The Risk of Traffic Accidents and Mobility Assistance in an Aging Society

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1. Introduction

According to the White Paper on Police (FY2017 edition),[1] while the overall number of fatal traffic accidents is on a downward trajectory, the number of fatal accidents caused by drivers age 75 and over has been holding steady in recent years. This means that the share of such accidents accounted for by elderly drivers is on the rise. Driving an automobile in Japan, which is now a super-aging society, makes it possible for people to travel from door-to-door and get around by freely choosing the time and place, while also minimizing the impact of fluctuations in the weather and temperature. As a result, it can lessen the considerable impact many experience from declining physical strength and physical function. Given these features, driving an automobile offers numerous advantages for elderly people, and serves as one of the most effective ways for them to get around (mobility).

When it comes to problems pertaining to elderly people and driving, we must resolve problems related to both the aspects of reducing traffic accidents for the safety of individuals and society, still ensuring freedom of mobility.

2. Driving behavior models

In Japan, so-called driving behavior models are thought to be comprised of three elements: cognition, judgment, and operation. This model could be called the information-processing model,[2] and it is shown in Fig. 1. Conversely, in the West, Michon’s three-stage model is considered to be the primary model for driving behavior.[3] This model is comprised of mutual feedback loops between three different levels: the strategic level, maneuvering level, and control level.

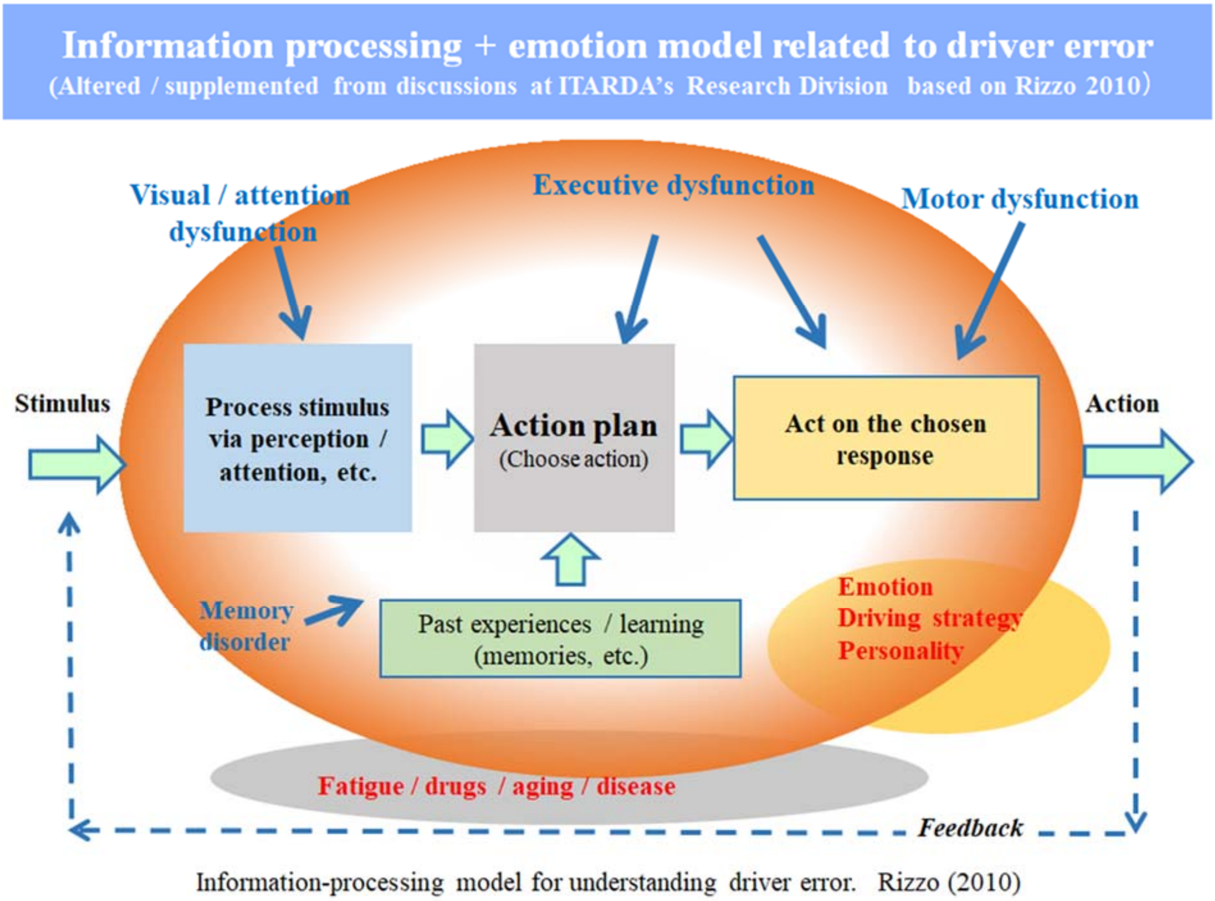


Fig. 1. Diagram showing the information-processing model related to driving and the impact of physical and/or cognitive dysfunctions

3. Basic analysis of the impact of aging

3.1. Examination based on reaction time

To examine the impact of aging when considering the driving of elderly people, we will need standard values related to driving that span across all age groups. Yet there is no getting around the fact that such data is exceedingly scarce and limited. Given this, this paper will analyze the impact of aging on driving from the data used to create the standard values for the test developed by the National Policy Agency to serve as its driving aptitude test.[(4)]

This test is comprised of four elements: simple reaction time (SRT), choice reaction time (CRT), steering tracking-based reaction time (STRT), and a composite test of STRT and CRT together (Fig. 2).

Both the average values and standard deviation for every age group for the tests of SRT, CRT, and the composite test of STRT and CRT for more than 2,000 people in total (including 100 men and women each from age groups from their late teens up through 80s) were shown as standard value data for the test (Fig. 3).

Impact of aging on driving

Examination from basic data

Target data: 100 men and women from each age group from ages 18 – 80s; 2,000 people total

(1) SRT: Visual stimulus in the middle of a straight road
Yellow: Accelerator on → off

(2) CRT: Visual stimulus in the middle of a straight road
Yellow: Accelerator on → off
Red: Accelerator off → Brake
Green: Continue pressing the accelerator

(3) Driving test on a curved road
Steering along a road with continuous changes to its rate of curvature)

(4) Composite test of (2) and (3)
(Present visual stimulus off to the periphery)

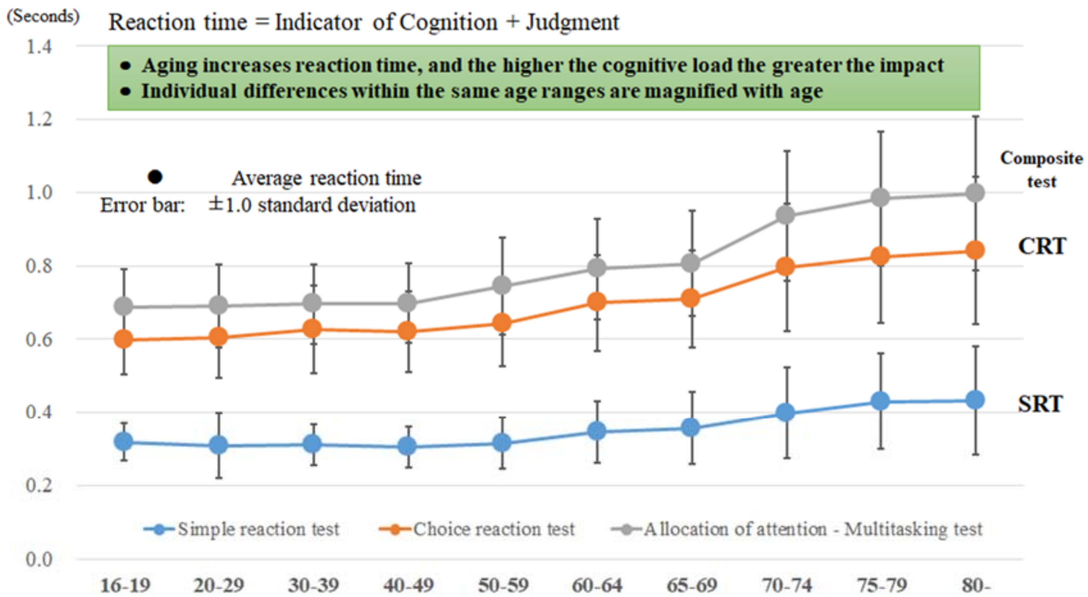
(1), (2) SRT / CRT **(3) Driving test on a curved road** **(4) Composite test**

Source: Results report from the collection of data from computer simulation on four-wheel vehicle driving / steering from training for elderly drivers by Tasknet Inc., 2001

Fig. 2. Overview of the driving aptitude test

Effects of aging observed in average reaction times

(From standard data from the NPA's CRT driving aptitude test)



Source: Results report from the collection of data from computer simulation on four-wheel vehicle driving / steering from training for elderly drivers by Tasknet Inc., 2001

Fig. 3. Trends in average values and standard deviation for reaction time by age group

This graph reveals a trend whereby people's reaction times grow longer the older they get, which is a change that can be described as an outcome of aging. However, one point worthy of mention is that the standard deviation values grow larger as the person ages. In light of this fact, the effect that aging has on driving cannot be denied. However, there are sizeable individual differences in this, such that uniform regulations over aging will presumably be unable to accommodate the driving abilities of individual elderly people and would therefore not lead to safe driving as a result. As such, what is needed is a way to determine if a person should be driving or not that takes the driver's individual characteristics into consideration.

3.2. Effect of aging observed in steering control

This paper will likewise perform an analysis on the impact of aging observed with steering based on the standard values from the driving aptitude test. For this, the average values for spatial errors (changing position within lanes) and time phase errors (delayed regulatory function observed with steering) were plotted out (Fig. 3).

The results indicate that the relative values for spatial errors increase among people in their 70s and older. As for time errors, people in their 20s through 60s display smaller relative values for these than those in their late-teens, which indicates that people between their 20s – 60s have progressed in their proficiency over those in their late-teens when it comes to steering errors. These results indicate that those between their 20s – 60s can either maintain the same skill level as those in their late teens or demonstrate greater proficiency. But they also indicate that from their 70s onwards, people suffer from spatial errors, time errors, and a decline in their skills.

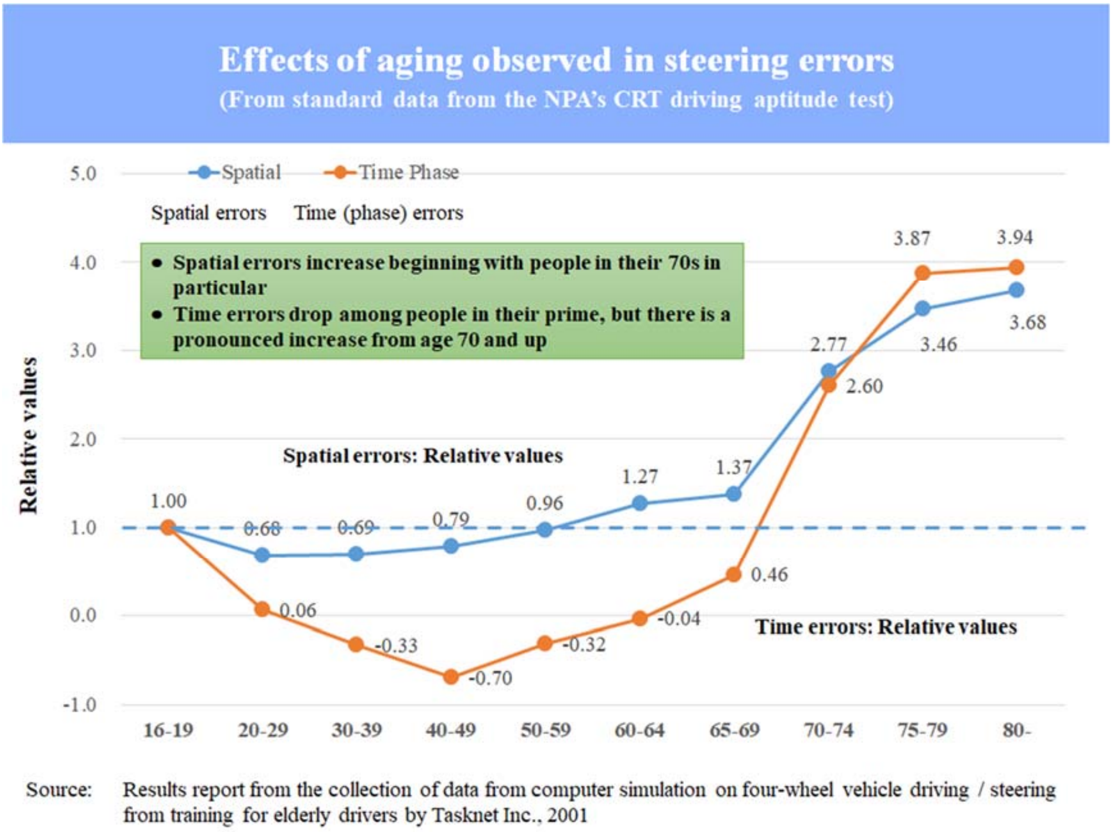


Fig. 4. Trends in the steering control of spatial / time errors by age group (relative comparison)

These results indicate that, by age group, few traffic accidents occur among the generation of people in their prime in Japan, but the results coincide with an upswing in traffic accidents among elderly drivers.

3.3. Occurrence rate for fatal accidents pertaining to human factors from ITARDA macrodata

The Institute for Traffic Accident Research and Data Analysis (ITARDA) has amassed the largest collection of data on traffic accidents within Japan, with this comprised of both macrodata (a database based on traffic accident ledgers) and microdata consisting of data that is more detailed despite being more limited in the number of accidents. From among the macrodata on more than 2,000 accidents, an analysis was performed on items classified under the category of failure to pay attention forward as items pertaining to driver-caused factors. Failure to pay attention forward can be further broken down into the categories of internal factors (lost in thought, aimless driving, listening to the radio, dozing off, etc.), external factors (looking at maps, adjusting the car navigation system while driving, distracted driving, etc.), and others (Fig. 5).

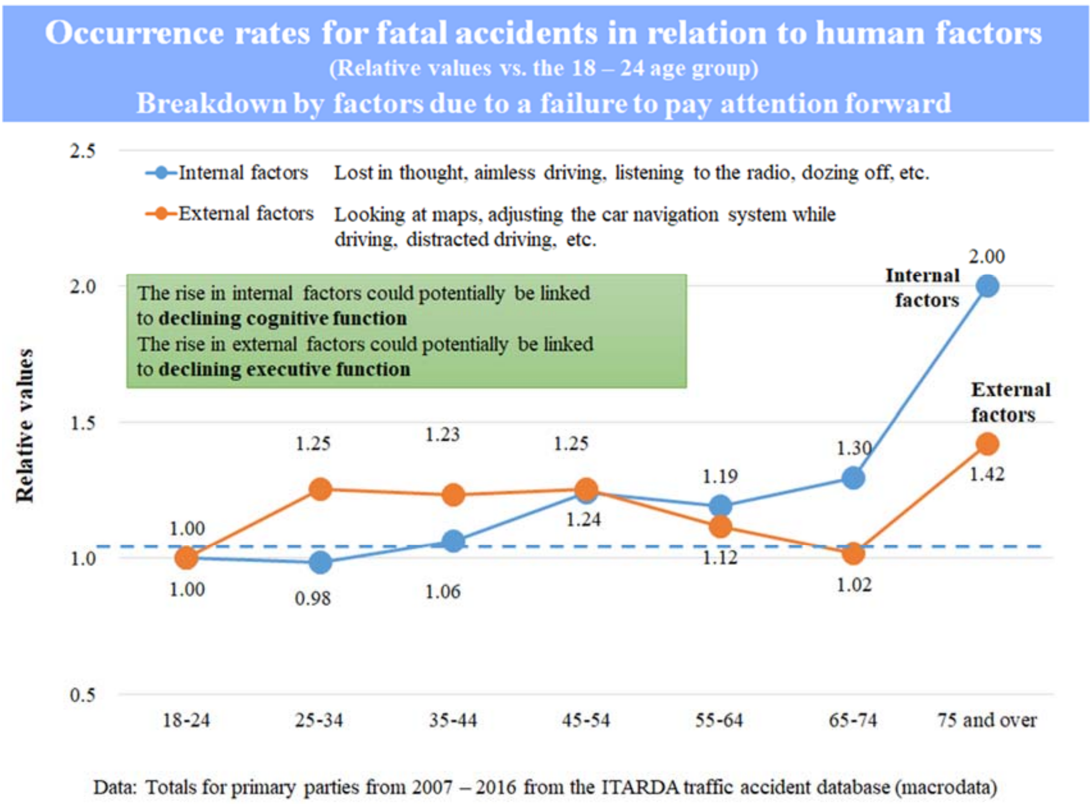


Fig. 5. Comparison between age groups for the occurrence rate for accidents due to factors caused by a failure to pay attention forward (relative comparison)

Based on a comparison of the relative values in which the late-teen group is taken as the baseline, the highest figure for both types of factors for age groups up through their early 70s is 1.3. But for the 75 and over age group this increases to 1.42 for external factors and 2.0 for internal factors.

In the information-processing driving model shown in Fig. 1, failure to pay attention forward can be thought of as corresponding to cognition / judgment processes. This suggests that the increase in the failure to pay attention forward due to internal factors in particular starting from one's late 70s on is linked with their declining faculties when it comes to these cognition / judgment processes. In addition to a decline in cognitive function, there is a growing impact from factors that serve to decrease their level of awareness and inhibit their attentional function, as well as a decline in their level of awakeness and alertness, all of which are factors that should be taken into consideration. Moreover, the decline in their executive function presumably also has an effect on their failure to pay attention forward due to external factors. As such, it is believed that the effects of aging have a comparatively smaller impact than those from internal factors.

3.4 Classification by judgment errors

A comparison by age group was performed on data classified as accidents due to judgment errors using the same method as that from 3) above (Fig. 6). This category was further divided up into the subcategories: failure to observe, failure to predict behavior, and failure to recognize the traffic environment. The category failure to predict behavior had relative values that stayed under 1.0 for age groups from late teens up to age 74. However, for the categories failure to observe and failure to recognize the traffic environment, this was seen to increase to 1.34-1.39 for the 75 and over age group.

When it comes to judgment errors classified under failure to predict behavior and the like, the 75 and over group with their proficiency acquired with age showed similar values as those of the young group. The thinking is that there are some functions that do not exhibit functional decline as a result of aging, making these results worthy of attention.

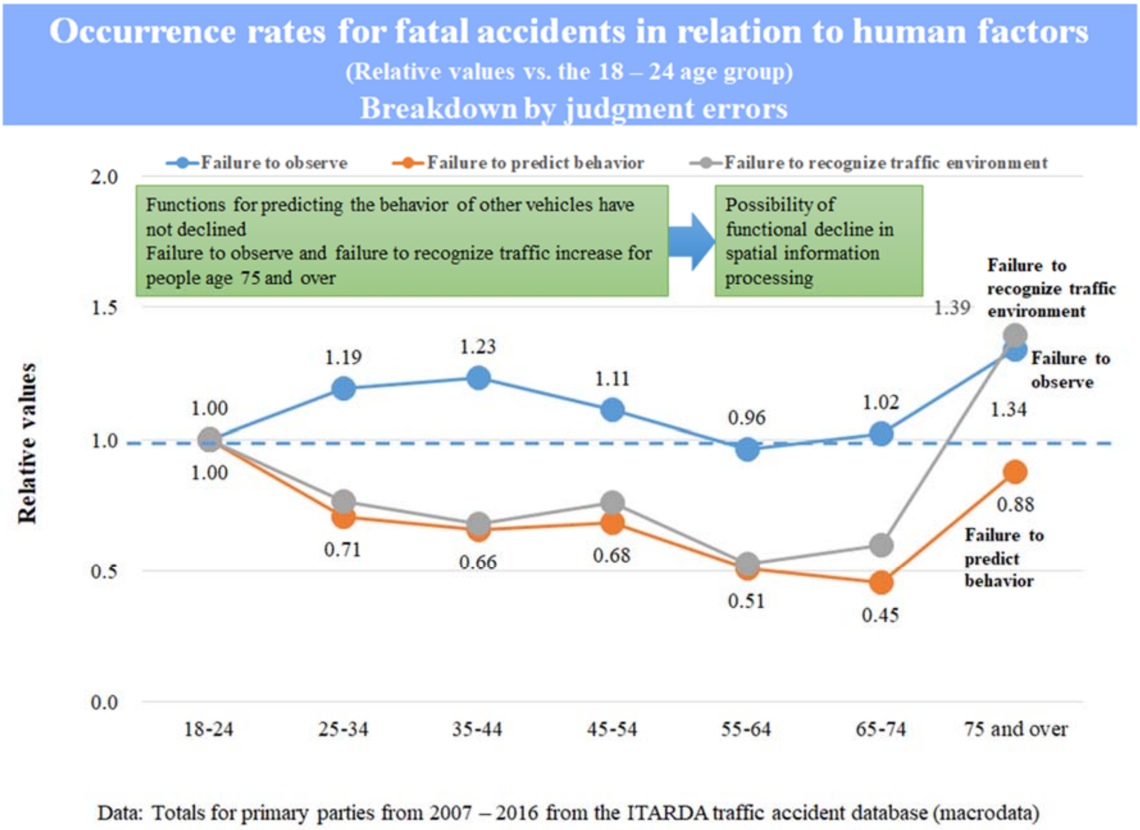


Fig. 6. Comparison between age groups for fatal accidents due to judgment errors (relative comparison)

3.5 Examination of the effects of aging seen in cognition- / judgment- / operating-related categories

Based on ITARDA's macrodata, this paper focused on the categories of failure to pay attention forward and failure to confirm safety factors as cognition-related indicators, failure to properly predict / judge the movement of or danger from other cars (drivers) as a judgment-related indicator, and operating errors (such as braking, accelerating, or steering, etc.) as operating-related indicators to perform a comparison of the relative values by taking the 18 – 24 age group as the baseline, as has been done thus far (Fig. 7).

From the results of this, no major fluctuations were seen in the relative values for the age groups between the late 20s and early 70s, but for people age 75 and over operating-related values and cognition-related values both exceeded 2.0 at 2.61 and 2.19, respectively. Conversely, judgment-related relative values increased for the 75 and over age group, but still remained at a relatively low value of 1.19 compared with the other two.

It is possible that compared with the extent of the functional decline in our sensory organs and motor systems, our judgment undergoes less functional decline as a result of aging. Moreover, cognition- and operating-related driving behaviors can be compensated for with various assistive devices relatively more easily than judgment-related behaviors. Therefore, the development of such devices could potentially diminish the effects of aging and lead to prolonging the length of time people can drive.

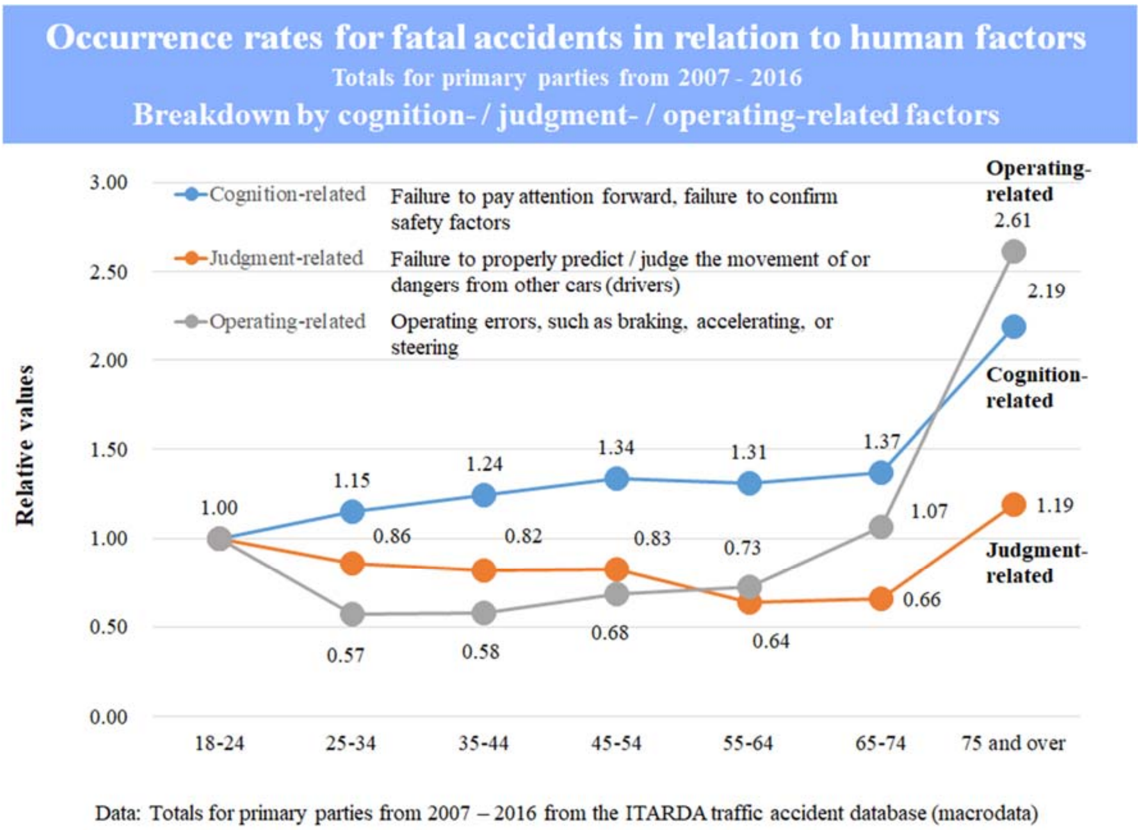


Fig. 7. Examination of the impact of aging seen in indicators in response to cognition-, judgment-, and operating-related factors

4. Declining cognitive function / cognitive impairments and traffic accidents

Presumably, there are a variety of different ailments that can have an impact on the driving of elderly people. Those ailments from among these that have a high rate of morbidity and risk of affecting driving must be analyzed in terms of their connection to decreased cognitive function and cognitive impairments.

Cognitive impairment is defined as: "A state in which one cannot lead their normal, everyday life or social life as a result of the chronic decline in or loss of a variety of mental faculties that have once developed normally post-birth" (5) (homepage of the Ministry of Health, Labour and Welfare). According to a recent survey, the estimated prevalence rate for cognitive impairments is 15%, which is roughly 1.5-times the conventional estimated figure, with it estimated that there are approximately 4.39 million patients suffering from a cognitive impairment throughout Japan (as of 2010).(6)

Alzheimer's disease (AD) is the ailment with the largest number of sufferers out of all of the cognitive impairments. With AD, symptoms such as impaired memory (impairments to recent memory and event memory, etc.), disorientation (declines in temporal orientation, spatial orientation, and awareness of people), executive dysfunction (increased difficulty in planning or performing certain tasks, etc.), and visuospatial disorders (difficulty with reproducing shapes, getting lost) are seen.(7)

A number of problems can be pointed out regarding the driving of patients with cognitive impairments exhibiting these sorts of symptoms. These include: (1) Getting lost on roads they are familiar with, (2) Decreased ability to modulate their speed (speeding, low speed), (3) Decrease in signaling lane changes and ability to confirm their surroundings, (4) Occupying inappropriate positions within lanes, (5) Disregarding stop signals, (6) Failing to notice traffic signs, and more.(8)

Based on an analysis of data like the occurrence rate for traffic accidents, a number of facts concerning AD can be pointed out. These include: (1) The rate of accidents among patients with AD is 2.5 – 4.7-times greater than that of healthy drivers,(9, 10) (2) They are at greater risk of causing accidents due to advancing cognitive impairments,(10) (3) While there is a preconceived notion that their declining cognitive function increases the risk of accidents, it is unclear whether their driving ability declines in the early stages of AD,(11, 12) (4) Medical examinations as well as actual driving evaluations are needed to determine whether or not they should give up driving,(9) (5) 88% of AD patients in the very early stages and 69% in the early stages pass road tests,(11, 12) (6) It is possible to predict drivers with declining cognitive function in the early stages by evaluating their executive function and caution,(13) and more.

It has been pointed out that there is a group in which declines in their cognitive function have been observed, albeit mild ones, as they do not meet the diagnostic criteria to be labelled as cognitively impaired. Classified as having Mild Cognitive Impairment (MCI), this group is situated in between the healthy group and the cognitively impaired group, and is considered to be more prone than the healthy group to advancing onto becoming cognitively impaired. The estimated prevalence rate for MCI throughout Japan is 13%, with it estimated from the results of this that there are approximately 3.8 million people with MCI throughout Japan (as of 2010).(6)

Methods for measuring and assessing whether these drivers with MCI and patients in the very early stages of cognitive impairment show any decline in their driving ability must be examined. Actual driving assessments offer a key to this as indicated above. But the manner in which they are carried out must be examined, along with the validity and reliability of behavioral observations and assessments of drivers by driving school instructors. When adopting actual driving assessments, this must be done in a manner in which they can be implemented objectively and consistently. Moreover, it must be possible to perform the assessments at a cost within an acceptable range, and ideally their power to predict traffic accidents will have to be verified as well.

5. Pedal misapplication accidents and declining cognitive function

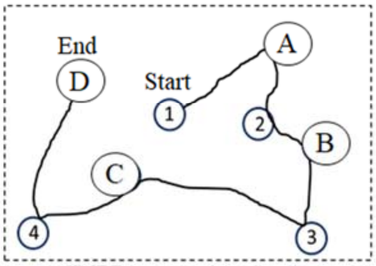
Accidents in which the driver misapplies the accelerator and brake pedals are recognized as a type of traffic accident characteristic to elderly people. This phenomenon has been reported on in a separate paper by Hirakawa (2017), so for this report the examination will be limited to an analysis of its connection with cognitive function tests.

The ability to predict pedal misapplication accidents was examined based on age, sex, tests screening for the decline of cognitive function (Mini-Mental State Examination or MMSE), tests of attentional function and others (both Parts A and B of the Trail Making Test : TMT), and the clock drawing test. From the results of this, significant differences were seen based on age and performance on the clock drawing test (group within the standard values and the group with performance below the standard values), but not with other neuropsychological tests.[14]

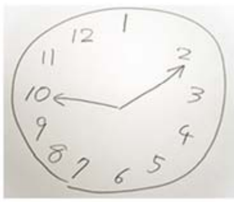
Factors of pedal misapplication accidents and their countermeasures

Suggests a connection with cognitive function, but has little predictive power (Freund 2008)

	Standard group	Target group	Odds ratio	p value
Age	65-72	84-89	**6.10**	$p<0.05$
Sex	Male	Female	1.18	n.s.
MMSE	Standard group	Standard values or lower	0.53	n.s.
TMT A test	70%ile or higher	Average or lower	3.42	n.s.
TMT B test	70%ile or higher	Average or lower	1.92	n.s.
Clock drawing test	Group within standard values	Functional decline group	**10.04**	$p<0.05$



TMT B test (exercise) – Sample



Clock drawing test – Sample

Recommendations from the National Highway Traffic Safety Administration (NHTSA) in the US

1. Adjust the seats, mirrors, and steering wheel, especially with cars you are not familiar with
2. Get in the habit of stepping on the center of the brake pedal
3. Never lose focus or let your mind wander until you have come to a stop and turned off the engine
4. Drive wearing footwear that is suited for driving

Recommendations: Don't apply the accelerator when starting up the vehicle (make use of vehicle creep)

- Freund B et al. Pedal errors among older driver, Accident Analysis & Prevention, 2008
- NHTSA Safety Advisory, Reducing crashes caused by pedal error, 2015

Fig. 8. Analysis of the connection between pedal misapplication accidents and cognitive function

Moreover, based on the authors' own outpatient experiences with forgetfulness, many of the cases in which the person's performance had declined more than the standard values on the clock drawing test were cases in which the decline in their cognitive function had progressed to a considerable degree. As such, it presumably offers little chance of predicting pedal misapplication accidents among drivers still capable of routine, everyday driving. While declines in cognitive function are presumed to be a causative factor behind such accidents, prior research would suggest that it is no simple feat to detect or predict the risk of causing accidents via neuropsychological tests or the like prior to the occurrence of said accidents.

6. Accidents from wrong-way driving on expressways

In the ITARDA macrodata, the number of accidents from wrong-way driving on expressways came to 250 over the ten-year period starting from 2007, with drivers age 65 and over accounting for roughly half of these at 119 accidents (47.6%). Conversely, even drivers between ages 18 – 24 and those in the prime of their life, for which the occurrence rate for traffic accidents is low, cause accidents from wrong-way driving, meaning that such accidents occur across all age groups. In addition, the share of such accidents out of the net number of casualty accidents on expressways is 0.22%, which is a figure that is similar to that found in data on the state of Michigan in the United States.[15] Based on this, the assumption is that there are no major differences between Japan and the United States when it comes to the occurrence of accidents from wrong-way driving.

The results thus far indicate that the causes behind wrong-way driving cannot be explained by aging and the decline in mental and physical functions that accompany it alone. There is very little in the way of evidence that would lead us to identify the causes behind accidents from wrong-way driving, so we must consider methods for obtaining new data.

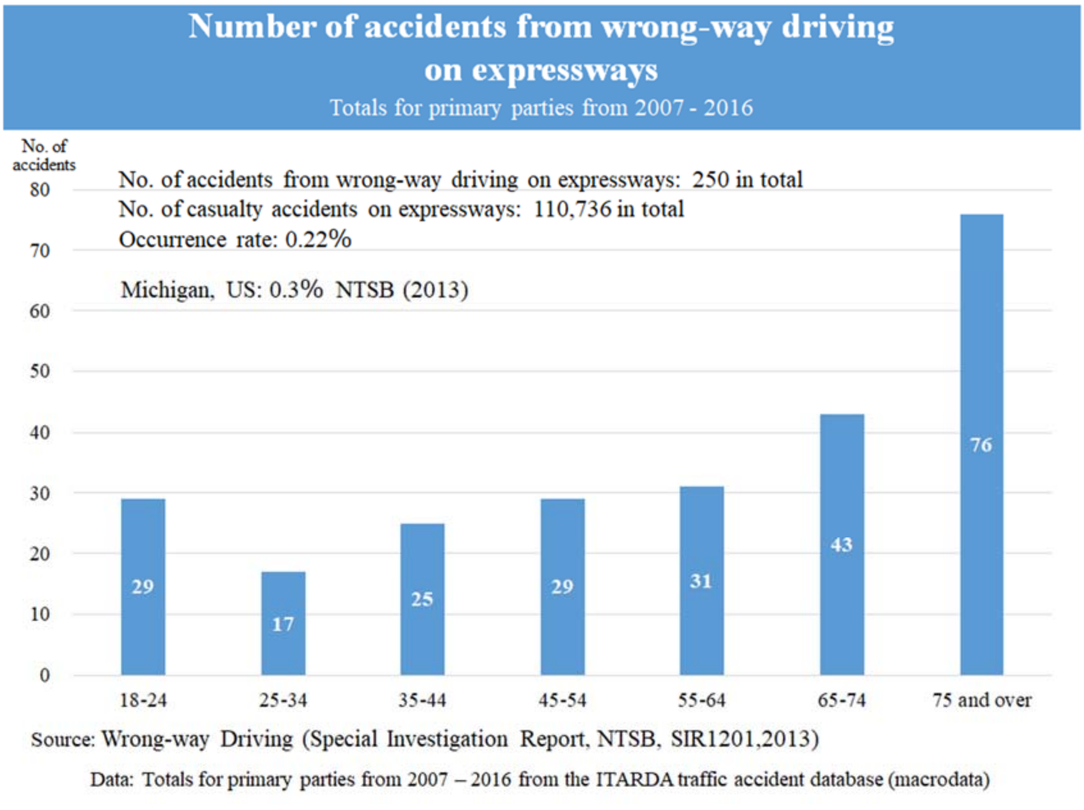


Fig. 9. Comparison between age groups of the number of accidents from wrong-way driving on expressways

7. Other ailments and traffic accidents

One important issue with respect to traffic accidents and ailments is the impact of acute onset. This type of accident involves a high fatality rate for the primary party, on top of which the impact it has on other drivers, passengers, and pedestrians is significant. In the ITARDA macrodata, epilepsy, cardiovascular disease, and cerebrovascular disease have been divided up into separate categories, with a comparison of the number of casualty accidents from each by age group shown in Fig. 10. (These categories include some assumed cases.)

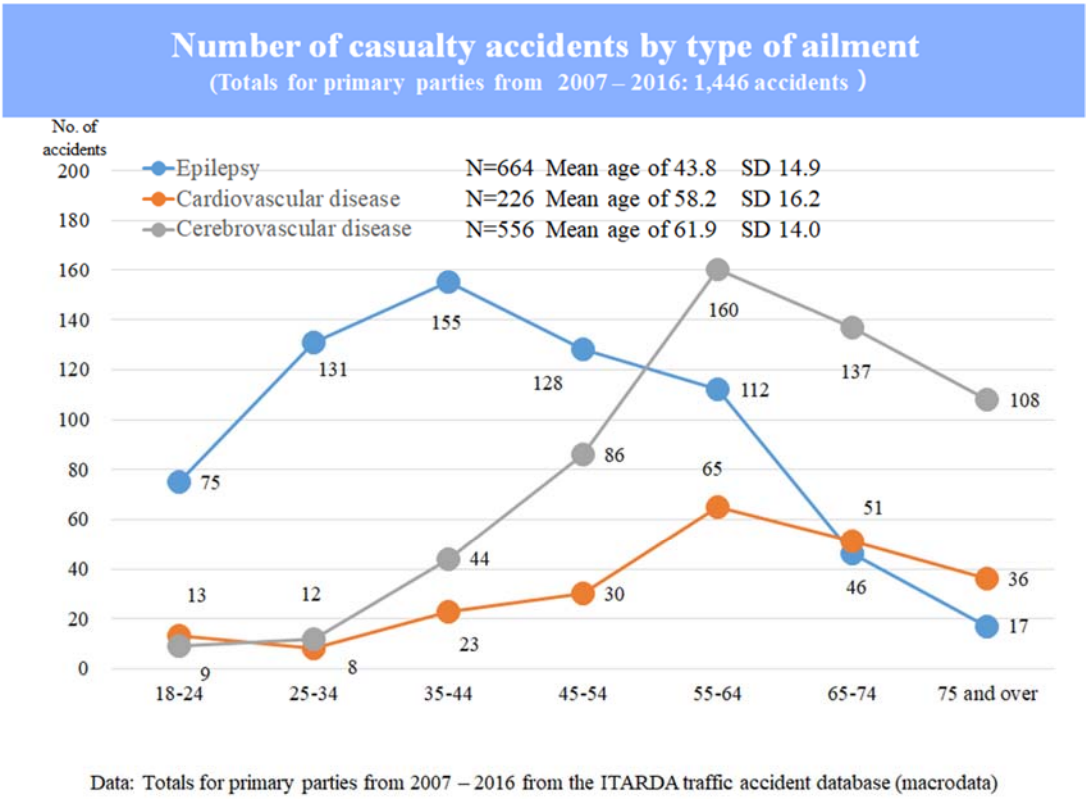


Fig. 10. Comparison between age groups of the number of casualty accidents by type of ailment

Of these, accidents related to epilepsy peak in the late-30s, whereas the peak for cardiovascular and cerebrovascular diseases shifts to the late-60s. Thereafter, the number of accidents falls as people grow older, which is believed to be influenced by the fact that older generations have fewer opportunities to drive and travel shorter distances. Therefore, this cannot be interpreted as showing that the risk of accidents due to ailments falls with this age group.

In addition, the three types of ailments in this analysis were categorized based on their severity (Fig. 11). In terms of the rate of occurrence for fatal accidents for each ailment, those attributable to cardiovascular disease showed high figures at 11.9%, versus 4.2% for epilepsy and 4.5% for cerebrovascular disease. To analyze the high fatality rates for cardiovascular disease, it will be necessary to perform detailed analyses on matters like loss of consciousness and the extent to which motor control of the upper and lower extremities becomes difficult following acute onset. Moreover, this analysis was limited to classifications of the illness severity among the primary party, so analyses must be performed on matters like the number of casualties including persons other than the driver.

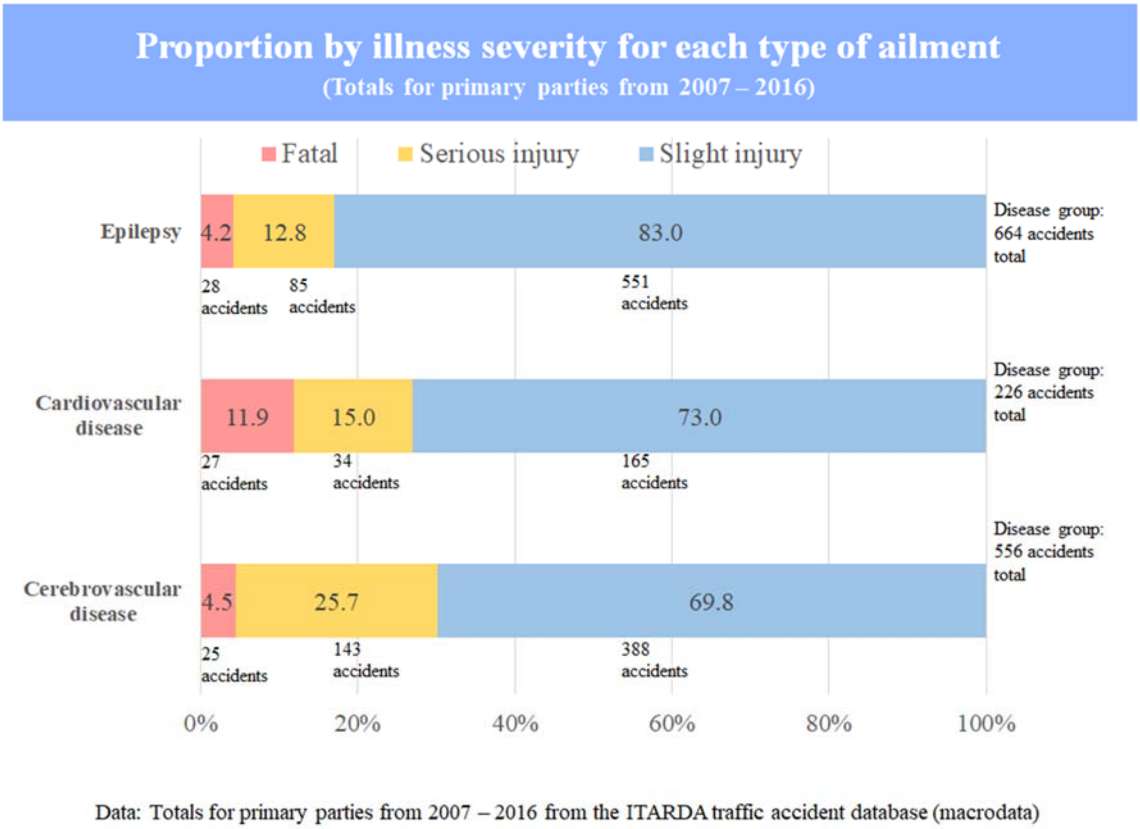


Fig. 11. Comparison of illness severity for the number of casualty accidents by type of ailment

To analyze the connection between illness and traffic accidents, we must examine the causes that lead to said accidents occurring. For this analysis, a comparison of the days on which accidents occur was performed (Fig. 12).

The results of this revealed that the number of accidents that occur on weekends is low, but tend to be higher on Mondays and Fridays. This trend was common to all three types of ailments. This tendency suggests that there is a connection between workload and acute onset. In this analysis, no analyses of significant differences or the like were performed, and so the statistical credibility of this will have to be reviewed. Furthermore, following the connection with workload, ongoing analyses will have to be conducted on the connection with work lasting into the evening / late at night, as well as the connection with acute onset among drivers of taxis, trucks, and so forth.

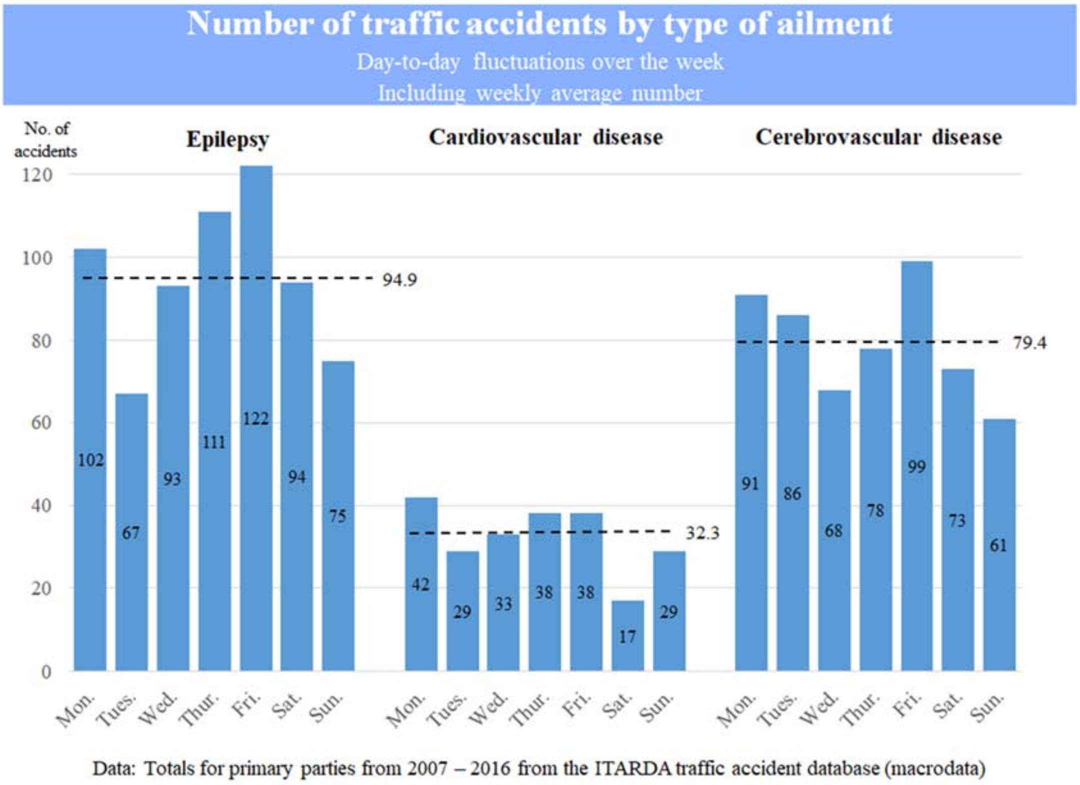


Fig. 12. Results of tabulating the number of casualty accidents that occur on each day

8. Determining whether or not someone should be driving

When it comes to determining whether or not someone should be driving, drivers who are at high risk for causing traffic accidents must be persuaded to give up driving or to choose to get around by some other means of transportation. But we should consider the possibility of allowing elderly people who are at the same level as ordinary drivers of same age groups in terms of their risk of causing accidents, to continue driving. However, as of yet no methods have been established that can be deemed the gold standard when it comes to such determinations of whether or not someone should be driving.

One conceivable approach here would be to propose comprehensive support methods based on the determinations of whether or not someone should be driving through the coordination of a large number of professionals. On the basis of the respective expert knowledge and experience of experts in related fields based on medical diagnoses and treatment strategies, it would conceivably be effective to provide comprehensive support to drivers via organizations that can make proposals on everything from determining whether or not someone should be driving to assisting people in getting around after they give up driving.

From the perspective of the costs that will be involved with this system, presumably it should start to be applied in certain select cases. Examples of these would include cases where there is hesitation over supporting determinations of whether or not someone should be driving, and cases where information is required to support people with MCI and other eligible parties in getting around after they give up driving. It can be said that it is necessary to accumulate model cases and create a support system for judging whether or not someone should be driving as well as the support path.

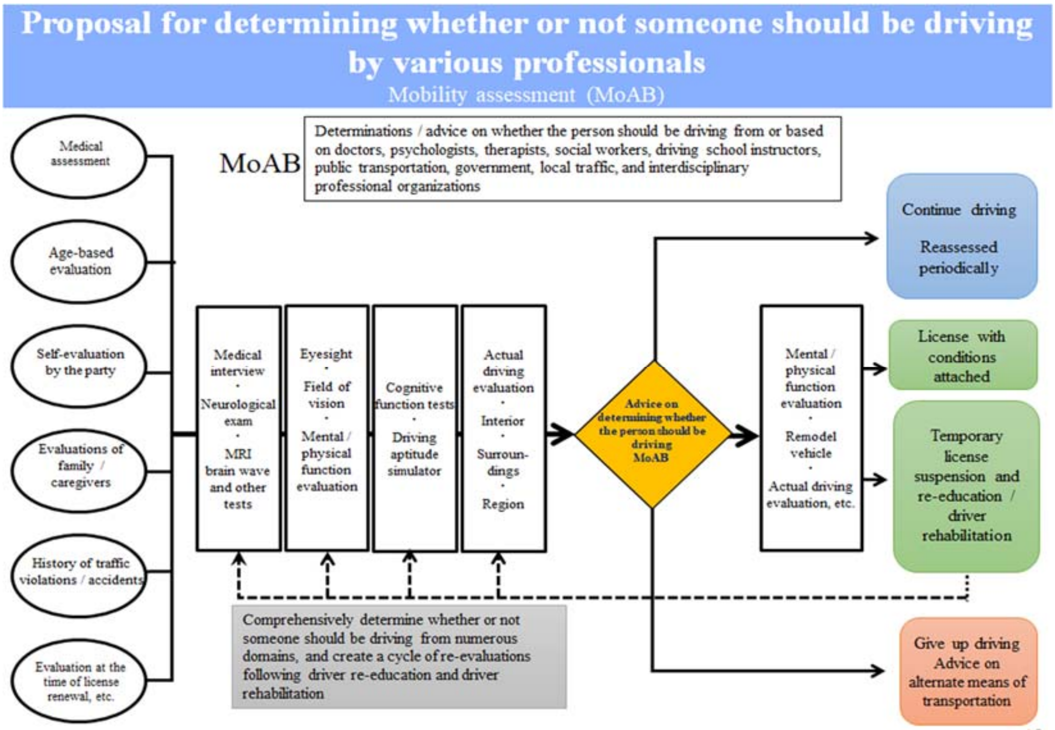


Fig. 13. Mobility Support System comprised of experts from related fields

Example of the Mobility Advisory Board (MoAB)

9. Conclusions

1. The number of elderly drivers is expected to increase as a result of the aging of society, and so countermeasures against accidents by such drivers must be strengthened.
2. Given the current status of traffic accidents, it will be important to continue taking countermeasures against accidents by young drivers as well.
3. It will be necessary to round out the data on the human factors behind accidents. In addition, a broad range of analyses must be performed on issues like the alterations in mental and physical function that accompany aging, the impact of acute onset as well as cognitive impairments and other such progressive aliments, and the side effects of medications.
4. In order to analyze the various effects that accompany aging, data must be accumulated on the everyday driving behavior of ordinary drivers for use as a subject for comparison.
5. In addition to the dissemination of vehicles that support safe driving and licenses with restrictive conditions attached, there is also a need to adopt more appropriate ways of determining whether or not people should be driving, driver re-education, driver rehabilitation, and other ways of extending how long people can drive.

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