Characteristics of and causative factors for accidents by elderly drivers

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Overview

The number of traffic accident fatalities in 2016 came to 3,904 people, a decline of 213 from the previous year. Elderly people accounted for 54.8% of these, with their rate increasing year by year. In addition, as a result of the increase in the number of elderly people with driver's licenses, there has been a 1.8-fold upswing in the rate of fatal accidents caused by elderly people driving medium-sized and small-sized motor vehicles over the past ten years, with this having come to pose a social problem. The major causative factor for the accidents that can be mentioned is the decline in physical function that accompanies aging, but what is happening to elderly drivers who have driven safely over a long time? This study seeks to bring to light the characteristics of accidents due to human errors unique to elderly drivers and the true causes for them based on accident data from within Japan. It will also discuss measures to reduce the number of accidents in the future.

1. Introduction

Even as the number of fatalities from traffic accidents in 2016 declined by 213 people from the previous year down to 3,904, the percentage of fatalities among elderly people age 65 and over has been trending upward year by year, accounting for as much as 54.8% of these. Moreover, this reveals that their fatality rate, which indicates the percentage of fatalities versus casualties, has risen to 6.4-times that of non-elderly people.

This is presumably influenced by the rise in the proportion of the elderly population in Japan. The government is aiming to achieve the objective of "realizing the safest road transport in the world by decreasing fatalities within 24 hours to less than 2,500 per year by 2020," which was set forth in its Tenth Traffic Safety Basic Plan. It goes without saying that reducing the number of fatal accidents by elderly people holds the key to achieving this objective. In recent years, the number of elderly people with driver's licenses has soared, which in turn has led to an increase in the number of traffic accidents caused by elderly drivers. This has come to pose a serious social problem. Therefore, as traffic accidents caused by elderly drivers is one of the mainstays of the research that ITARDA must address, this paper will explore the question: Why do elderly drivers tend to cause more accidents despite having continued to drive safely over many years? As such, this paper will consider the characteristics of accidents unique to elderly people based on an analysis of accidents using macrodata and microdata on traffic accidents based on the human factors in play, consider how to reduce accidents, and discuss measures for this.

2. Background / Goals

Fig. 1 shows the casualty composition rate by status for each age group in 2016 together with the fatality rate, which indicates the percentage of fatalities versus casualties. While the age group of elderly people

age 65 and over is seeing a drop in its casualty composition rate while driving automobiles, conversely its casualty composition rate while walking or riding a bicycle is trending upwards. It also indicates that they have a conspicuously high fatality rate as pedestrians in particular. However, the slope of the line graph showing the changes in the fatality rate for elderly people while driving an automobile reveals that as people grow older, they exceed the rate of increase in the fatality rate among pedestrians. Based on such circumstances, Fig. 2 shows the changes in the number of fatal and casualty accidents over the past ten years up through 2016, with 2007 taken as the baseline year for accidents in which an elderly driver driving a passenger car or truck (hereafter referred to as “four-wheel vehicles”) was involved as the primary party.*[1]

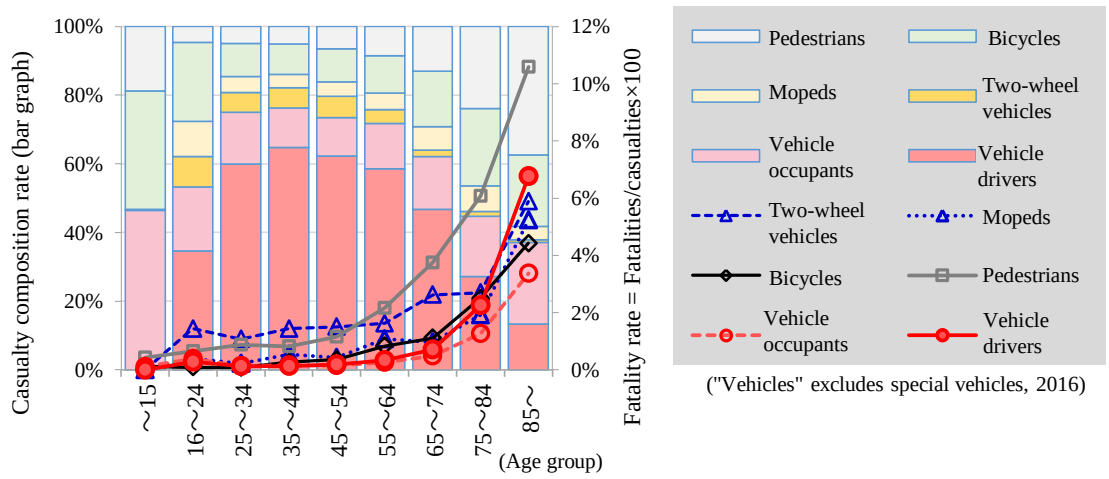


Fig. 1. Casualty composition rate and fatality rate by status

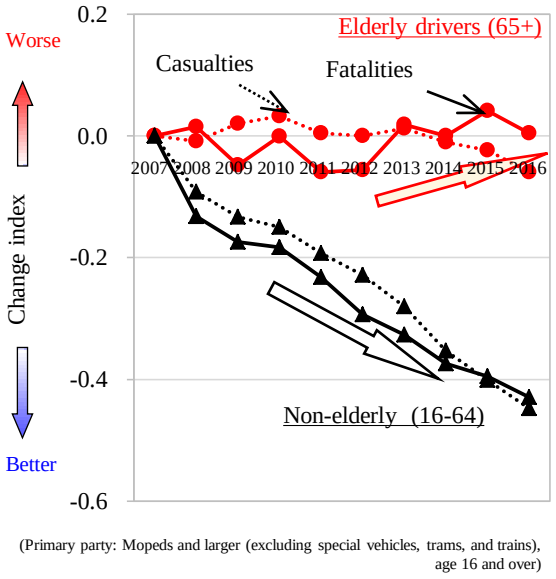


Fig. 2. Trends in accidents by elderly / non-elderly drivers

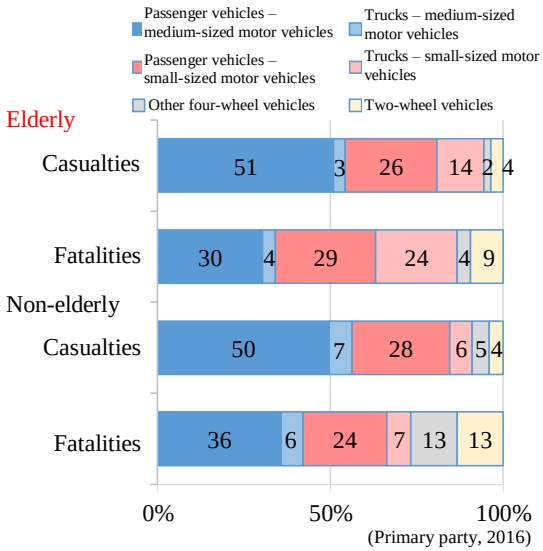


Fig. 3. Rate of accidents by vehicle type

Looking at the non-elderly group (age 64 or under) reveals that this is heading in a positive direction, given the downward trajectory this is on year by year. However, casualty accidents by the elderly group are holding steady and fatal accidents have been trending upwards since 2013, with some degree of fluctuation up and down. Fig. 3 shows the composition rate for the number of accidents by type of party between four-wheel vehicles and two-wheel vehicles in 2016. This indicates that the increase in fatal accidents by elderly drivers driving small-sized trucks has been striking compared to the rate of casualty accidents by elderly drivers driving small-sized motor vehicles of 40% (26% from small-sized passenger cars + 14% from small-sized trucks). These accidents account for 53% (29% from small-sized passenger cars + 24% from small-sized trucks) of the total, and are growing compared with the rate for non-elderly people.

*1 Primary party: This refers to the party at greater fault of the vehicle drivers or pedestrians initially involved in a traffic accident. Or if both parties are at equal fault, then it refers to the party that suffered less physical harm.

In order to reduce the fatal accidents caused by elderly drivers mentioned above, which are on an upward trajectory year by year, this paper will focus on "accidents in which an elderly driver was involved as the primary party." It will use traffic accident macrodata and micro accident research data to analyze and sort out the actual status for accidents caused by elderly drivers. By doing so, it will clarify the causative factors for such accidents and obtain source data for reducing fatal accidents in the future.

3. Actual status and characteristics of accidents by elderly drivers

Fig. 4 shows the trends in the numbers of fatal and casualty accidents up through 2016 by using 2007 as the baseline year. It narrows down the vehicles subject to analysis to four-wheel vehicles, which frequently get into accidents, and divides up the elderly driver group into early-stage elderly (ages 65 – 74) and later-stage elderly (ages 75 and over). Whereas the number of accidents by those in the non-elderly group (ages 18 – 64) has been decreasing and thus improving year by year, the number of fatal accidents by early-stage elderly has been on an upswing over these four years, despite some fluctuation up and down. Among the later-stage elderly group, the number of such accidents has continued to rise since 2009, thus continuing to worsen in the form of a 24% increase over the ten-year period. Conversely, while the number of casualty accidents has been slightly trending downwards since 2014, this decrease has been slowing down. As the proportion of the population consisting of elderly people continues to increase in the future, it is projected that the number of fatal accidents will continue to rise still further unless more effective measures are taken to counter this.

(1) Current status of accidents involving an elderly driver as the primary party

What types of accidents do elderly drivers frequently cause? Fig. 5 shows the composition rate for the number of accidents by accident type involving elderly drivers driving either medium-sized or small-sized vehicles as the primary party, as well as the occurrence rate of fatal accidents, which shows the percentage of fatal accidents versus casualty accidents (hereafter referred to as the "fatal accident rate"). The rate of

casualty accidents consisting of single vehicle accidents is low at 3%, versus 84% for vehicle-vehicle accidents and 13% for pedestrian-vehicle accidents. This reveals that as opposed to rear-end collisions, which are most commonly seen among non-elderly drivers, elderly drivers cause a higher rate of accidents in settings that require awareness of the traffic environment and judgment of the circumstances, such as angle collisions or collisions while turning left / right. Conversely, when it comes to the fatal accident rate, extremely high values are seen with single vehicle accidents like running off the road and collisions with roadside structures, while head-on collisions have extremely high rates among vehicle-vehicle accidents. The rates for later-stage elderly drivers indicated by the numbers in parentheses are even higher.

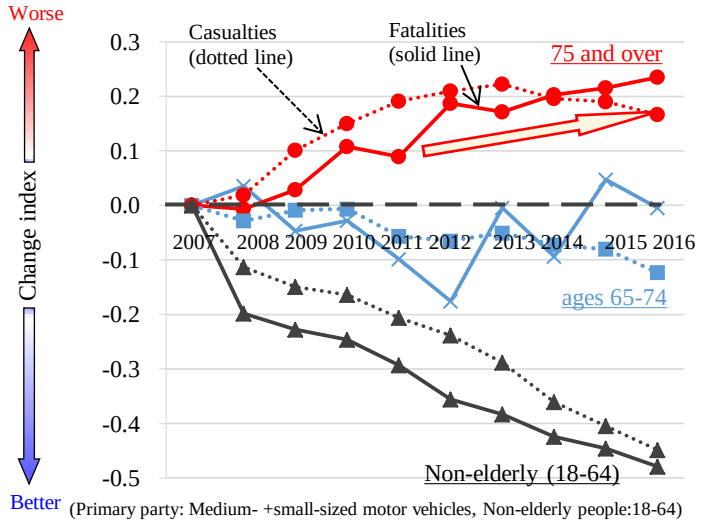


Fig. 4 Trends in the number of accidents by age group

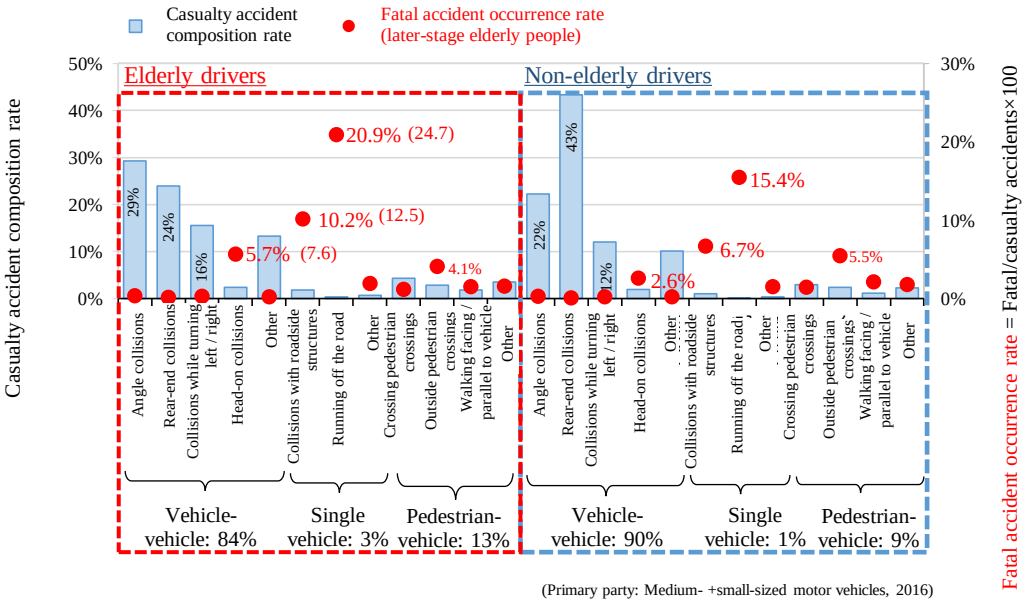


Fig. 5. Casualty accident composition rate and fatal accident rate by type of accident

This reveals that the fatal accident rate for accidents involving elderly people running off the road is particularly high at 20.9%, and is particularly severe among later-stage elderly at 24.7%. It is believed that the majority of these accidents are mainly caused by drivers deviating from their lane while driving as a result of operating errors, or from braking errors.(1) Therefore, this study will focus on accidents with a high occurrence rate from among all accident types, including angle collisions, rear-end collisions, and collisions while turning left / right, as well as head-on collisions, which have a high fatal accident rate, and collisions with roadside structures and running off the road, which both represent single vehicle accidents. The characteristics of and causes for these types of accidents will be analyzed below.

(2) Characteristics of accidents by elderly drivers

[1] Locations where accidents by elderly drivers frequently occur

Fig. 6 shows the composition rate for the number of casualty and fatal accidents for each type of accident by primary party and by road configuration over the ten-year period from 2007 to 2016. This is done for the road environments where angle collisions, collisions while turning left / right, and rear-end collision accidents occurred, which involve numerous casualty accidents due to collisions with four-wheel vehicle, as well as head-on collisions, collisions with roadside structures and accidents from running off the road, which have a high fatal accident rate. The analysis was performed by focusing on four-wheel vehicles and two-wheel vehicles regarding the secondary party.*2

The rates of angle collisions and collisions while turning left / right, which are accidents that frequently involve elderly drivers, for those that occurred at intersections are extremely high at 88% and 72%, respectively. For angle collisions, 76% of these occurred at non-signalized intersections, while 61% of collisions while turning left / right occurred at signalized intersections. This reveals that elderly drivers account for a larger rate of both types of accidents at non-signalized intersections over non-elderly drivers. They also account for no small rate of the accidents along non-intersection roads, such as collisions with other vehicles when pulling out onto a road from a parking lot, gas station, or similar entrance along roadways at 9% and 21%, respectively. Intersections are locations where a great deal of traffic converges and intersects. Since no traffic controls are instituted via traffic lights at non-signalized intersections, there is a particular need for drivers to acknowledge and make decisions on the surrounding traffic environment on their own, and control their vehicle in accordance with this.

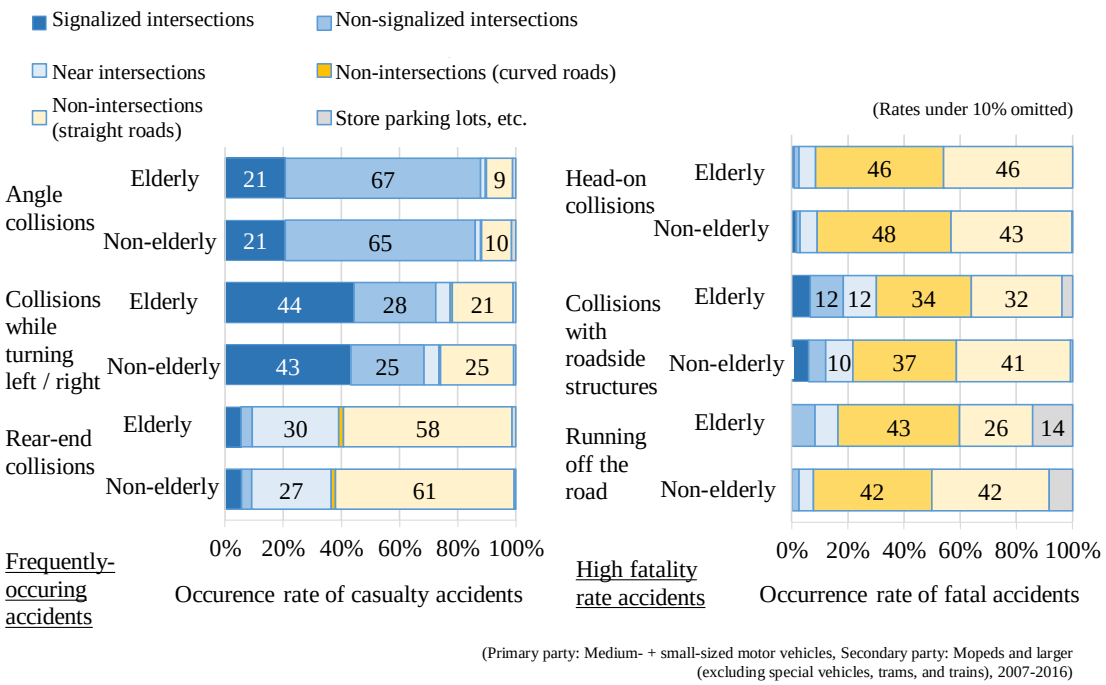


Fig. 6. Occurrence rates of casualty / fatal accidents by road configuration and by presence or absence of traffic signal for each accident type

Therefore, compared with signalized intersections there is an extremely large number of factors that must be confirmed at non-signalized intersections, and they represent an environment that is prone to angle collision accidents. However, for collisions while turning left / right many of the accidents occurred at signalized intersections and, as will be discussed later on, it is known that most of these accidents consist of collisions with oncoming vehicles moving straight when turning right. As for rear-end collisions, 58% of these occurred at non-intersections (straight roads), with 30% of these occurring near intersections. The majority of these are believed to have been caused by a failure to brake in time due to a delay in detecting the vehicle up ahead owing to careless driving or a failure to pay attention forward, or an extended braking distance resulting from the driver's weakened ability to press the brake, regardless of how fast the vehicle was moving.

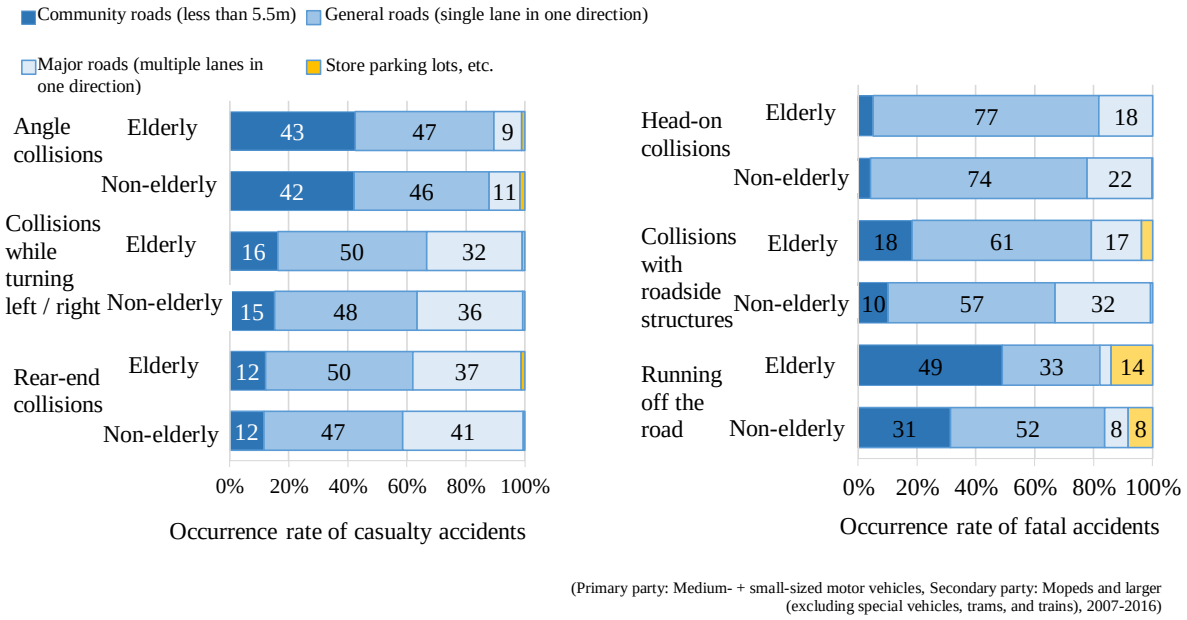
Conversely, with accidents involving running off the road, which carry the highest fatal accident rate, the rate of accidents at non-intersections (curved roads) is particularly high at 43%. Presumably, the drivers in these accidents failed to realize there was a curve up ahead due to a failure to pay attention forward or similar reason, or realized this right before reaching it but were unable to do anything about it, resulting in accidents due to improper driving operations. The rate of these accidents that occur at general traffic locations like store parking lots comes to 14%, with these being characterized by their prevalence compared with the other accident types. Furthermore, 22% of collisions with structures installed along the sides of roads occurred in the vicinity of these locations (which include intersections), while 78% occurred

at non-intersections. This also reveals that the vast majority of head-on collisions occurred at non-intersections at 92%. In cases where drivers deviate from their lane for some reason, such as due to operating errors, at non-intersections (including curved roads) and get into head-on collisions with oncoming vehicles or collide with utility poles or protective fences, the objects they collide with may differ, but they presumably share the same qualities that lead up to the occurrence of fatal accidents.

*2 Secondary party: This refers to the party at lesser fault of the vehicle drivers or pedestrians initially involved in a traffic accident. Or if both parties are at equal fault, then it refers to the party that suffered greater physical harm.

[2] Road environments at locations where accidents by elderly drivers frequently occur

As opposed to the road configurations where accidents frequently occur mentioned in the preceding paragraph, Fig. 7 similarly shows the composition rates for the number of casualty and fatal accidents by road environment, such as road width, for the type of accidents regarding casualty accidents that occur frequently and those with high fatal accident rates.



(Primary party: Medium- + small-sized motor vehicles, Secondary party: Mopeds and larger (excluding special vehicles, trams, and trains), 2007-2016)

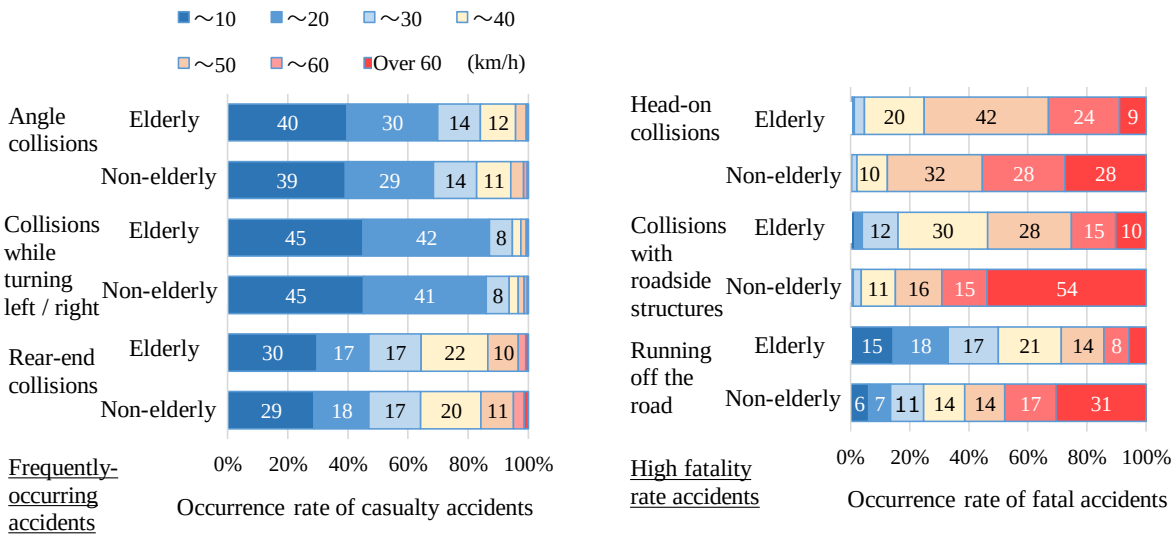
Fig. 7. Occurrence rates of casualty and fatal accidents by road type for each accident type

In general, accidents on general roads with single lane in one direction, which is the most common type of road in Japan, account for the majority of these. A higher rate of angle collisions is seen on community roads where the road is less than 5.5m wide, while a higher rate of collisions while turning left / right and rear-end collisions occur along major roads with multiple lanes in one direction. However, virtually no difference is seen between elderly people and non-elderly people. Conversely, a large percentage of accidents involving running off the road occur on narrow roads like community roads at 49%. These conceivably lead to serious accidents, including those where the driver's wheels run off into roadside ditches and their vehicle overturns, as well as where the vehicle falls into a field or waterway that is lower

than the road, or where they collide with structures off the side of the road. This also reveals that 14% of fatal accidents occur in store parking lots and the like, which is a relatively large rate compared with other types of accidents.

[3] Danger perception speed of elderly drivers

Generally speaking, the faster the traveling speed of the vehicle when collision accidents occur the greater the force of the collision, while the larger the size and greater the weight of the vehicle collided with the greater the damage done to one's vehicle, resulting in more serious accidents. Therefore, Fig. 8 shows the composition rate for the number of accidents divided up into 10km increments when the danger perception speed is 60km/h or less, [(2)] where most accidents involving elderly drivers occur, and those over 60km/h, by type of accident using the danger perception speed as one of the indicators. The danger perception speed is the speed the vehicle was traveling when the elderly driver driving the primary vehicle detected the other vehicle and perceived that they were in danger of colliding with said vehicle. This shows that the types of accidents that occur most frequently are angle collisions and collisions while turning left / right, with the majority of these occurring at low speeds of 30km/h or less at 84% and 95%, respectively. It also reveals that for rear-end collisions this grows to 36% at moderate to high speeds over 30km/h. However, it also indicates that there is virtually no difference when you compare the casualty accident composition rate by danger perception speed of elderly drivers and non-elderly drivers for each type of accident. Conversely, with head-on collisions and collisions with roadside structures, which have a high fatal accident rate, both of these have a high rate of fatal accidents at moderate to high speeds of over 40km/h at 75% and 53%, respectively. As opposed to this, accidents from running off the road account for 15% of the accidents that occur at extremely low speeds of 10km/h or less compared with other accident types. However, this type of accident occurs at the same rate across all the speed ranges for danger perception speeds of 50km/h or less. Running off the road can lead to one's vehicle falling, toppling over, rolling over, or colliding with structures off the side of the road after one's vehicle has deviated off, regardless of how fast the vehicle was traveling. This tends to inflict lethal damage on the vehicle's passengers, and therefore it could be described as an extremely serious accident type. In addition, on comparing the composition rates for the danger perception speeds of elderly drivers and non-elderly drivers, you find that elderly drivers do not go as fast as non-elderly drivers and drive in a compensatory manner that lessens the risk of accidents to some small extent by curbing their speed.[(3)] Yet despite this, elderly people are connected to fatal accidents for some reason that is unique to them.



(Primary party: Medium- + small-sized motor vehicles, Secondary party: Mopeds and larger (excluding special vehicles, trams, and trains), 2007-2016)

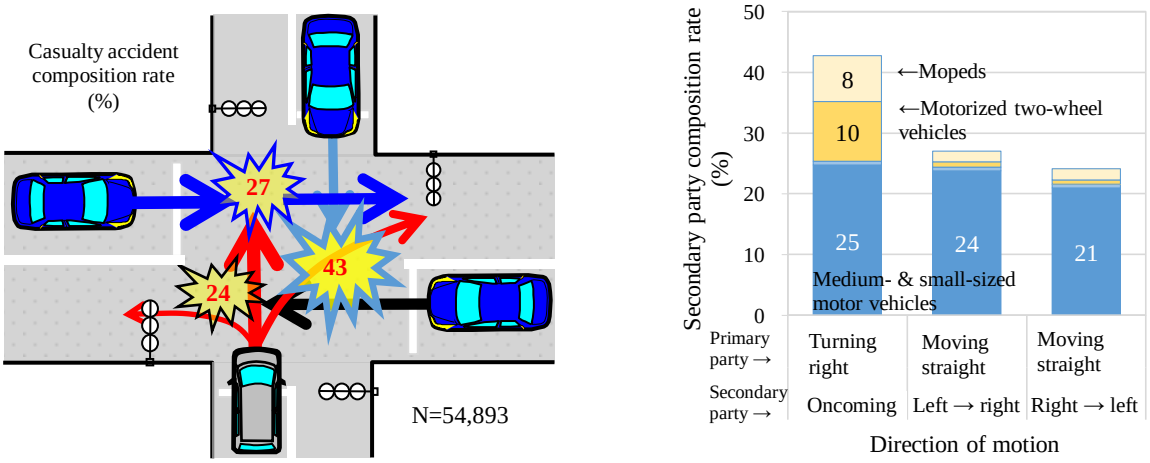
Fig. 8. Occurrence rates of casualty and fatal accidents by danger perception speed for each accident type

[4] Characteristics of accidents by elderly drivers at intersections

This section will take a look at the current status of intersection accidents, which frequently consist of casualty accidents caused by elderly drivers driving four-wheel vehicles, by whether the intersection was signalized or non-signalized.

- **Status of accidents at signalized intersections**

Angle collisions and collisions while turning left / right at signalized intersections are typical collision accidents that account for 31% of the total number of accidents at intersections. For these, the composition rate for the number of collision casualty accidents between an elderly driver driving a four-wheel vehicle as the primary party and a four-wheel vehicle or two-wheel vehicle as the secondary party by type of movement of the primary party is shown in Fig. 9 in the figure on the left, while a breakdown that also includes the direction of movement of the secondary party is shown in the bar graph on the right.



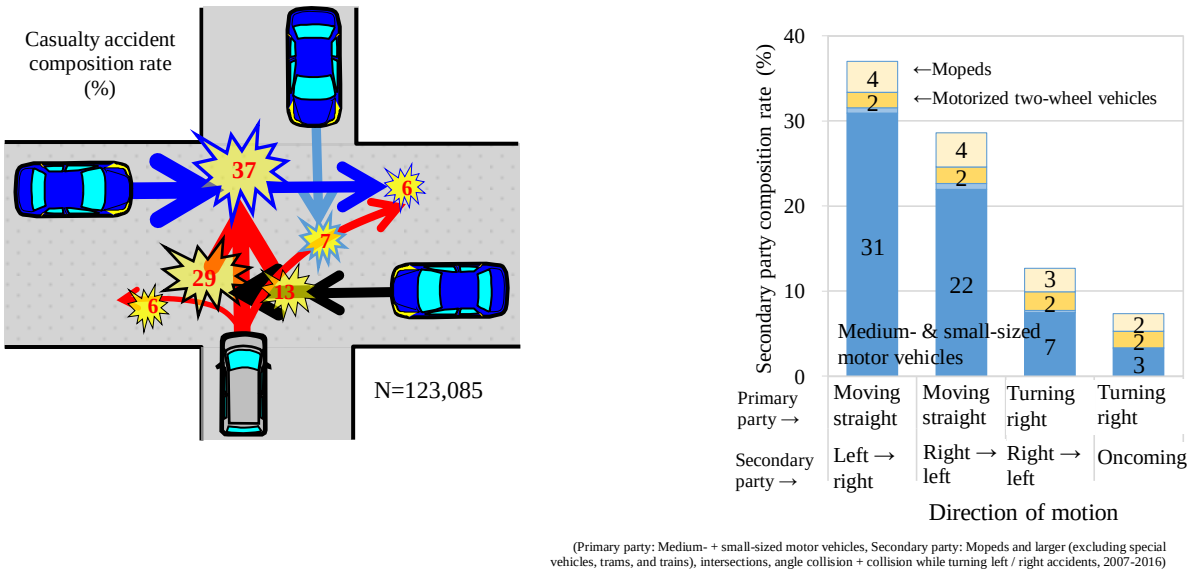
(Primary party: Medium- + small-sized motor vehicles, Secondary party: Mopeds and larger (excluding special vehicles, trams, and trains), intersections, angle collision + collision while turning left / right accidents, 2007-2016)

Fig. 9. Status of accidents involving elderly drivers as the primary party at signalized intersections

As can be gleaned from the rate of accidents, accidents between a vehicle turning right and one moving straight involving an elderly driver as the primary party colliding with an oncoming vehicle when turning right are the most typical at 43%, with motorized two-wheel vehicles (including mopeds) accounting for 18% of these. With these, numerous cases of accidents were seen in which the elderly driver completely failed to notice the other party prior to colliding with them. These were due to reasons such as misjudging the speed of or sense of distance to the oncoming vehicle as a result of the declining dynamic visual acuity that comes with aging as one reaches old age, or from failing to perceive the oncoming vehicle within their visual field for reasons such as a narrowing of their visual field. Moreover, there are numerous accidents involving collisions with vehicles coming from the left or right, regardless of whether or not the intersection had a traffic signal. From the analysis it was learned that most of these were caused by the person failing to notice the traffic signal.

・Status of accidents at non-signalized intersections

Angle collisions and collisions while turning left / right at non-signalized intersections account for 69% of the total for all accidents at intersections. The status for these collision accidents is shown in Fig. 10, similar to the accidents at signalized intersections. This reveals that the nature of accidents involving elderly drivers as the primary party at non-signalized intersections differ slightly from those of accidents at signalized intersections. Whereas there were a great many accidents between a vehicle turning right and one moving straight at signalized intersections, these were rare at non-signalized intersections at 7%. The most common accident pattern involved the primary party vehicle driven by an elderly driver entering the intersection with the intention of moving straight and immediately colliding with a vehicle that had been approaching from the left. Such accidents account for 37% of the total. Moreover, collisions with vehicles approaching from the right are also common at 29% of the total. There is also no shortage of cases involving collisions with vehicles approaching from the right immediately after entering an intersection with the intention of turning right, at 13%. The declining physical function that results from aging is thought to have a considerable impact on accidents that occur when moving straight through an intersection. Examples of this include overlooking stop signs, noticing that there is a stop sign but being unable to bring one’s vehicle to a stop in time, or the aforementioned narrowing of one’s visual field or small angle with which elderly drivers can turn their heads when checking that it is safe on either side.



(Primary party: Medium- + small-sized motor vehicles, Secondary party: Mopeds and larger (excluding special vehicles, trams, and trains), intersections, angle collision + collision while turning left / right accidents, 2007-2016)

Fig. 10. Status of accidents involving elderly drivers as the primary party at non-signalized intersections

4. Causative factors for accidents by elderly drivers

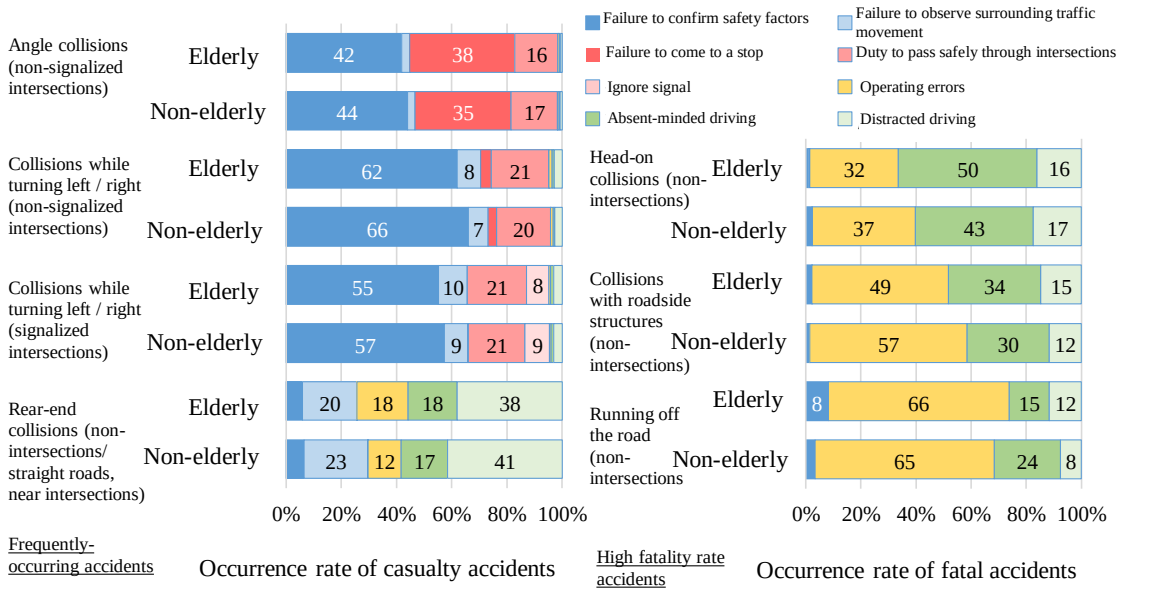
The previous section discussed the characteristics of accidents commonly caused by elderly drivers and six accident types with high fatal accident rates. Now, we will look at the question of why these accidents occurred by focusing on the factors of driver's legal violations and human negligence from among the causative factors intertwined with many of these accidents.

(1) Legal violations serving as causative factors for accidents

Many traffic accidents are caused by legal violations. Fig. 11 shows the status for this in terms of the composition rate for the number of casualty accidents and number of fatal accidents by major legal violations for each type of frequently-occurring accident, high-fatality rate accident, and road configuration (including traffic signals). The locations where accidents occurred for each type of accident are indicated by narrowing this down to respective locations where a large rate of accidents occurred as shown in Fig. 6.

Regarding accidents that frequently occur at intersections, the majority of these were caused by a failure to confirm safety factors and violations of mandatory safe driving. As for angle collisions at non-signalized intersections, violations involving a failure to come to a stop accounted for 38% of the total of these. However, almost no difference was seen in the rates for this based on age. Collisions while turning left / right at these same non-signalized intersections have a lower rate accounted for by a failure to come to a stop, but conversely more of them are due to a failure to confirm safety factors and failure to observe surrounding traffic movement. With these same collisions while turning left / right, a low rate of them are caused by violations involving ignoring traffic signals at signalized intersections, but this is trending upwards. The rate of violations involving a failure to come to a stop and ignoring traffic signals tend to increase among elderly people the older they get, presumably because of their increased number of perceptual errors such as failing to notice traffic signals, signs, and road markings.[(4)] Distraction accounts

for a large number of rear-end collisions at 38%, but this also reveals that they engage in all manner of other violations aside from this. When you consider the range of danger perception speeds of elderly drivers for the accidents that occurred in Fig. 8, then presumably the nature of each violation differs. Of these, operating errors such as delay in applying the brakes were more common with elderly people than with non-elderly people. The claim could be made that this is affected in no small part by their decline in physical function, such as misreading the distance between their vehicle and the preceding vehicle, or decrease in power to press the brake pedal.



(Primary party: Medium- + small-sized motor vehicles, Secondary party: Mopeds and larger (excluding special vehicles, trams, and trains), 2007-2016)

Fig. 11. Occurrence rates of casualty / fatal accidents by legal violation for each type of accident and road configuration

Fig. 6 indicated that most accidents with a high fatal accident rate occur at non-intersections. But more than 80% of all accident types are caused by operating errors or careless driving. The rate of head-on collisions and collisions with roadside structures accounted for by careless driving tends to be higher with elderly people than with the non-elderly. It is believed that such accidents occur for reasons like the driver being delayed in realizing that their vehicle has strayed from its path of motion as a result of careless driving and, when something unexpected suddenly happens, getting flustered and suddenly turning the wheel or being unable to brake properly. As for accidents involving running off the road, which have the highest fatal accident rate of all accident types, 66% of these are caused by operating error violations, making this their primary cause. Although not much difference is seen in the composition rate for operating error accidents with non-elderly drivers, it is known that there are differences in the content of the operating errors.[(5)] As this indicates, patterns for legal violations vary due to a combination of the accident type and the locations where they occurred.

(2) Human negligence serving as causative factors for accidents

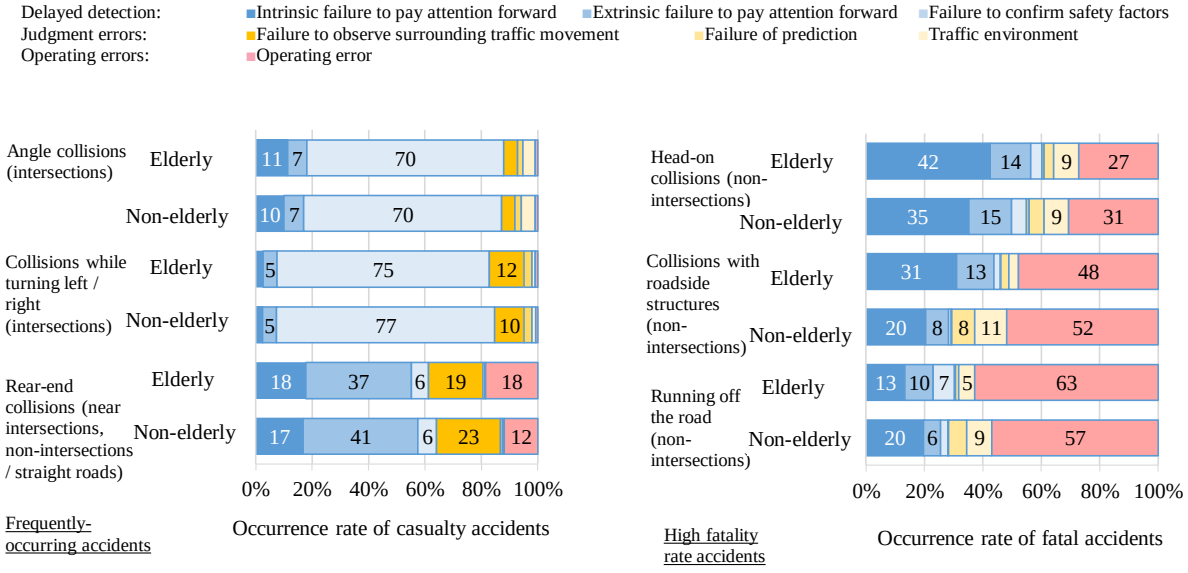
Legal violations by the party that caused the traffic accident are frequently cited as the cause for said accidents. But it is commonly known that elderly drivers naturally engage in compensatory driving in order to reduce the risk of accidents. However, these are often caused by human negligence, and as a result the violation the driver perpetrated often leads to the accident.(6) Numerous items can be brought up when you consider the causes attributable to human negligence that occur when driving a four-wheel vehicle. Here, the most common human factors leading to accidents caused by elderly drivers were divided up into a total of seven items, as shown in Table. 1. These include intrinsic / extrinsic failure to pay attention forward and failure to confirm safety factors, which lead to delayed detection of other vehicles, judgment errors that tend to be influenced by cognitive decline, such as mistakenly assuming the other vehicle will yield to them or misjudging the speed of and distance to the other vehicle, as well as operating errors involving mishandling of the steering or braking caused when their vehicle deviates from the lane it is traveling in. Based on these causative factors, characteristics of elderly drivers will be considered.

Table 1. Causes attributable to human negligence

Type of human factors among drivers		
Delayed detection	Intrinsic failure to pay attention forward	Psychological / physiological factors (dozing off, being lost in thought, or other absent-minded driving, chatting)
	Extrinsic failure to pay attention forward	Causes accompanying actions (dropping something, distracted by the scenery / other vehicles, etc.)
	Failure to confirm safety factors	Neglecting to confirm safety despite decelerating down to a speed at which confirmation can be made and failing or being delayed in detecting the other party
Judgment errors	Failure to observe surrounding traffic movement	Detecting hazards but mistakenly thinking they pose no specific risk or erroneously neglecting to pay attention to one's surroundings
	Failure of prediction	Mistaken impressions while driving such as the speed of one's own vehicle and the speed of, distance to, and behavior of another vehicle, erroneously thinking the other party is yielding
	Traffic environment	Misapprehension or misidentification of the traffic environment, such as the road configurations or traffic regulations
Operating errors	Operating error	Making an operating error despite confirming the danger and taking measures for it, or growing hesitant to take action based on surprise / fright (steering error, misapplication of pedals, weak braking)

Fig. 12 shows the composition rate for the number of casualty and fatal accidents by seven different human factors for each frequently-occurring and high fatality rate accident type, and each road configuration on which accidents frequently occur. In terms of the human factors for angle collisions and collisions while turning left / right, which are the accidents that occur most frequently at intersections, more than 80% of

these were due to delayed detection. Of these, 70% consisted of cases where a failure to confirm safety factors led to an accident. Examples of this include when the driver fails to confirm safety factors immediately prior to entering an intersection or insufficiently confirms safety factors (which all constitute neglecting safety), despite the driver decelerating to a speed where they could confirm the presence of another vehicle. Specifically, it is commonly known that many of the elderly drivers who cause accidents suffer from a narrower field of vision, decreased angle at which they can turn their head, or a decline in their dynamic visual acuity as they get older. This decline in visual performance, which makes it harder to detect vehicles approaching from the sides, for example, is believed to be one of the major factors for their failure to confirm safety factors. As a result, it is understood that an exceptionally large number of cases involve elderly drivers causing accidents because they failed to detect another vehicle until immediately prior to the collision. With rear-end collision accidents that occur near intersections or at non-intersections, a larger rate of these are due to both an intrinsic and extrinsic failure to pay attention forward (such as from distracted driving) out of the delayed detection category. There are also numerous cases in which judgment errors, such as when a driver starts up their vehicle after misjudging the movement of the preceding vehicle, lead to accidents. The same holds true for operating errors, such as drivers getting flustered for some reason and misapplying the brake / accelerator pedals, or extending the braking distance as a result of weakly applying the brake pedal. Conversely, this graph reveals that—as a general rule—operating errors account for a larger rate of the accidents that occur at non-intersections. Compared with non-elderly people, elderly drivers had a larger rate of head-on collision and collisions with roadside structures caused by an intrinsic failure to pay attention forward. As for accidents where they run off the road, operating errors served as a factor that caused them to deviate from their lane, and account for as much as 63% of these accidents. For elderly drivers in particular, while they do not drive all that fast, the claim could be made that they cause accidents as a result of multiple overlapping factors. These include delayed application of the brakes, failing to cut the wheel, and other operating errors, as well as misjudging the size of curves, failure to pay attention forward, and more. This is also thought to be influenced by the fact that elderly people, as opposed to the non-elderly, have a higher rate of running off the road accidents attributable to operating errors involving mistakes with braking and steering rather than a failure to pay attention forward.(7)



(Primary party: Medium- + small-sized motor vehicles, Secondary party: Mopeds and larger (excluding special vehicles, trams, and trains), 2007-2016)

Fig. 12. Occurrence rates of casualty / fatal accidents by human factor for each type of accident and road configuration

(3) Detailed breakdown of human factors

A more detailed breakdown of the human factors discussed in the previous section is shown in Fig. 13. This discussion of the human factor items should be prefaced by the fact that it focuses on how a comparatively large number of casualty accidents are caused due to human error by elderly drivers, and that the figures indicated in the bar graphs represent the composition rate for the number of accidents that also include other items as well.

Angle collisions and collisions while turning left / right are accidents that occur at intersections are mainly caused by the delayed detection of the other vehicle. The majority of these accidents are due to a failure to adequately confirm safety factors, but it has also become apparent that some are due to a complete failure to confirm safety factors. Even among road environments that are changing from moment to moment, intersections in particular are overflowing with an over-abundance of information necessary to travel through them safely. They are locations where numerous human errors are prone to occurring, such as from a failure to observe traffic signs or hazards. In such locations that are at high risk of accidents occurring, 45-46% of accidents are due to a failure to confirm safety factors, potentially making this a point that merits scrutiny. As for collisions while turning left / right, the rate of these caused by a failure to pay attention when there is no specific threat in particular is 10%, which is no small figure. This suggests that determinations based on mistaken assumptions are potentially leading to accidents. While rear-end collision accidents are caused by a number of different factors, compared with non-elderly people a large rate of such accidents involving elderly drivers are caused by failing to apply the brakes with enough force. This is presumably also affected not only by their sense of inter-vehicular distance with the preceding vehicle, but

also by the decline in the physical strength of their legs as well as their mental agility. Conversely, Fig. 12 showed that head-on collisions, which have a high fatal accident rate, are oftentimes caused by an intrinsic failure to pay attention forward. The rate caused by being lost in thought and other forms of careless driving of 31% is large compared with that of non-elderly people, on top of which 12% are due to dozing off. When drivers get lost in thought they neglect to confirm safety factors up ahead of them. It is believed that even though elderly drivers do not drive excessively fast, they fail to realize when their vehicle deviates into the oncoming traffic lane, causing them to collide with oncoming vehicles. This holds true not only on curved roads, but on straight ones as well. Conversely, compared with accidents at intersections, these accidents are characterized by the fact that most of them are attributable to improper steering from among the operating error category. Collisions with roadside structures share the same properties as the causes for head-on collision accidents that occur when a driver deviates from their lane. However, there tends to be a larger rate of these attributable to steering operating errors as opposed to head-on collisions.

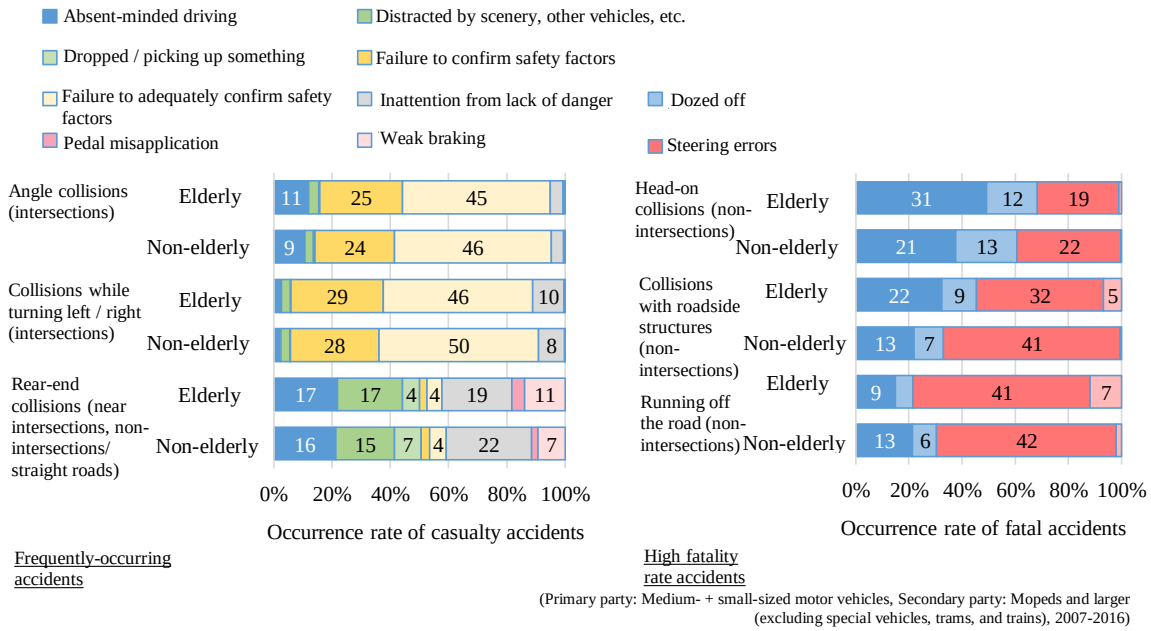


Fig. 13. Occurrence rates of casualty / fatal accidents by detailed human factor for each type of accident and road configuration

While misapplications of the brake and accelerator pedals account for a small rate at 5%, this graph reveals that this is a causative factor not observed among non-elderly people. This also reveals that a larger percentage of running off the road accidents are attributable to steering operating errors and misapplication of the pedals than with head-on collisions and collisions with roadside structures. While there is no difference in the rate caused by operating errors between elderly and non-elderly drivers, there is a drastic difference in the percentages for the different danger perception speeds at the time accidents occurred as shown in Fig. 8. Therefore, even though the operating error is the same, it seems that the circumstances are different.

(4) Conditions when accidents by elderly drivers occur (microdata analysis)

Based on the human error factors among elderly drivers discussed up through the previous section, cognitive judgment error samples were deduced for 206 accidents and 371 items from among the micro accident survey data for the past ten years from 2006 – 2015. Then the results of interviews with elderly drivers for each accident type and each cognitive judgment error from right before an accident with a comparatively high composition rate occurred were analyzed. The results of this are shown in Fig. 14. Looking at this by the major brackets here reveals that most of the cases involved accidents caused when the driver failed to pay attention to the traffic environment in particular, with these accounting for 42% of the total. This also indicates that a great deal were due to a decrease in concentration, which is interlinked with intrinsic factors, at 20%, as well as obstructed vision (including delayed detection of the other vehicle due to poor visibility) at 15%. First off, the item "Not paying particular attention" included familiarity with routine driving, with respondents saying things like "I thought the road was deserted, so I never expected a car to come from the side" and "Because it's a road I'm familiar with that I drive all the time." This familiarity makes it harder to recognize changes in the traffic environment, and produces carelessness on a grand scale. In other words, given their long years of driving experience, these drivers internalize a form of "habituated driving" in which they drive automatically without conscious awareness. This suggests that awareness of circumstantial changes is perhaps something that declines without the person being consciously aware of it.

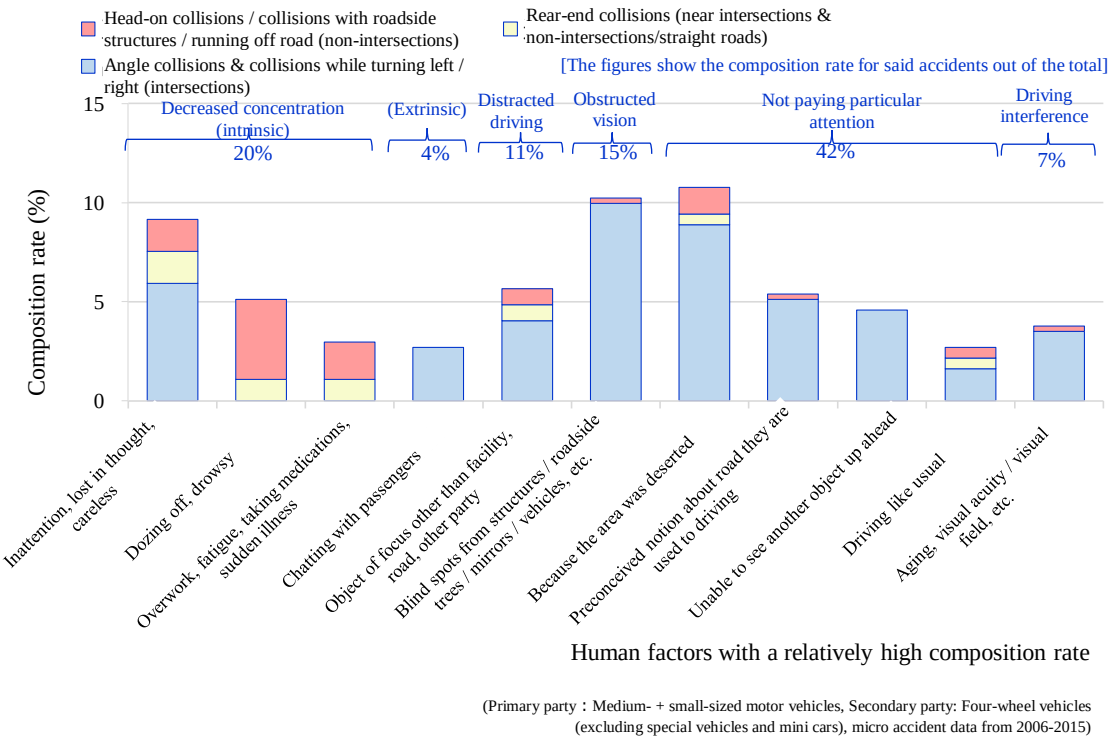


Fig. 14. Results of interviews with elderly driving party by human factor for each accident type

Moreover, based on an analysis of the results of interviews with the parties to accidents, one characteristic they are presumed to have is that the accidents occurred while the driver was unable to do anything to avoid them, either from failing to recognize the other party or from being unable to take evasive action despite recognizing the danger. Examples of this include responses like “I was completely unaware of the other vehicle until we crashed” and “I got flustered and couldn't do anything.” While items dealing with taking medication and sudden illness have small composition rates among the decreased concentration (intrinsic) items, they lead to accidents and are considered to be characteristic of elderly drivers. There are also a comparatively large number of cases in which drivers got into accidents because they were driving by falling back on customary habits as they normally do despite the fact that they were in an unsafe situation, such as a road environment with poor visibility around an intersection on account of obstructed vision.
Now then, the question is how do drivers find themselves in such situations? We will take a look at this by using behavioral error models for elderly drivers, who are prone to causing accidents, in the next section.

5. Causative factors for accidents by elderly drivers

(1) Driving behavioral model

A general driving behavioral model for driving a vehicle safely is shown within the box with the dotted line in Fig. 15. This involves instantaneously ascertaining information needed to drive safely based on a large volume of information taken in from outside. This includes information on the traffic environment, which is changing from moment to moment, as well as on the natural environment, such as the conditions of and weather along the roads they are driving. It also involves detecting and recognizing hazards and instantaneously making decisions on the extent to which they should respond in their own driving and the timing for this, then taking the appropriate response. In addition, drivers must continue to drive safely by promptly and perpetually rotating through this cycle based on information provided as feedback and the various environmental information all around them. Drivers must fully utilize their own physical function in order to do this. But with elderly drivers it is assumed that they get into accidents because they are no longer able to smoothly rotate through this “Perceive – Decide – Act” cycle due to their reduced physical function as a result of aging. For example, they tend to overlook hazards and signs or make judgment errors as a result of said decline, rendering them incapable of skillfully tying this in with their subsequent actions. Illnesses and other such factors further exacerbate the impact on safe driving.

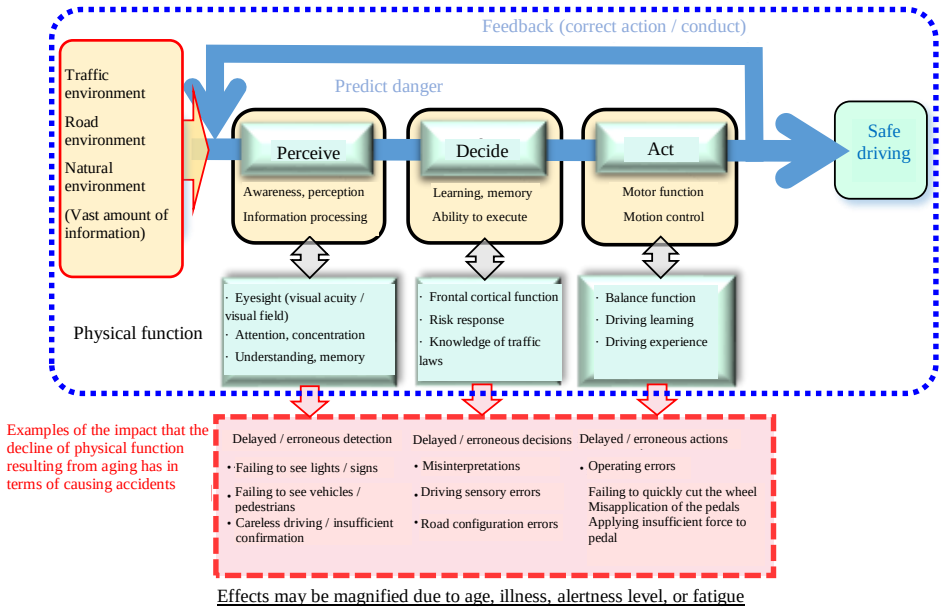


Fig. 15. Driving behavioral model and the effects of aging

(2) Unsafe driving behavioral model characteristic of elderly drivers

There are case examples to be found among those elderly drivers who caused accidents in which they were driving a vehicle they were unfamiliar with, such as driving the family car or switching over to a new car. However, one frequently hears comments from the parties to accidents like “I got flustered” and “Before I knew it I had caused an accident” in recent accident reports. The question of why elderly drivers are no longer able to smoothly rotate through the behavioral model for safe driving will be considered based on the behavioral model for unsafe driving characteristic to elderly drivers who cause accidents that is shown in Fig. 16. As a result of the decline in physical function that accompanies aging, elderly drivers may be receiving less of various types of information obtainable from the outside world as a result of a narrowing of their visual field, for example, which can lead to a lack of information that by nature is crucial for safe driving. What is more, declining capabilities when it comes to attentiveness, comprehension, and so forth further reduces the amount of information they can take in. Therefore, the thinking is that errors and delays in judgment occur, which produce imperfect situations when it comes to predicting danger, such as drivers being unable to pick up on some of the information needed in order to drive their vehicle safely. In addition, elderly drivers have a particularly pronounced tendency to make decisions after their own fashion by relying on the habits they have accumulated over their many years of driving experience. This reduces their ability to properly make decisions and respond according to the traffic environment, which changes from moment to moment, and therefore increases the risk of accidents occurring.

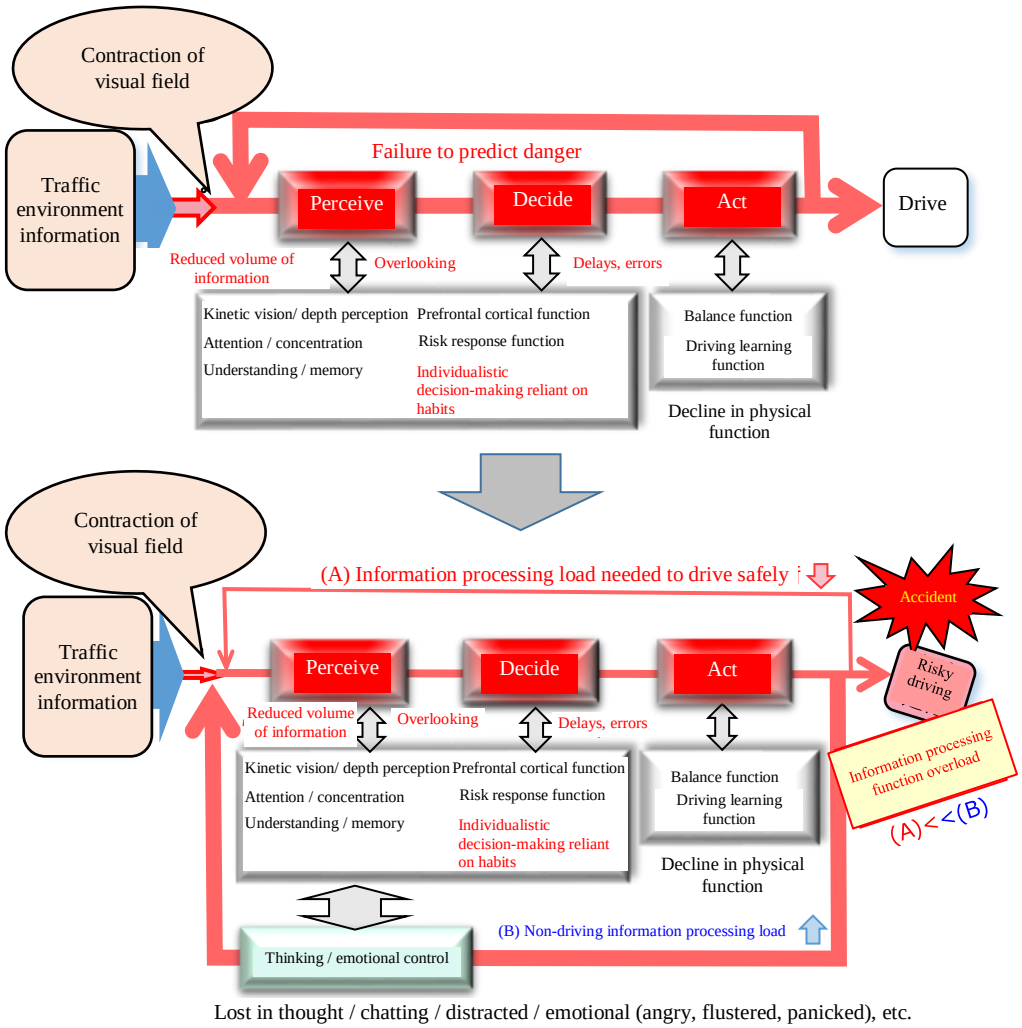


Fig. 16. Unsafe driving behavioral model for elderly drivers

Given such conditions, when a totally unexpected phenomenon suddenly occurs—such as when one's vehicle juts out into the oncoming vehicle lane and collides with another car—the situation changes to the accident occurrence model shown in the model diagram on the bottom. The information processing load (B) required for emotional control exerted in an effort to suppress thoughts not related to driving, such as those when something unexpected has happened, as well as to suppress one's surprise and sense of being flustered, suddenly soars. As a result, the information processing load (A) which they need to drive safely plummets, and they are unable to respond by avoiding danger, let alone realizing that they are still driving incorrectly. Accidents occur when (B) exceeds (A) and the capacity that can be handled by their information processing faculties (which have declined with age) overloads. When the load condition for (B) further surpasses that of (A), major accidents occur. In other words, conclusions that can be drawn from this include the fact that the capacity for the information that elderly drivers can process in the moment declines as they age, their information processing load balance can easily become significantly tilted to thinking / emotional control, and their driving skills that have become habituated and which have never led

them to cause an accident over a long period of time can make them overconfident in their driving, thereby giving rise to accidents.

(3) Model for accidents occurring due to operating errors by elderly drivers [5]

It was previously mentioned how elderly drivers tend to drive relatively more safely compared with non-elderly drivers through compensatory driving and the like. But it is also commonly known that the decline in physical function that accompanies aging produces inconsistencies between one's intentions and actions, which can lead to operating errors. Therefore, an example of an accident occurrence model for the pedal misapplication operating errors characteristic of elderly drivers (which cause accidents with high fatal accident rates among elderly drivers) is shown in Fig. 17. When it comes to driver conduct for driving safely, based on the information processing model required for safe driving behavior, the traffic and road environment situation and various other data needed to continue driving safely is taken in cognitively through one's sensory functions in the form of information. This activates "driving schema," and results in driving that occurs in accordance with sensorimotor patterns unconsciously and automatically. Since drivers with a long track record of driving experience are more used to driving, normally when they drive they do so without being consciously aware of the act itself all that much. However, the thinking is that, should some sort of error occur with this driving schema, this will lead directly to operating errors and therefore cause accidents. As shown in the figure below, errors in the schema for applying the brake pedal, such as mistakenly applying the accelerator pedal instead of the brakes for example, are thought to potentially occur as shown below (excluding cases caused by physical functions, such as declining leg strength).

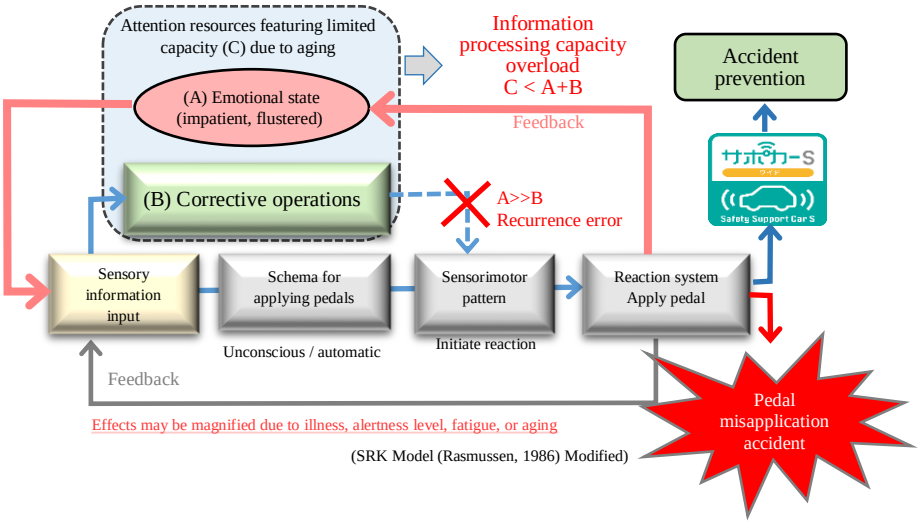


Fig. 17. Example of an accident occurrence model resulting from operating errors by elderly drivers

- The intention to step on a pedal alone activates, and the driver intends to apply the brake pedal located on the left-hand side. However, they actually end up applying the accelerator pedal, which is located slightly to the right from the center of the driver's seat.

- The driver has erred in assessing the situation and instead applied the accelerator pedal, when the situation inherently should have involved applying the brake pedal.
- While the driver intended to apply the brake pedal, since this is similar to the situation whereby they normally apply the accelerator pedal, they instead ended up applying the accelerator pedal.

Even if the driver makes a mistake in applying the pedals, when they only have a small load of information that must be processed regarding the driving environment and their own emotional state, then they can take some sort of corrective action. An example of this would be realizing right away that they made an operating error, thereby working to correct their actions by devoting attentional resources to their own driving, and then taking their foot off the accelerator pedal. It is safe to assume that most elderly drivers have previously had experiences like where they have pressed the accelerator then pulled their right foot off the pedal when they accelerated faster than they meant to. Or where they made a mistake when shifting gears and started moving forward when they meant to go in reverse, figured out what was happening right away, and took their right foot off the accelerator. However, while this happens to non-elderly drivers as well, for most elderly drivers when an unexpected phenomenon occurs, such as a schema error leading them to misapply the pedals and sending their vehicle shooting out of control, this can induce emotional states such as desperation and cause them to get flustered. When this happens, most of their limited attention resources (C) are devoted to processing their emotions (A) and cannot be used for correcting their driving (B). So when this schema remains uncorrected once it has been activated, the act of pressing the accelerator pedal once more continues to be repeated over again. Oftentimes these sorts of human errors are especially dominated by the habits we have internalized and occur unconsciously and automatically, and therefore it is difficult for the driver to prevent them through their own efforts alone. With elderly drivers, the capacity and processing functions they need to process information decline as they get older. As such, they require countermeasures from the external environment, such as the Safety Support Car S Wide, even though these cannot handle every scenario.

6. Reducing accidents by elderly drivers

(1) Improvements for reducing the risk of accidents without being overly-reliant on long-standing driving habits

- Enhancing danger prediction and avoidance skills in a hands-on manner that people will not tire of
- Fun learning designed to improve skills

Improving danger prediction capabilities that are not dependent upon driving habits is important when it comes to getting drivers to drive their vehicles safely. Elderly drivers have a tendency to drive by relying on their long-standing driving habits, and so they must be made self-aware of the decline in their own physical function and the extent to which this has occurred. At present, opportunities for elderly drivers to take driving training courses have been established in law when they renew their driver's licenses. In addition to these, there are also opportunities where they can have their driving skills objectively evaluated through practical skills training and driving practice simulators. But it is conceivable that many elderly

drivers who are self-confident when it comes to their driving will refrain from taking up these sorts of opportunities, perhaps because they tend to think that they are fine unless strongly prompted to think otherwise for some reason. Therefore, it will perhaps be necessary to devise ways to enhance elderly drivers' danger prediction and risk avoidance skills in a manner suited to various places and settings. This can be done by, for example, developing and popularizing fun learning apps that can instill drivers with awareness and consciousness while they have fun learning with a simple game feel that they can play at home and which they won't tire of by utilizing VR technologies that combine together technologies like smartphones and simple goggles.

(2) Further improving the road traffic environment

- Substantially reducing the volume of information that must be processed while driving
- Installing / establishing road sign designs with outstanding visibility suited to the physical characteristics of elderly people

Ideally, further improvements are expected be made to the road traffic environment in order to reduce the volume of external information that must be processed while driving and enable drivers to properly rotate through the safe driving cycle. Examples of this include improving the visibility of road signs that are suited to the physical characteristics of elderly drivers to ensure that they do not overlook or misjudge them, as well as designing intersections in which traffic does not intersect.

(3) Popularizing the Safety Support Car S and advancing driving support technology

- Understanding the effectiveness of the Safety Support Car S and proactively introducing it to the market
- Setting in place an environment for boosting elderly people's motivation to purchase safety vehicles
- Advancing Human Machine Interface (HMI) driving support technology

Currently, government agencies, local governments, JAF, auto manufacturers, and others are working together to hold hands-on test drive sessions for the Safety Support Car S all around the country. The fact that drivers are being given the chance to actually drive these cars and experience their positive aspects is outstanding. However, many elderly drivers still do not fully understand the effectiveness and advantages of the Safety Support Car S, while there are presumably a great many of them who do not even know the first thing about it. The hope is that activities to promote the popularization of safety vehicles will be carried out in striving to boost elderly people's motivation to purchase them. In particular, the hope is that the Safety Support Car S Wide (which is equipped with a lane-deviation warning system) shown in Table 2 will be introduced to the market and the market for this will be expanded from an early date in order to reduce accidents from running off the road, collisions with roadside structures, and head-on collisions, which carry a particularly high fatal accident rate. In conjunction with this, the hope is that driving support technologies centered around HMI will be advanced, with consideration given to typical accidents caused by elderly drivers.

Table 2. Ancillary functions equipped on the Safety Support Car S

Symbol	Description
	**Support Car S Basic** · Automatic braking at low speeds (versus oncoming vehicles) · Acceleration control device for when the pedals are misapplied
	**Support Car S Basic+** · Automatic braking (versus oncoming vehicles) · Acceleration control device for when the pedals are misapplied
	**Support Car S Wide** · Automatic braking (versus oncoming pedestrians) · Acceleration control device for when the pedals are misapplied · **Lane deviation warning device** · Advanced lights

(4) Promoting research into the special characteristics of elderly drivers

- Research into quantitatively assessing driving characteristics that come about as a result of declining physical function
- Research into human characteristics designed to improve information processing faculties
- Investigating measures to prevent accidents from a psychological dimension

It is strongly hoped that various research institutes will promote human research on not only physical function, but also the psychological characteristics unique to elderly people, in order to cut down on accidents by elderly drivers.

Conclusion

As the population of elderly people continues to rise in the future, we must succeed in further reducing the number of fatal accidents. For this, there are incredibly high hopes that the achievement of autonomous vehicles will be effective at preventing traffic accidents by compensating for the driver's cognition and decision-making, as well as their operating errors. However, the time when all vehicles on the market come equipped with self-driving technology is still off in the distant future. When this is taken into consideration, it is conceivable that new accidents will occur under a traffic environment in which vehicles equipped with cutting-edge safety technologies and ordinary vehicles are intermixed. As such, it is important that all drivers have a strong sense of safety awareness prompting them to absolutely avoid causing accidents without being bound by their own distinctive driving habits, in order for Japan to achieve the world's safest road traffic environment.

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