for expressway use included travel (sight-seeing, holiday trips, vacations, etc.), and visits to their hometowns, homes of adult children, and graves of deceased relatives. Except for travel, their driving tended to be on limited expressway routes.

A quarter of the survey participants reported driving over 100 km once a month or more. Some said they drove over 1,000 km for travel purposes. All together, there was a wide variation in senior drivers' uses of expressways. A number indicated that they had to drive their cars because there were no other transport means such as bus or train service or other public transportation.

Reasons for decreased expressway driving

The reasons survey participants commonly gave for decreased use of expressways were as follows.

- 1) They self-recognized their reduced driving ability and physiological function, so they avoided expressway driving, driving at night, and driving in rainy weather.
- 2) They felt anxious about driving an unknown expressway route because they generally drove the same routes to the same close destinations.
- 3) They could no longer easily see and read traffic signs, so they realized there had been a decline in their dynamic vision and physical abilities.
- 4) They didn't understand how to reach their destination using expressways because of the opening of new routes and new interchanges.
- 5) They felt anxiety in their reaction to sudden events, such as when being overtaken by large trucks on both sides of their car.
- 6) Drivers of other vehicles fail to use their indicators when changing lanes, bunch up too closely, or ride their bumper when trying to pass.

Physiological changes in respect to expressway driving

Within the survey groups, 62% of the senior drivers were aware there were changes in their driving behavior compared to when they were younger. Examples included not speeding, avoiding driving at night or in rain, and maintaining greater following distance due to reduced physical ability, especially vision. From this background, we interpreted that senior drivers tend to have more anxiety over their ability to cope with unforeseen events, so tried to drive more carefully in order to reduce the possibility of an accident.

Experience with frightening incidents on expressways

When asked to relate frightening experiences encountered on expressways, two types in particular stood out:

- 1) The actions of other drivers such as sudden lane changes, aggressive overtaking, and aggressive queue jumping.

- 2) Their own carelessness and delays in their own judgment and reaction.

Coping behavior when driving on expressways

The survey participants answered that they tried to cope with extended expressway driving by keeping left (i.e., out of the passing lane), taking frequent rests, reducing speed, maintaining adequate vehicle separation, and avoiding driving at night or in rain.

Desire for senior driver training

The drivers in the group survey indicated a strong desire for driving diagnosis using driving simulators and driving course training for senior drivers at the time of driving license renewal, because they felt this was the best way to objectively understand their own driving ability. Of the survey takers, 52% expressed interest in being given senior drivers training at any time depending on its contents. The participants said they especially wanted to learn practical and useful information such as expressway driving techniques, road signs and markings, new traffic rules, new expressway routes, etc.

QUESTIONNAIRE SURVEY

Outline of survey

The questionnaire was developed based on the group interview survey results and mainly asked the reasons they avoid expressway driving, the experience of physiological function during expressway driving, and whether they had experienced any frightening incidents while using expressways. Table 2 shows the outline of the survey and Fig. 2 gives the age breakdown of the respondents. (Note: The percentages in the age breakdown are calculated after removing the number of “no” responses for each question.)

Results of questionnaire survey

Driving frequency

Of the respondents to the questionnaire-based survey as shown in Figs. 3-5, 81.3% said they drove 3-4 times a week including on expressways. Driving times of less than 1 hour constituted 73.5% of all trips, with most drivers tending to take road trips with shorter times and distances. The frequencies given for expressway driving were “over once a month” 16.7%, “once or more in 3 months” 38.1%, and “no expressway driving” 34.6%. Men drove more often than women, and the frequency of drivers over age 80 fell sharply compared to other age categories.

Senior drivers' self-recognition and physiological function in expressway driving
(Takahashi, Xing, Okubo, Hirai, Konda)

Table 2 Outline of questionnaire survey

Item	Content
Subject of investigation	Senior driver trainees at license renewal (over 69 years old)
Region of investigation	Kanagawa, Shizuoka, Aichi, Yamanashi, and Nagano prefectures
Period	May – July, 2011
Sample size	932 persons (75% male, 25% female)
Method of investigation	Questionnaire survey on senior driver training for license renewal (10 - 20 minutes)
Items of investigation	<ul style="list-style-type: none"> • Experience of expressway driving • Awareness of driving rules • Frightening incidents experienced • Need for driving training • Family wishes for them to continue driving • Individual attributes

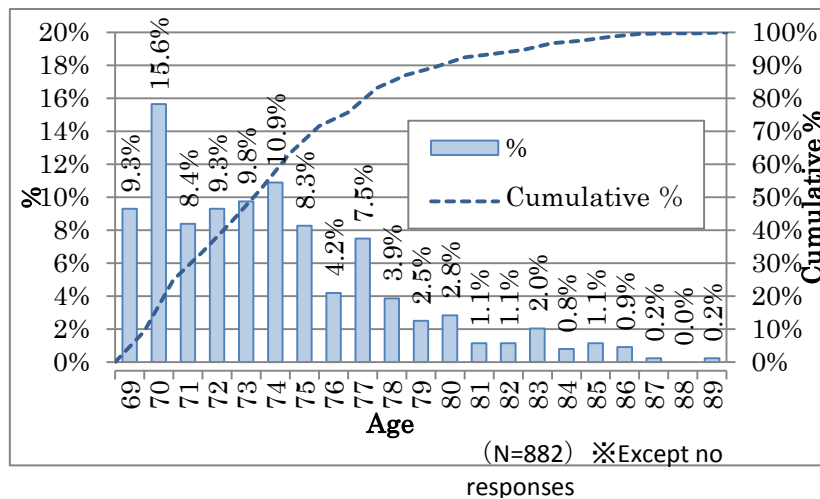


Fig. 2 Age breakdown of questionnaire respondents

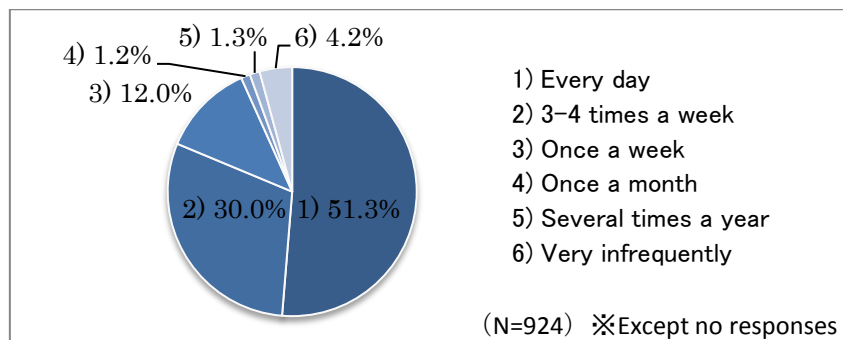


Fig. 3 Driving frequency

Senior drivers' self-recognition and physiological function in expressway driving
(Takahashi, Xing, Okubo, Hirai, Konda)

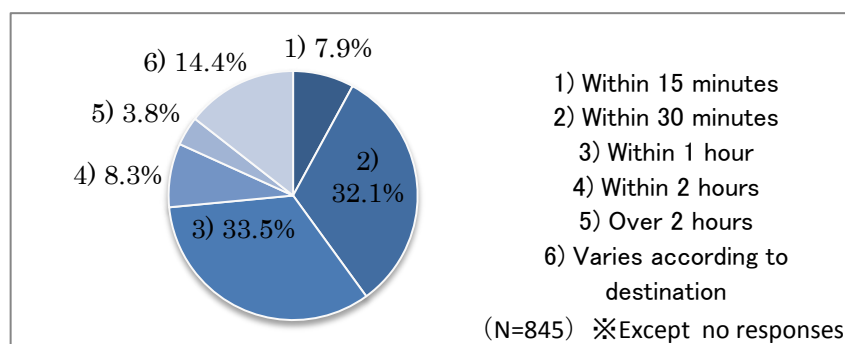


Fig. 4 Driving duration

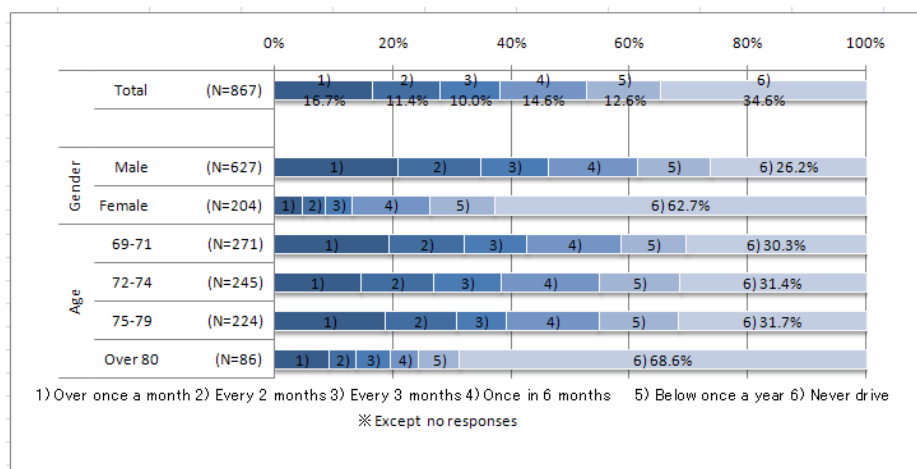


Fig. 5 Driving frequency on expressway

Driving purpose

The result of driving purpose is shown in Table 3. The survey respondents listed many same destinations and routes such as shopping (92.8%), going to the hospital (72.0%), engaging in hobby and circle activities (50.5%), and welcoming and dropping off relatives or friends at train stations, etc. (48.4%). On the other hand, the purpose of travel and sightseeing involving unlimited routes was 49.9%, while business use was about 30%. (Multiple responses were possible.)

Table 3 Driving purpose

Question items	Response %
Shopping (832)	92.8%
To go to hospital (678)	72.0%
Hobby or circle activity (643)	50.5%
Travel or sightseeing etc. (665)	49.9%
Welcome and send (651)	48.4%
Business with transports (613)	28.2%
Business without transports (583)	24.4%
Commuting (614)	22.8%

※1 Except no response ※2 () Number of response ※3 Multiple responses

Reasons for never driving on expressways

Table 4 describes the reasons for no driving on expressway. Of those who said they never drive on expressways, 63.6% gave the reason that they preferred not to drive by themselves on the expressway. Another 24.1% indicated they avoided expressway driving due to general anxiety while 21.9% felt it was simply too dangerous.

Table 4 Reasons for no driving on expressway

Question items	Response %
No confidence to drive on expressway	24.1%
Not to understand the rule and how to drive on expressway	1.6%
To think it danger to drive on expressway	21.9%
No need to drive by oneself on expressway	63.6%
Others	15.0%

※1 Except no answers ※2 N=187 ※3 Multiple responses

Physiological experience in expressway driving

Table 5 shows the physiological experience during expressway driving obtained from questionnaire survey. The general trend of expressway driving from a physiological standpoint is as follows.

- 1st -- "To refrain from speeding" (76.2%, always + sometimes)
- 2nd -- "It is hard to do extended driving and I become tired easily" (58.5%)
- 3rd -- "It is difficult to watch forward in rain" (55.2%)
- 4th -- "My attention is becoming less" (54.1%)

So we found that senior drivers do realize their lower abilities of physiological function and motility, and that they behave in accordance with their abilities.

Next we show the main trend of each age and driving frequency as follows.

- 1) Feeling fatigue during long-distance driving (Table 6)
The response of "often" increased with age (69-71 years old 6.8%, over 80 years old 14.3%). The response of "often" did not increase with greater expressway driving frequency (under once a year 13.9%, once a month 5.0%).
- 2) Careful driving (i.e., refraining from speeding)
The response of "often" increased with age (from 24.0% to 35.9%), but there were many responses of "seldom" in over-80s drivers (30.8%). The response of "often" decreased with frequency of expressway driving (from 28.8% to 40.2%).
- 3) Not being able to remember the meaning of traffic signs
The response of "always" and "sometimes" increased with age (from 24.0% to 35.9%). The response of "always" and "sometimes" decreased with driving frequency (several times a year 33.3%, every day 24.1%).
- 4) Self-recognition of poorer vision in rainy conditions

Senior drivers' self-recognition and physiological function in expressway driving

(Takahashi, Xing, Okubo, Hirai, Konda)

Until the 70s there was not much difference, but in the over-80s group the response of “often” and “sometimes” increased steeply (from 54.3% to 61.9%).

5) Maintaining a greater following distance

The responses of “often” and “sometimes” were about 20% and many senior drivers felt that it was very difficult to maintain adequate following distances.

Table 5 Physiological experience during expressway driving

Question items	Always	Sometimes	Seldom
1, To get tired and feel painful than before (633)	9.8%	48.7%	41.5%
2, To drive lower speed than before (635)	32.6%	43.6%	23.8%
3, To want to drive a rest frequently (620)	2.7%	25.6%	71.6%
4, Hard to recognize road and destination signs (633)	3.9%	34.6%	61.5%
5, Easy to forget road and destination signs (628)	2.5%	24.0%	73.4%
6, To overlook road and destination signs (633)	2.5%	40.0%	57.5%
7, Hard to watch cars and scenery ahead in daytime (631)	0.5%	9.4%	90.2%
8, Not to watch cars and scenery ahead in the evening and night (637)	3.1%	41.1%	55.7%
9, To be invisible difficulties in rain (631)	4.6%	50.6%	44.8%
10, To feel become a narrow vision field (624)	3.4%	30.0%	66.7%
11, To feel slowly put on the brakes when one feel danger (633)	1.4%	30.2%	68.4%
12, To become slowly in all driving behavior (643)	4.8%	36.9%	58.3%
13, To take much time to recognize (643)	3.9%	40.1%	56.0%
14, To feel lower attentiveness (643)	5.4%	48.7%	45.9%
15, Hard to control the following distance such as longer and shorter (647)	1.4%	18.7%	79.9%

※1 Except no answers ※2 () Number of response

Table 6 Becoming tired and feeling more pain

1, To get tired and feel painful than before

		Always	sometime	seldom
Total(633)		9.8%	48.7%	41.5%
Gender	Male(506)	9.3%	49.2%	41.5%
	Female(99)	11.1%	49.5%	39.4%
Age	69-71(206)	6.8%	49.5%	43.7%
	72-74(189)	8.5%	52.4%	39.2%
	75-79(166)	13.3%	48.8%	38.0%
	Over 80(42)	14.3%	38.1%	47.6%
Frequency of driving (include expressway)	Everyday(331)	10.6%	45.9%	43.5%
	3-4times a week(198)	6.1%	51.5%	42.4%
	Once a week(76)	15.8%	55.3%	28.9%
	Once a month(6)	0.0%	33.3%	66.7%
	Several times a year(6)	16.7%	33.3%	50.0%
Frequency of driving on expressway	Seldom(10)	20.0%	50.0%	30.0%
	Over once a month(140)	5.0%	43.6%	51.4%
	Every 2 months(97)	2.1%	51.5%	46.4%
	Every 3 months(81)	7.4%	44.4%	48.1%
	Every half year(113)	13.3%	55.8%	31.0%
	Below once a year(101)	13.9%	51.5%	34.7%
	Not to use(75)	20.0%	44.0%	36.0%

※1 Except no answer ※2 () Number of responder

Experience with frightening incidents on expressways

Table 7 shows the experience of frightening incidents answered by respondents. The frightening incidents while driving on expressways were reported as “when being overtaken or passed by other vehicles” (41.6%) and “when overtaking or passing other vehicles” (27.0%). Most respondents thought that these frightening experiences were caused by other drivers, while the next leading cause of a frightening experience was their own carelessness and delays in judgment or reaction. As well, 3.3% of the respondents said they thought they had the potential to go the wrong way on a one-way road and cause a serious traffic accident as shown in Table 8. This response increased with age (from 2.9% to 4.9%), and decreased with frequency of expressway driving (from 6.1% to 2.2%).

Table 7 Experience of frightening incidents

Question items	Always	Sometimes	Seldom
1, To feel danger to pass or overtake another cars (644)	0.9%	26.1%	73.0%
2, To feel danger to be passed or overtaken by another cars (637)	1.4%	40.2%	58.4%
3, to feel danger with driving blankly and looking aside (631)	0.5%	15.1%	84.5%
4, To feel danger with getting sleepy (633)	0.6%	16.6%	82.8%
To feel danger be apt to make a wrong divergence (632)	0.9%	21.2%	77.8%
6, To feel danger not to recognize another cars on merging main flow (634)	0.3%	8.8%	90.9%
7, to feel danger be going a wrong way from SA (634)	0.3%	3.0%	96.7%

※1 Except no answers ※2 () Number of response

Table 8 Apprehension about going wrong way on one-way road

7, To feel danger to be going a wrong way from SA

		always	sometime	seldom
Total体(634)		0.3%	3.0%	96.7%
Gender	Male(515)	0.4%	2.9%	96.7%
	Female(93)	0.0%	4.3%	95.7%
Age	69-71(204)	0.0%	2.9%	97.1%
	72-74(192)	0.0%	3.1%	96.9%
	75-79(168)	1.2%	3.0%	95.8%
	Over 80(41)	0.0%	4.9%	95.1%
Frequency of driving	Everyday(336)	0.3%	2.7%	97.0%
	3-4 times a week(196)	0.5%	3.1%	96.4%
	Once a week(75)	0.0%	4.0%	96.0%
Include (expressway)	Once a month(7)	0.0%	14.3%	85.7%
	several times a year(5)	0.0%	0.0%	100.0%
	Seldom to drive(9)	0.0%	0.0%	100.0%
Frequency of driving expressway	Over once a month(139)	0.0%	2.2%	97.8%
	Every 2 months(98)	1.0%	2.0%	96.9%
	Every 3 months(82)	0.0%	2.4%	97.6%
	Every half year(117)	0.0%	1.7%	98.3%
	Below once a year(98)	0.0%	6.1%	93.9%
	Not to drive(65)	1.5%	4.6%	93.8%

※1 Except no answer ※2 () Number of responders

Senior drivers' self-recognition and physiological function in expressway driving

(Takahashi, Xing, Okubo, Hirai, Konda)

Table 9 Awareness of traffic rules for expressway driving

	Total	Age				Driving frequency(Include expressway)						Driving frequency on expressway					
		69-71	72-74	75-79	Over 80s	Everyday	3-4 times a week	once a week	once a month	Several times a year	No use	Over once a month	Every 2 month	Every 3 month	Once a half year	Below once a year	No use
To drive on vacant lane of multi lanes expresswy	32.7% (686)	25.7% (226)	34.2% (202)	33.9% (183)	40.4% (47)	34.6% (355)	27.9% (204)	31.7% (82)	25.0% (8)	50.0% (8)	40.9% (22)	32.1% (134)	28.3% (92)	35.8% (81)	31.0% (113)	26.5% (102)	39.4% (137)
To get off next IC, if pass the distinate IC.	2.1% (705)	1.3% (231)	1.4% (209)	2.2% (186)	6.3% (48)	1.4% (364)	3.3% (209)	1.2% (85)	0.0% (9)	0.0% (8)	8.7% (23)	0.0% (135)	1.1% (95)	1.2% (83)	4.2% (119)	1.0% (103)	4.2% (142)
To decelerate under 20km/h at ETC gate	5.1% (691)	5.3% (228)	3.9% (205)	5.5% (182)	4.3% (46)	3.1% (360)	6.9% (202)	8.3% (84)	0.0% (8)	0.0% (8)	9.1% (22)	3.6% (137)	2.1% (95)	4.9% (82)	5.1% (118)	6.9% (102)	7.0% (129)
To drive on road shoulder in hurry	3.0% (702)	2.2% (230)	1.9% (209)	3.8% (186)	4.2% (48)	3.0% (364)	3.4% (208)	1.2% (84)	0.0% (8)	0.0% (8)	8.7% (23)	2.9% (137)	2.1% (94)	0.0% (82)	2.5% (118)	1.0% (103)	6.4% (140)
No parking and stopping on main lane (Except breakdown and accident)	9.1% (701)	4.8% (230)	11.5% (208)	10.3% (184)	12.5% (48)	9.6% (364)	10.1% (208)	4.7% (85)	42.9% (7)	0.0% (8)	0.0% (22)	10.9% (137)	6.3% (95)	6.0% (84)	10.9% (119)	7.8% (103)	10.4% (135)
To stop road shoulder on breakdown and accident	2.0% (707)	2.2% (232)	2.4% (210)	1.1% (186)	2.1% (48)	2.5% (367)	1.9% (209)	1.2% (84)	0.0% (9)	0.0% (8)	0.0% (23)	3.6% (138)	0.0% (95)	0.0% (83)	1.7% (119)	1.9% (103)	2.8% (141)

※1 Except np response ※2 () Number

Awareness of traffic rules on expressways

Table 9 shows awareness of traffic rules for expressway driving. Of the survey respondents, 32.7% gave the wrong answer for the question of which lane the driver should use on a multi-lane road. This wrong answer increased with age (from 25.7% to 40.4%) Also the wrong answer was given by about 30% of drivers with decreased driving frequency on expressways (26.5% to 35.8%). Of those who never drive on expressways, 39.8% answered wrongly.

Of other questions answered incorrectly, 9.1% were wrong that it is OK to sometimes stop or park on expressways, 3.0% were wrong that driving was permitted on road shoulders, and 2.0% were wrong that stopping on the road shoulder after an accident or breakdown was allowed – in each case being driver errors that can directly lead to traffic accidents. Of respondents over 80 years of age, 12.5% answered wrongly on no stopping or parking on expressways, and people who never drove on expressways were 6.4% wrong for no driving on the road shoulder. Of over-80 respondents, 6.3% were wrong on whether it is OK to pass another car when going through an interchange. These responses indicated that there are some senior drivers who don't fully know the traffic rules for expressway driving.

Expressed need for senior drivers training

The survey respondents were asked several questions related to senior driver training. These mainly concerned the subjects of evaluation of current abilities, such as “evaluation for physiological function and driving abilities using senior driver aptitude test” (77.4%), and “driving training” (74.2%). Many also expressed concern over not being able to easily recall the points of everyday driving such as “lecture on basic rules” (70.9%), “new traffic rules and routes of expressways” (66.9), and “explanation of traffic signs” (61.7%).

SENIOR DRIVERS DRIVING BEHAVIOR

Based on the results of the group interview survey and the questionnaire survey, we found that the driving behavior of senior drivers can be summarized as follows.

- 1) Most senior drivers drove every day, but their driving frequency on expressways is not high. There was a wide range of driving behavior of senior drivers including some who reported driving as much as 1,000 km a day.
- 2) The driving frequency of senior drivers on expressways decreased with age. However, since those of the Baby Boom generation holding a driver's licence are now entering their 60s and 70s, their driving frequency on expressways will greatly increase.
- 3) Senior drivers tended not to alter their usual destinations and routes, because they felt anxiety over driving new routes.
- 4) In the above case, they wanted better route guidance and suitable signs.
- 5) Most senior drivers realized their own reduction in physiological function such as declines in visual acuity, memory, concentration, reaction, and judgment, but we couldn't find that all persons were the same. To cope with these declines they kept their distance, took many rests, tried to be aware of other cars, avoided driving at night or in rain, and avoided driving on expressways.
- 6) Senior drivers realized their decline of physiological function with age, but those in their 80s were different from other ages in respect to driving behavior or self-recognition.
- 7) Most senior drivers think that the frightening experiences they had on expressways were caused by other drivers such as "tailgating," "sudden lane changes," "aggressive overtaking," and "aggressive queue jumping." But we could identify as well that these experiences were also self-caused by inattention to other vehicles and misunderstanding certain traffic rules.
- 8) Many senior drivers didn't understand the rule on passing lanes very well, and some drivers answered incorrectly on rules that, if broken, can lead directly to traffic accidents.
- 9) Senior drivers thought that driving simulators and driving skill training were effective for senior driver training. They also expressed a desire for evaluations conducted on driver training courses that can demonstrate their current driving ability.

PHYSIOLOGICAL FUNCTION SURVEY

Outline of survey

As part of our study, 21 senior drivers (over 70 years of age) and 21 younger drivers (under 39 years of age) were asked to drive on the Tomei Expressway between Ooi-matsuda and Numazu (Fig. 6). The first driving route constituted a 51.6 km round trip from Ooi-Matsuda IC to Gotenba IC, and the second driving route constituted a 90.8 km round trip from Ooi-Matsuda IC to Numazu IC, for a total of 141.4 km continuously. Both routes together took about two hours. Basic statistics of the subjects surveyed are shown in Table 10. Before, during, and after driving, we measured physiological functions.

Senior drivers' self-recognition and physiological function in expressway driving
(Takahashi, Xing, Okubo, Hirai, Konda)

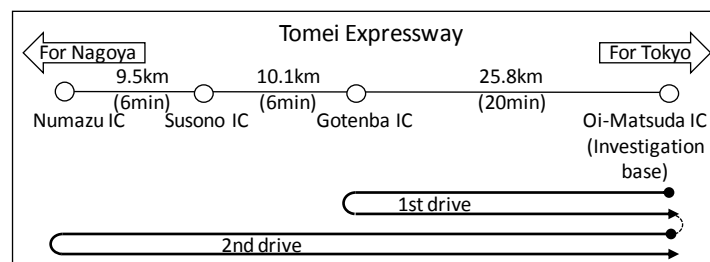


Fig. 6 Routes for 1st and 2nd drives

Before starting, we explained to the subjects the contents of the survey, the guarantee of security, their right to suspend the test at any time, and the protection of private data. Thereafter we obtained their agreement in writing to participate in the survey.

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

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

Table 10 Basic statistics of subjects

Group	Younger age group (21)		Senior age group (21)	
Average age	Male	30.3 (16)	Male	72.6 (19)
	Female	26.5 (5)	Female	71.5 (2)
Age category	20-25	4	70-75	18
	26-30	12	76-80	3
	31-35	4		
	36-40	1		
Occupation	Company employee	8	Company employee	0
	Self-employment	8	Self-employment	3
	Part-time worker	0	Part-time worker	2
	Student	2	Student	0
	Others (unemployed)	1	Others (unemployed)	16
	Housewife	2		
Daily driving car type	Passenger vehicle	20	Passenger vehicle	19
	Light vehicle	1	Light vehicle	2
	Motorcycle	1		

Table 11 Survey results on vision and hearing

Evaluation items		Young age group (best, worst)	Senior age group (best, worst)
Static vision	Right	0.4 (1.3-0.4)	0.6 (1.3-0.1)
	Left	0.9 (1.2-0.6)	0.6 (1.0-0.1)
	Both	1.0 (1.5-0.7)	0.8 (1.5-0.4)
Dynamic vision	Right	0.4 (0.8-0.1)	0.3 (1.1-0.0)
	Left	0.5 (1.2-0.1)	0.3 (1.1-0.0)
	Both	0.6 (1.1-0.2)	0.4 (1.2-0.1)
Evaluation of total vision	A	3	1
	B	4	1
	C	5	3
	D	8	10
	E	1	6
Deep vision	normal	21	18
	abnormal	0	3
Auditory selection reaction	Shortest (s)	0.3	0.4
	Longest (s)	1.3	2.3
	Average (s)	0.7	1.0
	Abnormal reaction	non	non

Results of survey

Static vision

Table 11 shows the results of the vision survey. On average and on an individual basis, the left eye and right eye static vision of the senior group was found to be inferior to that of the

younger group. As well, the binocular vision of the younger group was superior to that of the senior group, in both average and individual binocular vision assessment. The dynamic vision needed while driving was, for both groups, much lower than their static vision, while there was not much difference between binocular and singular dynamic vision. In the senior group, there were many people who had especially lower total vision which defines static and dynamic visions (levels [C] and [D]) (Tanaka et al., 1994). But in the younger group, it was quite noticeable that there was one young person who had especially lower total vision. We considered that the lower total vision individuals had a high risk when driving at night and in a fatigued state especially for the senior group (level [E]). As found by the survey, 40% of senior people were at level [E]. So we expect that there are many level [E] people driving cars on the nation's roads.

Hearing

Table 11 also shows the results of the auditory survey. In the auditory reaction test that asked the subjects to identify a 1000Hz tone from among 800Hz, 1000Hz, and 1200Hz tones, the senior age group naturally had an extended reaction time, with the longest time of the senior group double the reaction time of the younger group. Differences among individuals of the senior group were greater than that of the younger group, which demonstrated one of the characteristics of aging overall.

Feelings of stress and risk

We also provided a questionnaire that asked for indication of any stress or risk in response to changes in driving condition, driving environment, and driving method in the younger group (21 persons) and senior group (21 persons), totalling 42 persons. The survey results are shown in Fig. 7. The two groups' characteristics were as follows.

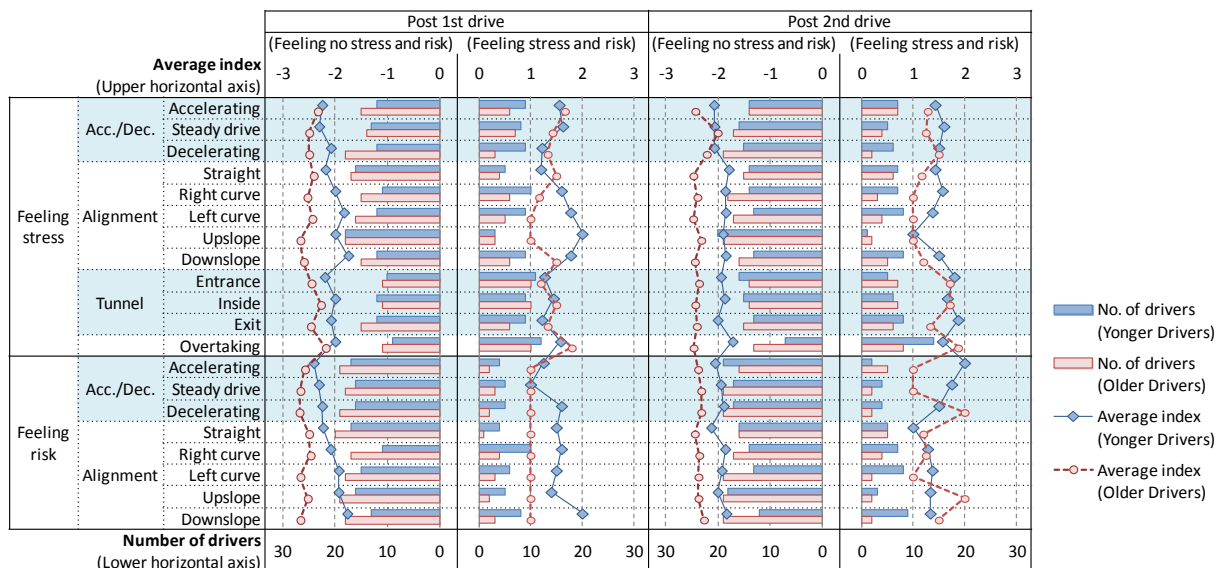


Fig. 7 Stress and risk felt by drivers in different driving conditions

1. Both the senior and younger group became tense when asked to accelerate up to a specific speed, and the younger group indicated 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 more stressful when overtaking another car.
3. According to those who answered "no stress or feeling of danger" in detail, more senior group members said they had no stress or feeling of danger in the 1st and 2nd drives than the younger group members.
4. The senior group did not become stressful and felt little danger as expressed by subjective symptoms.

Self-awareness of fatigue before, during, and after driving

Fig. 8 shows fatigue felt by drivers after the 1st and 2nd drives. The self-awareness of fatigue for both the young and senior age groups before, during, and after driving was assessed. The apparent stamina/willpower of senior age drivers was higher than that of younger age drivers (as evidenced over both driving routes). The driving stress of the senior age group on the expressway showed the same trend as that of the younger age group and senior drivers did not feel especially higher stress during expressway driving.

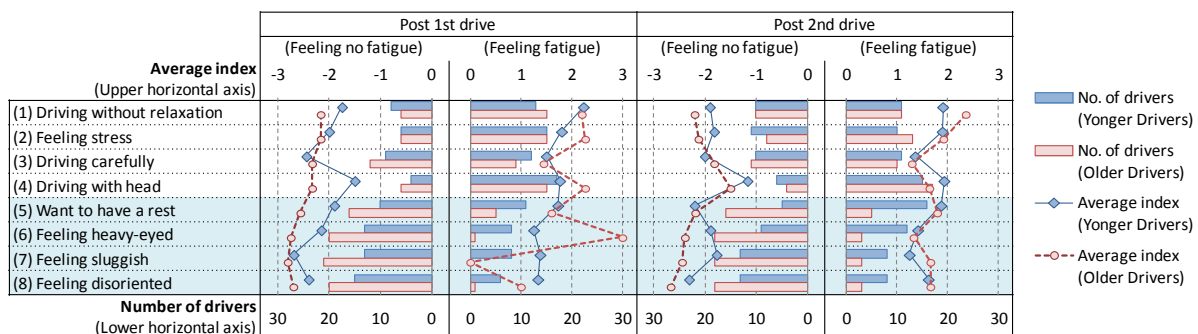


Fig. 8 Fatigue felt by drivers after 1st and 2nd drives

Nature of driving fatigue and location in body

We asked both groups of drivers whether they felt fatigue before, during, or after driving at 18 different locations in their bodies. The result is the following.

- 1) A number of senior drivers reported feeling less fatigue than reported by the younger drivers.
- 2) The fatigue locations of the senior drivers were reported to be less than that of the younger drivers before, during, or after driving.

Summary of interview survey on self-awareness when driving

The summary of the survey results on self-awareness when driving is as follows. Senior drivers are prone not to feel as stressful or apprehensive compared with younger drivers. Senior drivers are prone not to be aware of fatigue themselves.

Effects on flicker values during extended driving

Table 12 describes the progress of flicker value compared to before 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”) are as shown below.

- 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 older age group than the younger age group.
- There was greater variation between individuals in the senior age group than in the younger age group, with larger absolute maximum and minimum values, standard deviation, and other factors.
- 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% ^[11] value that is considered the maximum allowable decrease for one day, and decreased to close to the maximum allowable limit of 10%. This suggests that cerebral cortex activity decreased significantly as a result of expressway driving lasting approximately 2 hours. Therefore this indicates that senior drivers require a break within 1 – 2 hours.

Table 12 Progress of flicker value compared to before driving

		Younger drivers		Older drivers	
		[1]	[2]	[1]	[2]
All drivers	Average (%)	1.41	-0.30	-0.85	-2.22
	Standard deviation	4.32	6.44	7.86	9.23
Acceleration 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
Decline group	Minimum (%)	0.27	1.85	1.67	1.05
	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
Decline group	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

Relationship of sympathetic nervous system activity and driving behavior

A number of existing studies have made clear that heart rate response, directly and indirectly, connecting with various life-action behaviors including driving tasks, is deeply related to autonomic nervous system activity. According to one recent study (Kawai et al., 2003), it is clear that the ratio of low frequency to high frequency (referred to as L/H 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 L/H ratio of the motorists' heart rate during expressway driving and inspected whether each driver's sympathetic nerve activity adjusted normally, and to what extent, to psychosomatic activity. Then we wanted to ascertain the condition of sympathetic nerve activity. (Number of examinees: younger age group 16, senior age group 17.)

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

(a) Average L/H ratio (sympathetic nervous system stress level) when driving

Fig. 9 shows that many seniors generally drove under conditions that caused strong sympathetic nervous system stress. But on analyzing the elements causing the high level, such as the behavior of other drivers, traffic volume, entering and exiting tunnels, going down grades and upgrades, and negotiating curves, we found that there were many times that the younger age group showed very strong tension. For example, the younger age group was shown to have 39 incidents of over 50 L/H ratio while the senior age group had only six incidents. So after assessing the driving survey, we could presume that younger age drivers often had higher sympathetic nervous system stress levels caused by the driving conditions. In contrast, we saw that senior age drivers generally become mentally dull / less aware in similar traffic conditions and that they sometimes could not adequately judge their own driving performance or the actual traffic situation.

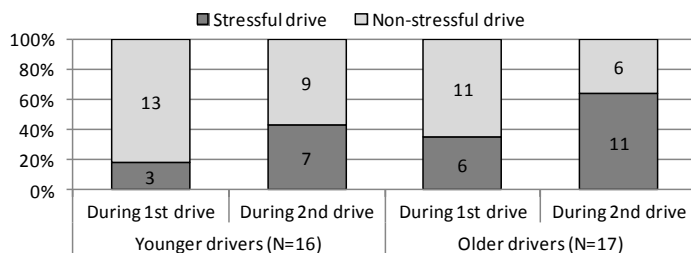


Fig. 9 Driving stress levels for extended expressway driving [1st and 2nd drives]

(b) Case study of senior driver's response to extended expressway driving

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 Tomei Expressway. Below shows the autonomic nervous system incidents for this case as indicated by a rise in the L/H ratio while driving on the expressway from descending order of the L/H ratio as indicated in Figure 8. The following statement includes driving actions not detailed in Fig. 10.

1. He overtook a passenger car on a left curve in a high traffic flow situation. (L/H ratio 60)
2. He passed a big bus on a right curve. (L/H ratio 49)
3. He drove into a tunnel and on a downhill left curve. (L/H ratio 45)
4. He drove into a tunnel and after traveling for a time on a right 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. (L/H ratio 42)

Senior drivers' self-recognition and physiological function in expressway driving
(Takahashi, Xing, Okubo, Hirai, Konda)

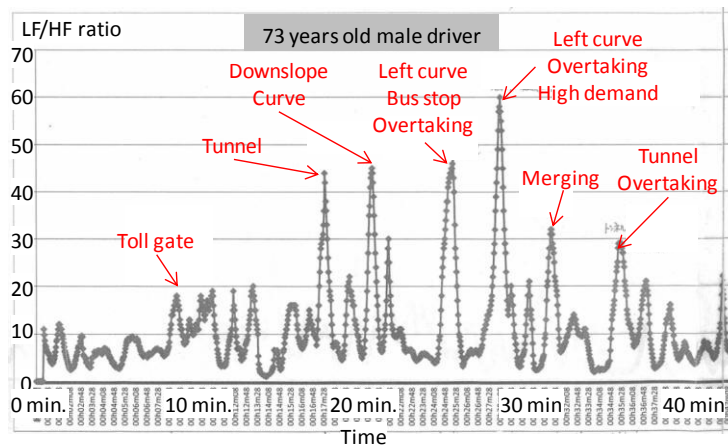


Fig. 10 Example of profile of LF/HF ratio by a senior driver

Total evaluation

- 1) Younger age drivers had extremely high stress of the sympathetic nervous system compared with the senior drivers group.
- 2) Compared with the younger drivers group, the senior drivers group had very few incidents of over-stress, although they drove with a much higher base level of sympathetic nervous system stress.
- 3) 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.

Summary of physiological function survey

In this study, we made clear that increases in tension and unsafe behavior by senior drivers are affected by a reduction of total visual ability, a decrease in arousal level caused by heightened fatigue, and during extended driving a reduced awareness of actual conditions. Also, we found that senior drivers were not aware of their tension and fatigue level themselves. So we determined that it is very important for senior drivers to be taught how to relieve their mental and physical burden by taking rests and to help them better understand the tension and fatigue they were not recognizing on their own. We also learned that there is a wide dispersion of these factors among individuals.

CONCLUSIONS

In this survey, we found that senior drivers are aware of the decline of their physiological function, but without exception they didn't 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 a driving test or through 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 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 by self-awareness but also by obtaining knowledge on

physiological function and to take certain actions to recover from driving fatigue by taking periodic rests, etc.

In our physiological function survey, we found there is a large gap between senior drivers' recognition and their personal physiological function, and furthermore that the physical abilities of senior drivers are widely spread from individual to individual. We also found that there are some important factors they could not recognize in normal daily life, such as a decline in total vision.

ACKNOWLEDGMENTS

This study was funded by the Expressway Related Social Contribution Council (ERSCC). We appreciate the highly useful advice received from the following noted specialists: Kei Nishiyama, Professor Emeritus, Hiroshima University, Hirokazu Akahane, Professor, Chiba Institute of Technology, Shinichi Muto, Associate Professor, Yamanashi University, and Naoto Uemura, Lecturer, Kochi University. The results and comments expressed here are those of the authors, not the ERSCC.

REFERENCES

- Akamatsu, M. et al. (2005). Change in senior drivers' driving behavior with aging. Proceedings of JSAE Annual Congress, No. 63-05, 15-18.
- Cabinet Office Government of Japan (2011). White paper on traffic safety in 2010.
- Hashimoto, K. (1973). Fatigue and monotony of driving. *Traffic Medicine*, Vol. 27, No. 1, 1-29.
- Japan Society of Neurovegetative Research (2007). *Inspection of Autonomic Nervous Function*. 4th ed., Koubunn-do, .164-165.
- Kimura, K. et al. (1991). Study of senior drivers' use of expressways. Proceedings of 14th Infrastructure Planning and Management Conference, 87-91.
- Kawai, K. et al. (2003). Senior drivers' driving behavior at merges of expressways. The Research Institute Report of Japan Highway Public Corporation, Vol. 40, 1-8.
- Lang, B., A. Parkes and K. Fernández Medina (2013). Driving Choices for the Older Motorist - The role of self-assessment tools. Transport Research Laboratory.
- Matsumura, T. et al. (1992). Senior drivers' driving behavior on car-following drive. Report of the National Research Institute of Police Science, Traffic part, Vol. 33, No. 1, 23-29.
- Nagahama, T. (1998). Experimental study on senior drivers' dynamic visual acuity. *The Journal of Fukui University of Technology*, Vol. 28, 169-175.
- National Police Agency (2011). Statistics on driver licenses.
- Nishiyama, K. (1985). Study of aged persons' driving behavior. *Journal of Traffic Psychology*, Vol. 1, 17-23.
- Oxley, J., J. Charlton and B. Fildes (2003). *Self-Regulation of Older Drivers: A Review*. Austroads.
- SafetyNet (2009). *Older Drivers – web text*, retrieved 10 November 2011.
- Tanaka, M. et al. (1994). Tolerable traffic conditions for senior drivers on expressways. *Expressway and Automobiles*, Vol. 37, No. 9, 21-29.
- Uno, H. (2003). Senior drivers' typical driving characteristics. Vol. 34, No. 2, 101-106.