Development of System for Comprehensively Measuring Driving Ability for Elderly Safe Driving

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Abstract

Traffic accidents caused by elderly drivers and resulting in personal injury or death have nearly tripled over the last decade; the elderly now total more than 40% of all traffic fatalities. Although driving ability decreases with advanced age, few elderly people recognize the decline in their own visual, cognitive and decision performance; this lack of awareness is a major cause of accidents. To reduce the number of accidents involving elderly drivers, it is critical that, beginning early in middle age, drivers undergo regular assessments of driving ability (particularly visual, cognitive and decision performance), are aware of their own abilities and driving aptitude, and maintain and improve their driving ability through reeducation and training.

For this research, video simulations of actual driving situations were created and used in developing an experimental system for comprehensively measuring functions essential for safe driving such as visual performance (in particular, the narrowing of the useful field of view caused by aging) as well as cognitive and decision performance (visuo-spatial perception at intersections and the decline in attentiveness). This paper describes the proposed system for measuring driving ability, the method of measurement, and sample results for driving ability in the elderly.

Key Words: Traffic accidents, Elderly drivers, Driving ability, Measurement and evaluation, Simulators

1. Introduction

As Japan becomes the first "super-aged" society in the developed world, the number of accidents caused by elderly drivers is rapidly increasing. For the past few years, the elderly have accounted for more than 40% of all traffic fatalities, a very high percentage relative to other age groups [1),2)]. The growing number of serious accidents caused by healthy elderly drivers with reduced cognitive ability, as well as elderly drivers with suspected or diagnosed dementia, has drawn public attention to the issue of driver license renewal [3)].

Although advanced age is generally accompanied by a decline in physical and mental attributes related to cognition, decision-making and mobility, few elderly people recognize how far their visual, cognitive and decision performance have declined since their youth. This lack of awareness is a major cause of accidents [4)]. To reduce the number of accidents involving elderly drivers, it is extremely important that drivers, beginning early in middle age (say, in their 50s), regularly check their driving ability (particularly visual, cognitive and decision performance) to gain a better awareness of their own abilities and driving aptitude, as well as work to maintain and improve their driving ability through reeducation and training.

The objective of the current research is to incorporate situations that closely approximate actual driving into the development of a system for comprehensively measuring visual, cognitive and decision performance, which are essential for recognizing the various objects encountered while driving and for ensuring safe driving.

2. Accidents and Declining Driving Ability Among Elderly Drivers

A review of the statistical data for accidents and traffic violations involving the elderly enables the following summary of common patterns [4)]:
(1) Most accidents caused by elderly drivers occur at intersections; an especially high number occur at intersections without stoplights.
(2) Many vehicle-to-vehicle accidents are either offset frontal or right-turn collisions.
(3) Single vehicle accidents tend to be either roadway departures or collisions with structures at curves.
(4) Common violations leading to accidents include failure to come to a complete stop, running red lights and impeding the right of way of others.

These accidents and violations, which occur more commonly with advanced age, are closely related to driving behaviors characteristic of elderly drivers such as errors of cognition or decision, that is, to the decline in driving ability that comes with age.

Elderly drivers experience a marked decline in their ability to attend simultaneously to multiple objects in high traffic situations and to rapidly grasp changing conditions (cognitive and decision performance). In addition, they have greater difficulty maintaining appropriate attention levels for long periods of time.

With regard to visual performance, which plays a large role in recognition, a reduced range of vision while driving means peripheral objects are more easily overlooked; reduced dynamic and kinetic visual acuity and distance perspective (depth perception, etc.) mean spatial relationships are more easily misjudged [5)]. Another important characteristic is that objects more frequently go unseen in low-light conditions such as twilight and nighttime due to reduced night visual acuity (night myopia) and dark adaptation. Furthermore, since roughly 70% of those in their sixties and 80-90% of those in their seventies have age-related cataracts, there is concern that significantly reduced static visual acuity may lead to accidents not only in low-light conditions but also under glare conditions (caused, for example, by the setting sun or oncoming vehicle headlights).

3. Problems with Conventional Assessments of Driving Ability

Given that 70-80% of accidents are caused by errors of cognition or decision, it is important when assessing driving ability to emphasize cognitive and decision performance, including visual performance. Major aspects of cognitive and decision performance include visuo-spatial abilities (such as dynamic visual acuity, field of view and depth perception) [6] and various attentional functions (such as focal attention, divided attention, sustained attention) [7].

Methods for assessing the driving ability of elderly drivers now in use at driving schools include both written and computerized National Police Agency driver aptitude tests [8].

The former evaluates attentiveness and judgment by having examinees find targets in photographs of driving scenes and select proper responses. The latter uses a computer screen to assess some aspects of driving ability using simple and selective reaction times to test primarily for reaction and decision-making speed and to check reaction consistency and relaxation response.

The results of both tests serve primarily as a guide for safe driving instruction and are inadequate for reminding elderly drivers of dangerous driving situations or promoting awareness of safe driving.

Past research on driving ability assessment has largely looked at ways to measure driving operations and behavior in emergency avoidance situations using driving simulators [14,15]. Because such assessments focus on driving operations and behavior when avoiding unexpected emergencies, they are ill suited for measuring or assessing cognitive and decision performance during normal driving.

At the same time, while field of view (static field of view and useful field of view), kinetic and dynamic visual acuity (KVA and DVA), depth perception, night visual acuity, dark adaptation and glare are well-known as important aspects of visual function indispensable when driving, current workshops for the elderly measure only KVA, dark adaptation time and ordinary static visual acuity. Useful field of view [11], believed to be the most important factor related to accidents by the elderly, is not tested and it is rarely measured using driving simulations. Furthermore, the prevalence of age-related cataracts in people over sixty years of age creates a need to measure static visual acuity under evening or nighttime driving conditions when it is difficult to see.

4. Driving Ability Measurement System

In consideration of the accidents caused by elderly drivers, their decline in driving ability and their cognitive and decision performance errors, the authors developed a comprehensive system for measuring visual, cognitive and decision performance, factors indispensable for safe driving [12,13]. The basic principles are outlined below.

(1) Main elements of the system include simulated driving images that closely approximate actual driving situations and a driving simulator that enables replication of driving operations (steering, accelerating, and braking). The simulated driving images cover a variety of driving situations (urban locations, highway driving, driving school courses, etc.) and can be replayed at will. The timing of the appearance of objects like traffic signals, vehicles and pedestrians can be controlled, and the degree of difficulty (driver workload) adjusted flexibly.

(2) Measurements are made of visual functions indispensable for driving such as field of view (static field of view and useful field of view), kinetic and dynamic visual acuity (KVA and DVA), and depth perception to address age-related cataracts, static visual acuity. Measuring field of vision requires displaying the visual target over a broad viewing angle. Measuring KVA and depth perception requires the ability to display depth in three dimensions. Measuring static visual acuity to address age-related cataracts requires measurements under low light and glare. Also, as an indicator of attentional function, cognitive and decision performance is evaluated by measuring driving performance (task achievement rate, time required, etc.) in situations (like at intersections) where accidents involving the elderly frequently occur.

Figure 1 indicates the composition of the driving ability measurement system based on the basic principles above. The system is made up of a driver's seat (steering wheel, accelerator, and brake), a curved screen (140° horizontal), three projectors and a processing unit.

When measuring visual function, one projector displays simulated driving images on the center of the screen while the remaining two projectors display visual targets, used to confirm range of view and the like, on either side. Visual targets include simple marks or Landolt rings and vary with the aspect of visual function being measured. To provide visual targets with the appearance of three dimensional depth as well as planar breadth, the two projectors are equipped with orthogonal polarizing filters and subjects wear polarizing glasses.

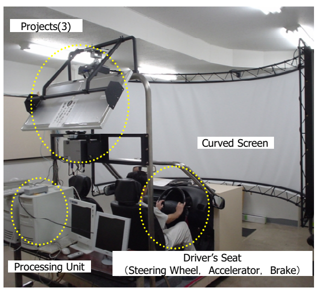

Fig.1 Composition of the driving ability measurement system

To evaluate the cognitive and decision performance of elderly drivers (attention to multiple objects, ability to grasp position relative to objects, decision-making ability, etc.), simulated driving images are displayed across a wide-field screen using three projectors and various aspects of driving performance at intersections, etc. are measured.

5. The way to measure driving ability and measurement example

This section explains how to measure driving ability and measurement example in this measurement system. It explains about the measurement of field of view (static field of view and useful field of view).

When static field of view is measured, a gaze point (●) is displayed in the center of the screen. Examinee watches a gaze point (●) carefully. Under the condition, visual targets for inspection (●) are displayed around the gaze point (●) (on the right and left of the gaze point in 140^o, top and bottom inside the range of 70^o) at random 70msec. Examinee answers orally if they can see visual targets for inspection (●). Static field of view is evaluated by the detection rate (detection number of times/indication number of times) of visual targets for inspection (●).

Figure 2 shows how to measure useful field of view. Simulated image for driving is displays in the center of the screen to measure useful field of view. Examinee drives carefully not to collide with the car and the man which appears on the simulated image for driving. Visual targets for inspection (●) are displayed at random 70msec around the gaze point (●) in the same way as the static field of view. The detection rate is used for this measurement in the same way as the static field of view. Figure 2 shows the measurement example of field of view (static field of view and useful field of view).

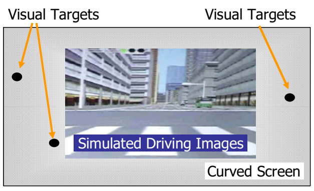

Fig.2 Measuring useful field of view

Figure 3 is youth person's (the 20's 20 people) and old man's (the 60 20 people) results. Little difference was found among young people between the results with and without driving operations. The detection rate of results with driving operations (static field of view) is remarkable lower than without it (useful field of view) among the elderly. The field of view during the operation is limited remarkably.

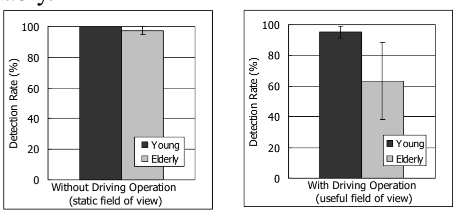

Fig.3 Sample measurements of field of view (Static and Useful)

It explains about the measurement of the static visual acuity. First, static visual acuity is measured in ordinary brightness. Next, static visual acuity is measured under the condition that contrasts with view object for inspection and the background is low. Glare source is putted over view object (the position where a visual angle with view object for inspection is 4^o). Static visual acuity is measured under the glare condition that glare source is turned on. View object for the inspection of this static visual acuity measurement uses the sign of "E" (Snellen eye, JISC conformity). The sign of "E" indicates a gap in 4 directions at random. Figure 4 shows the measurement example of the static visual acuity.

It is youth person's (the 20's 15 people) and former term old man's (a 65-74 years old 22 people) result. It is hard for the elderly to read when the contrast of inspection view object is low in comparison with the youth person. And, the static visual acuity of the elderly of age-related cataract is declined more remarkable than the healthy elderly. Declining of Static visual acuity under glare condition is especially remarkable.

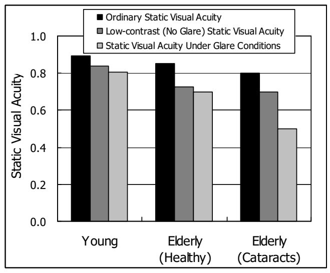

Fig.4 Sample measurements of Static Visual Acuity

It explains about the measurement of the cognitive and decision performance. We made the crossing which accident caused by the elderly is abundant in. Made simulated image is the course for driving contains many crossings. Examinee drives in the made course for the driving about 10 minutes. Cognitive and decision performance is evaluated from the driving performance. Many usual methods is presumed urgent scene to take out bursting from path. Simple response time and response unevenness are measured by those researches. It is not an urgent scene, but we suppose driving daily scenes, and measure the cognitive and decision performance made necessity. We measure two items of "car and the existence of the contact with the person" and the "crossing passage time". Figure 5 shows the method (when it turns right.) that driving performance around the crossing is measured.

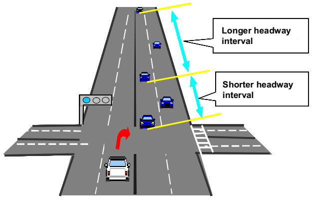

Fig.5 Method for measuring driving performance at intersections (Right turns)

Oncoming cars run first at the short headway time (the time interval for the tip part of two vehicles) when the turn right crossing. As car headway time becomes long when time passes, the passage of the crossing becomes easy for the examinee. "Crossing passage time" becomes short as much as examinee recognizes the one related to the position with the oncoming car and a speed exactly and passes in the quick judgment. It seems that measurement result is the driving performance which the quickness of the cognitive and the decision performance is reflected on. Furthermore, not only oncoming cars but also walker's crossing is set up in the course. Crossing passage time is the relations of trade-off with being careful in more than one object at the same time and passing safely.

The degree of difficulty (the size of the operation load) of the crossing passage sets up 3-step level by the number of the attention object (signal, oncoming car, walker) which a cognitive and decision performance is necessary for and the speed (Figure 6). It explains about the way of confirming three steps of the operation load a level (low・medium・high). We measured mental work load by NASA-TLX. So, confirmed whether driving burden was set up in three steps as our assumption. We teach examinee to pass through the crossing at as short time as possible with complying with the traffic rule and driving safely when we measure cognitive and decision performance. Examinee drives only with starring, the

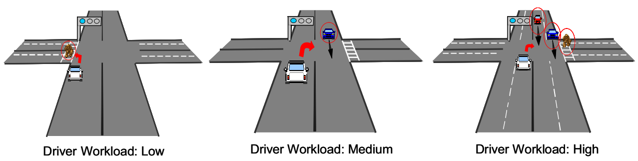

Fig.6 Relationship between the difficulty of passage through intersection and driver workload

accelerator, and the brake. The turning signal isn't used. And, examinee doesn't need to memorize a course in advance to run through the course by the directions of the experiment person during the driving. We explain the data of "car and the existence of the contact with the person" and "crossing passage time". Figure 7 shows the measurement example of the "crossing passage time". As an age rises, time to pass through the crossing is long. And, the rate that crossing passage time increases when an operation load is raised rises when it is compared in the level of the driving load by the degree of difficulty of the crossing. It is understood that the ability of the cognitive and the decision performance declines by age.

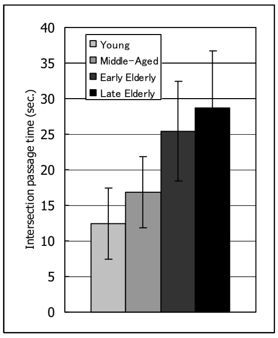

Fig.7 Sample measurements of driving performance (Intersection passage time)

6. The simple measurement system for driving car school

We aimed at making it the system which the measurement system manufactured as an experiment so far could be actually made use of for. And, the simple measurement system that it thought of elderly class in driving car school and so on was developed. A simple measurement system limits it to the measurement of the visual function (field of view and static visual acuity complying with the elderly of age-related cataract) and the cognitive and the decision performance. The appearance is shown in the figure 8. This system is the size of the degree that it is about the same as driving simulator being used in present car school. It gave careful consideration for the elderly so that it could do comparatively simple and easy measurement in a short time. Performance evaluation was done by the elderly and young people examinee. We confirmed that it could be measured in the same way as the measurement system of the previous development. From now on, the evaluation of the convenience and a trial in car school will be done.


Fig.8 Exterior of the simplified measurement system

7. Conclusion

This paper has described the development of a system to better grasp the driving ability of the growing numbers of elderly drivers (including those who have been diagnosed with dementia) through the comprehensive measurement, under situations approaching actual driving, of the visual, cognitive and decision functions indispensable for recognizing the various objects encountered while driving, as well as the methods for measurement and sample results. In the future, there are also plans to assess not only healthy drivers but also those suspected of dementia in order to consider ways to predict dangerous driving behavior and method for the early detection of dementia.

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