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Elderly Driver Cognitive Function and Traffic Accidents
—Cognitive Assessment Utilization and Actual Vehicle Driving Assessments—

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1. Introduction

The Institute for Traffic Accident Research and Data Analysis (hereinafter, “ITARDA”) has been conducting various investigative research activities focused on two forms of analysis. The first is macro analysis performed using statistical data - such as that on traffic accidents, vehicles, roads - provided by government agencies such as Japan’s National Police Agency. The second is micro analysis performed using accident investigation data collected by ITARDA offices in Tsukuba and Tokyo. Although ITARDA had been conducting various research on issues regarding elderly driver cognitive function and traffic accidents since 2018 using their Traffic Violation/Road Traffic Accident Integrated Database (hereinafter, Integrated Database), which was constructed by integrating driver management data including road traffic accident statistics provided by the National Police Agency and results from cognitive assessments, they were unable to perform investigative research such as the previously mentioned accident investigations due to a lack of cooperation from professionals in fields where work on the cognitive function of elderly drivers is being performed.

This research is aimed at solving this problem by enabling discussion regarding future measures for elderly drivers from a wide range of viewpoints and using the results of clinical research performed at Saga University. This clinical research was performed using elderly drivers’ cognitive assessments, drive simulator examinations, and actual vehicle driving assessments in combination with the results from analysis of cognitive function and traffic accidents performed using ITARDA’s Integrated Database.

2. Environment surrounding elderly drivers

2-1. Traffic accidents and mobility in a super-aging society

In 2019, the population of individuals aged 65 and over in Japan reached 35.8 million, which comprises 28.4% of its overall population and is the highest percentage of any nation. Japan is truly becoming a super-aging society unlike any ever seen.

This aging of society is resulting in changes from a wide range of aspects, particularly in terms of problems surrounding health and mobility. In terms of health, dementia has become a problem, as have changes in mental and physical functions due to aging and increases in so-called “lifestyle diseases”. The main symptoms that develop in individuals with dementia are a deterioration of orientation, memory, and judgment, and its causes are diverse. Numbers of patients with dementia are also increasing, with prevalence expected to reach approximately 20% (7 million people) in 2025, up from 15% (4.62 million people) among the elderly aged 65 years and older in 2012. Furthermore, the existence of individuals with mild cognitive impairment (MCI) has also been observed. With numbers estimated to be approximately 13% (4 million) in 2012, this group is likely to transition to dementia in the near future, with continued increases in the MCI group also expected as the elderly population itself increases.

Another problem seen in aging societies is that of traffic accidents. This is a social problem that can be often observed in the many reports of fatal and serious injury accidents involving the elderly. In particular, serious accidents such as those caused by pedal misapplication or wrong-way driving accidents have been reported, raising concerns regarding driving by the elderly. Data has shown that fatal accidents involving drivers aged 75 or older have increased from 7.4% in 2005 to 12.8% in 2015. Furthermore, it has been reported that nearly 50% of drivers aged 75 or older who have caused a fatal accident have been judged to have had a "risk of dementia" or a "risk of declined cognitive function" (National Police Agency, 2017).

2-2. Driving behavior processes and their models

Driving behavior is considered to be one type of adaptive behavior requiring advanced and complex problem-solving skills and in which various mental and physical functions are performed in cooperation. Several models have been proposed from fundamental research performed on driving behavior, including the (1) Cognition - Decision - Operation process (Rizzo, 2010) and the (2) three-level hierarchal model for driving plans consisting of a Strategical (Planning) Level - Manoeuvring Level - Control Level (Michon, 1985).

In addition to the mental and physical characteristics of a driver, driving behavior is also affected due to fatigue, being under the influence of drugs, aging, and illness. Furthermore, factors such as vehicle characteristics, relationships with other vehicles/pedestrians, road environments, and weather are also involved.

2-3. Declined cognitive function and automobile operation

Cognitive function tends to decline with aging, although there are sizeable individual differences. Cognitive function is an indispensable function for vehicle operation, and it is expected an individual’s ability to drive will decline with aging, resulting in increased traffic accidents. Since coming into effect in 2017, Japan’s Revised Road Traffic Act requires license holders aged 75 or older to undergo an examination when renewing their license. If judged to be Class 1, they must then be examined and diagnosed at a medical institution (special aptitude examination). Furthermore, when individuals of other ages renew their driver’s license, they are obligated to report any physical changes, etc. This includes any experience of epilepsy, sleep apnea, loss of consciousness due to improper glycemic control, and a history of stroke. Penalties shall be levied on those individuals who fail to report such changes or who provide false reports.

2-4. Relationship between fitness-to-drive assessments and the medical field; Clinical pathways for making such assessments

As described above, problems regarding automobile operation and health have become more urgent for all license holders, with medical professionals such as nurses now being assigned at driver license centers throughout Japan to provide consultation.

Although the primary purpose of medical institutions is to perform diagnosis and treatment, it may also be necessary for them to perform fitness-to-drive assessments when creating medical reports. There are relatively few problems with disqualifying an individual from driving due to them having one of the specific illnesses listed in the Road Traffic Act as being reasons for disqualification of a driver's license. However, when an individual is in a gray zone for having one of the various ailments, it may be difficult for medical professionals to create medical reports when performing fitness-to-drive assessments. In addition, there can be several levels to the symptoms and pathology of each ailment. Although driving can be difficult when an ailment has progressed, there are cases in which it may not have a significant effect on driving in the early stage. Related academic societies have issued guidelines and policies to assist medical professionals in making determinations of whether patients are fit to drive.

At the hospital where the author practices, a clinical pathway has been formed to assist medical professionals in performing fitness-to-drive assessments and to provide subsequent mobility support to the elderly. This clinical pathway is based on many years of clinical experience and has undergone numerous modifications.

3. Characteristics of elderly drivers based on the results of cognitive assessments and traffic accident data (ITARDA)

[Method] We used the data of license holders aged 75 and older who took the cognitive assessment in 2014 and were registered in the Integrated Database as of the end of 2017 and analyzed the results of their cognitive assessments and casualty accident data for that three-year period (1,438,361 subjects in total). Cognitive assessments are made of three sub tests: (1) Temporal orientation, (2) Cued recall, and (3) Clock drawing test. Overall scoring was performed in range of 0 to 100 and calculated as follows:
Temporal orientation × 1.15 + Cued recall × 1.94 + Clock drawing test × 2.97

Data analysis was performed using Excel spreadsheet software, “R” statistical analysis software, JMP 14.2 statistical analysis software (SAS Institute), and SSPS Ver. 26.0 (SSPS).

[Results] By classifying based on overall score, Class 1 (diagnosed as having a reason for driver’s license disqualification due to dementia, etc., when examined at a medical institution) comprised 3.6%, Class 2 (judged to have declined cognitive function) 32.5%, and Class 3 (judged to have no decline in cognitive function) 63.9%. Furthermore, when examining the data, 26,621 subjects were found to have been the primary party in an accident.

From this point onwards in this paper, we used adjusted residual analysis to analyze (1) cross tabulations of the three categories of cognitive assessment results and the human factors of primary parties, (2) deviations between the expected values and measured values calculated using marginal frequencies, and (3) whether or not those deviations are significant values. In addition to cross tabulations for numbers of persons, we calculated and tabulated the ratios of primary parties in each class from Class 1 to Class 3, as well as the ratios when Class 3 is set as “1.0”.

Note that in this paper, analysis results common to both Class 1 and Class 2 are shown as “group with declined cognitive function (1&2)”, with “1&2” being an abbreviation of “Class 1 & Class 2”.

3-1. Analysis on relationships between cognitive function in elderly drivers and subsequent primary party accidents

(1) Declined cognitive function and fatal/serious injury traffic accidents

The results of residual analysis showed that the group with declined cognitive function had a higher number of individuals who were the primary party in a fatal or serious injury accident than was expected. Among Class 3 individuals, there were many who were the primary party in minor accidents, but few who were the primary party in fatal or serious injury accidents. This indicated that declined cognitive function led to more accidents in which the affected individual was the primary party. Furthermore, we observed that higher driver ages had an impact on variables such as daily driving frequency, time, and distance, as well as the fact that declined cognitive function also resulted in decreased driving frequency (Kosuge, 2019), etc. These are facts that must also be taken into consideration.

(2) Analysis of human factors in traffic accidents — Aimless driving and distracted driving

The percentage of primary parties engaged in aimless driving—considered to be a failure to pay attention forward due to internal factors and classified as the human factor “delay in noticing”—was significantly higher for individuals in the group with declined cognitive function (1&2), while being significantly lower in the case of Class 3 individuals. Furthermore, the percentage of primary parties engaged in distracted driving—considered to be a failure to pay attention forward due to external factors such as performing other operations while driving or not paying attention to the road—was significantly higher for individuals in the group with declined cognitive function (1&2) than in the case of Class 3 individuals, showing that the composition rate increases as cognitive function declines.

Although driving while performing other operations is dangerous for individuals of any age, driving when not paying attention to the road particularly increases the risk of traffic accidents in the case of the elderly. For this reason, it is imperative that driver re-education and driver rehabilitation programs be implemented to instruct elderly drivers on managing their health and improving their driving attitude to prevent them from engaging in aimless driving and enable them to prolong the length of time in which they can drive.

(3) Human factors in traffic accidents — Accidents caused by pedal misapplication and steering errors

Pedal misapplication often results in serious accidents and measures for its prevention are urgently needed. When analyzing all 3 Classes of cognitive function and accidents due to pedal misapplication, it was observed that Class 2 individuals made up a significantly high percentage of primary parties, with the percentage of Class 3 individuals being significantly lower. Although the percentage of primary parties consisting of Class 1 individuals was lower than that of Class 2 individuals, it was still higher than that of Class 3 individuals. Accidents due to pedal misapplication are occurring in large numbers by individuals in the group with declined cognitive function (1&2), with many individuals being in Class 2. Because it was observed that Class 2 individuals engaged in more activities and had higher levels of driving frequency than Class 1 individuals, it is imperative that warning signs for accidents be detected via the measurement and recording of daily driving behavior.

Accidents in which an individual becomes an primary party due to a steering error are occurring in large numbers by individuals in the group with declined cognitive function (1&2), with Class 1 individuals having a particularly high ratio compared to that of Class 3 individuals. Because it is assumed that the causes of steering errors include transient reactions, such as instant reactions that occur at the time of an accident, as well as continuous reactions during daily driving, it is necessary to understand such driving behaviors to prevent accidents by elderly drivers.

3-2. Analysis of cognitive assessments / sub-test scores for each Class

Class 1 individuals are diagnosed for reasons to disqualify their driver's licenses due to "specific illnesses" through examination at a medical institution. Analysis performed over the course of this research showed that the risk of accidents is high for both Class 2 and Class 1 individuals. Comparatively speaking, sources such as epidemiological surveys have shown that the prevalence of dementia in Japan is estimated to be approximately 15%, with individuals in the -mild cognitive impairment group (MCI) estimated to be approximately 13% (estimated in 2014 using materials from Japan's Ministry of Health, Labour and Welfare).

[Comparison of each Class] Wide score distributions and high detection sensitivity for declined functions were expected during the cued recall portion of sub tests, and comparisons of cued recall scores and cognitive assessment results showed cued-recall scores distributed across areas adjacent to Class 3. This suggests that it is possible to identify groups close to Class 1 in the Class 2 group, or groups close to Class 2 in the Class 3 group. In particular, groups with 13 points or less who scored -1.5SD during cued recall may overlap with individuals with mild cognitive impairment (MCI). There is an urgent need to study the details of traffic accidents by this group, as well as how to set thresholds that enable efficient detection of these groups.

4. Saga University Hospital's Fitness-to-Drive Assessment Database

At Saga University Hospital, we obtained multifaceted information related to fitness-to-drive assessments from individuals who gave their consent to the collection, use and disclosure of their personal information and reported those results. We were also able to directly evaluate driving abilities using actual vehicle driving assessments performed at driving schools. Not only is the information obtained important as supporting information in medical treatment, but the guidance provided by examiners is highly effective in motivating test subjects to review their driving habits.

4-1. Suggestions from case studies based on evaluations via actual vehicle operation

A total of 170 examinees have undergone actual vehicle driving assessments, with examiner assessments and vehicle behavior analysis results obtained via a sensor system placed into a database. Shown below are some thought-provoking case examples.

(1) Case example in which declined driving ability was detected for the first time during actual vehicle driving assessment

A male in his late 60s suffering from mild cognitive impairment but not to the level of dementia showed no particular decline in ability even during driving simulator tests. However, he had a history of accidents and results from the actual vehicle driving assessment showed signs of dangerous behavior such as a failure to stop at stop signs and not recognizing intersections. This resulted in him being deemed at high risk for an accident. The individual himself was not aware of his own decline in driving ability, and although he had desired to continue driving for work purposes, he finally decided to turn in his driver's license after many discussions.

(2) Case example of a professional driver who aimed to return to work by undergoing observation

A male in his 70s employed for many years as a professional night time driver underwent an actual vehicle driving assessment in the hopes of returning to driving following time spent undergoing treatment in the hospital due to a stroke. Although his after-effects were minor, a declined in his ability to steer was observed. Following many months of continuous treatment and observation, he underwent the actual vehicle driving assessment for a second time.

(3) Case example of dangerous behavior due to visual field impairment being observed during actual vehicle driving assessment

A male in his 50s employed as an architectural engineer underwent an actual vehicle driving assessment in the hopes of returning to work following time spent undergoing treatment in the hospital due to a cerebral hemorrhage. Despite his hopes of returning to work, dangerous driving behavior due to visual field impairment was detected during the assessment, after which he abandoned his plans to restart driving or return to his former job.

(4) Case example of an individual who restarted driving after undergoing driver rehabilitation due to after-effects of a stroke

A male in his late 60s had a strong desire to restart driving once his condition stabilized 1 1/2 years following the after-effects of a stroke. Although dangerous driving behaviors were initially observed, such behaviors eventually declined during the repeated actual driving training at the driving school, with no problematic driving being observed during practice driving on regular roads. He was finally able to restart driving upon consultation with related organizations.

5. Conclusions

(1) Relationship between cognitive assessments and human factors in accidents: Compared to Class 3 individuals, Class 1 and Class 2 individuals are much more likely to cause accidents due to decreased abilities in terms of "cognition" (pay attention forward) and "operation".

(2) Detailed analysis of the three categories of cognitive assessment results: In addition to the three categories of cognitive assessment results, analysis related to mild cognitive impairment (MCI) is particularly necessary.

(3) Effects of combining cognitive assessments and actual vehicle driving assessments: In addition to cognitive assessments, a highly accurate method of detecting drivers at a high risk of accidents is required, and actual vehicle driving assessments are an effective indicator.

(4) Multifaceted usefulness of actual vehicle driving assessments: Actual vehicle driving assessments are useful not only for convincing individuals to turn in their driver's licenses, but also for making determinations as to whether individuals can return to driving, such as through driver re-education and driver rehabilitation.

(5) Coordination between traffic accident deterrence and medical care: Adding comprehensive fitness-to-drive assessments that include actual vehicle driving is extremely important in preventing traffic accidents, as well as maintaining the health and self-reliance of the parties concerned.

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