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Influence of Attention on the Control of Speed and Steering in Older Drivers and Stroke Patients

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Abstract

Objective: Attention is important for driving an automobile. The aim of this study was to identify driving behaviors that are influenced by attention.

Methods: This study included 49 healthy individuals (19 men and 30 women) and 10 stroke patients (8 men and 2 women). The subjects' attention was assessed using the Trail Making Test and the Simple Reaction Time task of the Continuous Performance Test. In a driving simulator with driving conditions set in accordance with the traffic regulations in Japan, including two lanes on each side of the road and a speed limit of 60 km/h, the subjects performed four left turn tasks, six right turn tasks, and six changing lane tasks. Road edge excursion frequency, speeding frequency and duration, crash frequency, speed during driving, distance from the vehicle ahead after entering the passing lane, vehicle positioning, and braking reaction time for a suddenly crossing vehicle were recorded.

Results: The results showed that attention deteriorated in the older subjects and that this affected driving behaviors, particularly for staying in one´s lane. We identified the characteristics of driving behaviors during right and left turns as well as changing lane. Elder subjects delayed corrections of steering and the control of speed.

Conclusion: In this driving simulator study, deterioration of attention in older drivers was related to road edge excursion and a delay in the control of speed and steering required for responding to the external environment under changing traffic conditions. It would be predicted the characteristics of the driving behavior by evaluating the attention. Although driving behaviors were similar for the stroke patients and the healthy subjects, stroke patients´ attention while driving requires a more detailed evaluation.

Keywords: Driving behavior; Attention; Control; Elderly; Stroke; Driving simulator

Abbreviations DS: Driving Simulator; TMT: Trail Making Test

Introduction

Driving an automobile can improve one´s quality of life. However, driving involves complex processes that involve physical and cognitive functions, and deterioration of these functions may lead to traffic violations, accidents, and serious injury. Traffic accidents have been declining in Japan. According to a report by the Institute for Traffic Accident Research and Data Analysis in Japan, the number of traffic accidents peaked at around 953,000 cases in 2004, and declined over the following 13 years with 422,000 cases reported in 2017. The number of fatal accidents has also declined after peaking in 1970 with around 16,000 cases, only 4,013 cases were reported in 2014. However, even with these declines, each year alone one-in-one-thousand people in Japan experience a traffic accident. A greater number of fatal accidents involve elderly people (>65 years) than individuals of other age groups, accounting for approximately 2,200 cases annually. The incidence of traffic accidents (the number of traffic accidents/the number of licensed individuals) is high for drivers younger than 30 years, and gradually declines with age. However, the incidence of accidents tends to gradually increase again after age 55, and so measures to prevent automobile accidents involving the elderly have been attempted, including lectures targeted at this age group. Fatal accidents involving the elderly are also frequent in other countries.

Compared with drivers aged in their 40s, drivers in their late 60s have a higher probability (1.29-fold) of having an accident. It has been reported that the accident rate per kilometre starts to increase at approximately 55 years of age and then increases abruptly at approximately 70 years of age [1]. As physical and cognitive functions tend to deteriorate with age, it is suspected that the elderly experience an on-going deterioration in the functions required for driving an automobile. The required cognitive functions found to deteriorate most often are attention, memory, and/or ability to carry out functions; this may be due to deterioration in visual acuity and hearing and/or the capacity to react to external stimuli. Driving characteristics of the elderly include reduced attention to traffic signals and stop lines, erroneous reaction to stimuli and traffic signs, vehicle positioning errors, and difficulty in judging gaps and speed regulation [2,3]. These problems are influenced by attention and other perceptual and cognitive functions [3-5]. Elderly people also often have medical conditions, and it has been suggested that such medical conditions and the deterioration of their cognitive or visual functions may underlie the causes of many accidents involving elderly drivers [5,6]. Stroke is a

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frequent reason for hospitalization and admission of the elderly [7], often leading to greater deterioration in physical and cognitive functions. Driving by stroke patients can be characterized by several hazardous driving behaviors, including impaired speed control with respect to the current traffic situation and environment, an imprecise position with respect to the side of road and other road users, and changing lanes without being aware of a vehicle at one´s side [8]. These behaviors are influenced by visuoperceptual, attention, and memory functions [9-13]. As reduced attention and perception can cause traffic accidents [14], it has been speculated that the deterioration of attention and visuoperceptual functions influence automobile driving behaviors of healthy individuals and stroke patients.

When using a driving simulator, a significantly greater number of older drivers experienced car crashes and demonstrated unsafe driving performance in controlling speed, steering, and making lane changes compared with younger drivers. The frequency of car crashes, and performance in lane changing and vehicle positioning were associated with the drivers' scores in the Trail Making Test (TMT) [15], a measure of attention and related cognitive functions. As described earlier, it is understood that speed regulation and control, and vehicle positioning are related with attention. However, this relationship has not been quantified. To date, are no published reports have analyzed whether attention influences the response to the external environment in changing traffic conditions, including when turning left or right or changing lanes.

The TMT is one of the most widely used tests in neuropsychological assessment, and poor performance may indicate difficulty with driving [10,11,13,16,17]. Other methods to evaluate driving behaviors include driving an actual vehicle and using a driving simulator (DS). Evaluations in a DS reportedly differ from those made of actual driving, but it has also been demonstrated to be useful tool for evaluating driving behaviors because safety and environmental factors are controlled [18-20].

Identifying driving behaviors that result from human and environmental factors is important for improving road safety and may help develop measures to prevent traffic accidents, including evaluation of an individual's driving ability and providing advice on traveling conditions. It has been reported that crash rates increase with age in healthy individuals starting at around 55 years of age in Japan [21] as well as other countries [1]. Therefore, it is important to compare the driving habits of individuals of ≥ 55 years of age with those of younger individuals in order to design preventive measures for traffic accidents. In recent years, evaluations and interventions that enable stroke patients to return to driving have been implemented. To evaluate changes in driving after stroke, it is important to have a better understanding of driving behaviors in healthy individuals.

This study investigated the relationship between attention, as measured by neuropsychological testing, and automobile driving behaviors, as evaluated by DS software modified for use in this study. This study´s aims were as follows: 1) to identify driving behaviors influenced by reduced attention; 2) to determine whether reduced attention affects driving behaviors by one´s environment while driving that includes making right and left turns, or changing lanes; and 3) to determine whether elderly people and stroke patients differ in their driving behaviors. This study was approved by the Ethics Committee of Kobe University Graduate School (Approval No. 204), Japan.

Method

Subjects

This study included 49 healthy individuals (19 men and 30 women) and 10 stroke patients (8 men and 2 women) who were local residents. The healthy subjects all drove a vehicle on a daily basis and were not affected by any disease that could influence their driving behaviors. The stroke patients exhibited no reduction in physical function that could influence driving behaviors and had either resumed automobile driving or expressed a desire to resume driving. The stroke patients were attending our institute's Information and Support Center for People with Higher Brain Dysfunctions. All subjects gave informed written consent, the stroke patients in conjunction with their family members.

Driving simulator

The hardware used for the study comprised a personal computer, three displays (473 mm × 296 mm screen size), and a steering-type controller (Driving Force GT in switzerland) (Figures 1 and 2). The DS software was developed in this study.

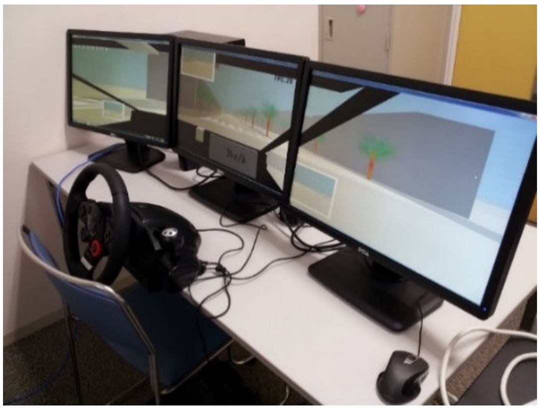

Figure 1: The driving simulator apparatus.

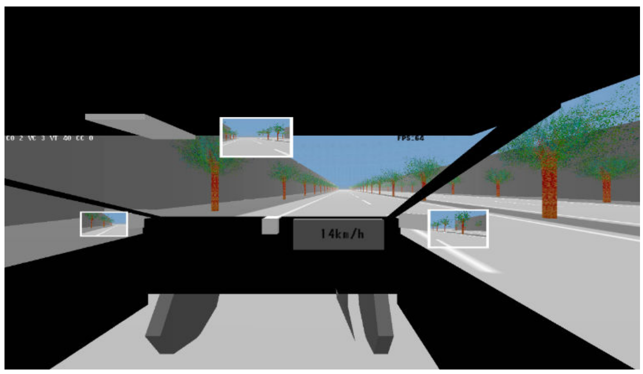

Figure 2: The screen of the driving simulator.

The simulated driving conditions were in accordance with the traffic regulations in Japan and included two lanes on each side of the road and a speed limit of 60 km/h (specified by a road sign). The overall task involved four left turn tasks, six right turn tasks, and six changing lane tasks during approximately 15 min and over a simulated distance of 15 km. The situations presented during the task included a pedestrian encountered during a left turn, a pedestrian and an oncoming car during a right turn and another vehicle in the passing lane when lanes had to be changed before turning right. In addition, a situation in which a vehicle suddenly crossed while the subject was driving in a straight line was presented twice. During the driving task, the frequency of road edge excursions, the frequency and duration of speeding (higher than 60 km/h), and the frequency of crashes (off-road crashes and vehicle collisions) were measured. The software recorded the vehicle speed in increments of 0.01 s, the distance from the vehicle ahead after entering the passing lane, the vehicle position (was given as the distance from the midpoint of the road; Figure 3), and the braking reaction time when the other vehicle crossed suddenly. The navigation system was set to use voice.

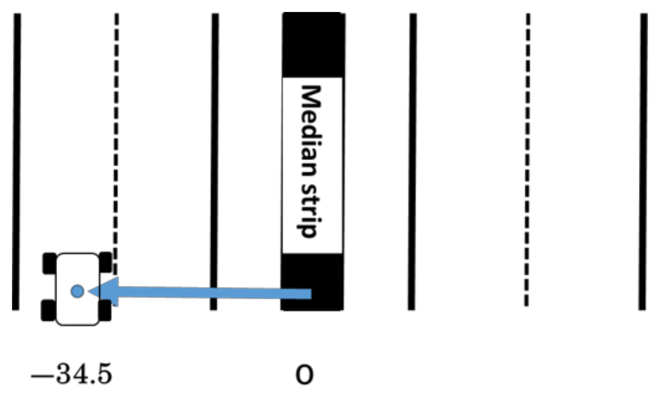

Figure 3: Vehicle position (The position was measured from the median strip between the carriageways).

Hazardous driving performance was characterized as road edge excursions, speeding, the duration of speeding, crashes, and driving with an unsafe distance between cars. Unstable driving was indicated by higher standard deviations of the average speed or vehicle positioning.

Attention tests

Attention was evaluated using two instruments: the TMT (described earlier) and the Simple Reaction Time (SRT) task of the Continuous Performance Test (CPT). The TMT has two parts, A and B. It has been reported that TMT (A) mainly indicates selectivity and visuoperceptual function in attention, TMT (B) is mainly related to the allotment of attention and working memory, TMT (B-A) is related to visuoperceptual functions and working memory, and TMT (B/A) indicates flexibility of thought and executive function [22-24]. The SRT is a simple computer task that provides the subject's reaction time, standard deviation, coefficient of variation, validity, and predictive value.

Procedure

The subjects completed a written questionnaire that consisted of questions about their years of driving experience, crash history, past medical history, medication status, and their physical condition on the day of the survey. Subjects' ≥ 55 years of age and stroke patients were administered the Mini Mental State Examination (MMSE), and all subjects completed the TMT A and B and the SRT. After the tests, the subjects practiced driving on the DS, performing tasks different from those that were used in the study. The practice was terminated when no remarkable problems were observed with right or left turns or with steering and when the subject felt comfortable using the DS.

Before starting the actual driving task, the tester re-confirmed the physical condition of the subject. The tester then asked the subject to drive for the average driving duration, abiding by the distance travelled and staying in the correct driving lane. The subject was then instructed to stop driving if he/she felt motion sickness. The DS task was discontinued if a subject was expected not to complete the task or the subject experienced motion sickness. The subjects took approximately 40 min to complete the test. After completion of the task, the following parameters were calculated from the data: road edge excursion frequency, speeding frequency and time, crash frequency, speed during driving, distance from the vehicle ahead after entering the passing lane, vehicle positioning, and braking reaction time when another vehicle suddenly crossed the carriageway.

Statistical analysis

To investigate the influence of aging, healthy subjects were divided into two groups by age: ≥ 55 years and <55 years. Means, standard deviations, and coefficients of variation were calculated for the following: speed during driving, acceleration, and distance from the vehicle ahead after entering the passing lane, and vehicle positioning during right and left turns, and lane changes. Correlations between the driving behaviors of the healthy subjects and their age, years of driving experience, TMT time, and SRT were analyzed using Spearman's rank correlation. Mann–Whitney U tests were used to compare characteristics of driving behavior, age, years of driving experience, MMSE score, TMT time, and SRT between the two age groups of healthy subjects and between the healthy subjects' ≥ 55 years and the stroke patients. The analyses used the SPSS statistical analysis software, with the significance level set at 5%.

Results

Subjects

A total of 47 healthy subjects (19 men and 28 women) completed the DS task with a mean age of 54.9 ± 17.4 (range 24-77) years. Two female healthy subjects felt sick during the DS task. Eight stroke patients (all men) with a mean age of 60.3 ± 9.8 years and 40.6 ± 11.2 years of driving experience also completed the task. Of the two female stroke patients initially enrolled in the study, one discontinued the DS task and the other did not complete the task because of frequent crashes. The group of healthy subjects aged ≥ 55 years included 30 subjects (15 men and 15 women) with a mean age of 67.1 ± 5.6 years and 41.6 ± 9.1 years of driving experience. Of these, 24 said that they had been involved in an accident, and the remaining 6 had not. The group of healthy subjects aged <55 years included 17 subjects (4 men and 13 women) with a mean age of 33.5 ± 7.0 years and 14.7 ± 6.8 years of driving experience.

Attention and driving behaviors

Table 1 presents the statistically significant correlations between age or the attention measures and the driving characteristics of the healthy

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subjects. The driving characteristics that were significantly correlated with age were road edge excursion frequency, braking reaction time for a suddenly crossing vehicle, average speed during driving, and the coefficient of variation of the average speed during driving. Age was also significantly correlated with attention test results, such as TMT (A), TMT (B), TMT (B–A), SRT task validity, SRT task predictive value, SRT task standard deviation, and SRT task coefficient of variation. Driving behaviors that were correlated with TMT (A) were road edge excursion frequency, average speed.

	Age	Road edge excursion	Speeding	crash	Braking reaction time	Average speed	Vehicle positioning	Speed (CV)	Acceleration SD)
Age		0.663**			0.33*	-0.431**		0.382**	
TMT (A)	0.691**	0.502**				-0.36*			
TMT (B)	0.740**	0.538**			0.318*	-0.368*		0.342*	
TMT (B-A)	0.487**	0.322*			0.303*				-0.302
Simple reaction time			-0.291*			-0.33*			
SRT Validity	-0.387**			-0.308*			0.293*		
SRT Predictable value	-0.421**			-0.325*					
SRT (SD)	0.467**	0.294*					-0.418*		
SRT (CV)	0.405**	0.29*			0.446**		-0.317*		

Table 1: Correlations between measures of attention and the driving behaviors of the healthy subjects (Spearman's rank correlation*p<0.05; **p<0.01; TMT: Trail Making Test; SRT: Simple Reaction Time; SD: Standard Deviation; CV: Coefficient of Variation).

Driving behaviors that were correlated with TMT (B) were road edge excursion frequency, braking reaction time for a suddenly crossing vehicle, and average speed, the coefficient of variation of speed. Crash frequency was correlated with SRT task validity, SRT task predictive value, and road edge excursion frequency was correlated with standard deviation of the SRT task, whereas road edge excursion frequency and braking reaction time for a suddenly crossing vehicle were correlated with the coefficient of variation of the SRT task.

Comparison of driving behaviors during right turns, left turns, and changing lanes

Table 2 presents a comparison between the two age groups of healthy subjects (<55 years and ≥ 55 years) of their attention test results and driving behaviors. The older group was found to have significantly slower attention in the TMT test (p=0.000), as well as significantly lower validity (p=0.038) and predictive value (p=0.015), and significantly higher standard deviation (p=0.011) and coefficient of variation (p=0.015) for the SRT task. Their road edge excursion frequency was significantly higher (p=0.000), braking reaction time for a suddenly crossing vehicle (p=0.000) and average speed (p=0.005) significantly slower, and the variation of the average speed (p=0.008) significantly higher.

	Age <55 years	Age ≥ 55 years	p-value
TMT (A) (s)	29	45.6	0
TMT (B) (s)	51.5	99.8	0
TMT (B-A) (s)	23.8	49.1	0
SRT Validity (%)	100	98	0.036
SRT Predictable value (%)	100	98	0.015
SRT (SD)	45.8	54.9	0.011
SRT (CV)	13.5	18.3	0.015
Road edge excursion	1	9	0

Braking reaction time (ms)	756.5	925.5	0
Average speed (km/h)	44.9	37.2	0.005
Speed (CV)	0.39	0.45	0.008

Table 2: Comparison of attention measures and driving behaviors between the two age groups of healthy subjects (Mann–Whitney U test; TMT: Trail Making Test; SRT: Simple Reaction Time; SD: Standard Deviation; CV: Coefficient of Variation).

Table 3 presents a comparison between the two age groups of healthy subjects in their performance in the specific driving tasks. When turning left, the older group had a significantly lower average speed (p=0.012), right-sided vehicle positioning (p=0.000), lower standard deviation of the average speed (p=0.001), and lower deceleration (p=0.000). When turning right, they had a significantly lower average speed (p=0.000), left-sided vehicle positioning (p=0.01), lower standard deviation of the average speed (p=0.001) and acceleration (p=0.002), and lower deceleration (p=0.000).

	Age <55	Age ≥ 55 years	p-value
Turn left:Average speed (km/h)	19.5	16.8	0.012
Turn left: Vehicle positioning (1/10 m)	-37.8	-36.5	0
Turn left:Average speed (SD)	13.9	10	0.001
Turn left:Acceleration (m/s^2)	-10.1	-2.8	0
Turn left: Acceleration (SD)	4.7	4.1	0.015
Turn right: Average speed (km/h)	24.9	20.2	0
Turn right: Vehicle positioning (1/10 m)	-23.1	-23.7	0.01
Turn right: Average speed (SD)	12.4	10.2	0.001
Turn right: Acceleration (m/s^2)	-9.1	-7.7	0
Turn right: Acceleration (SD)	5.7	4.3	0.002
Lane change: Average speed (km/h)	57.7	51.7	0.003
Lane change: Vehicle positioning (1/10 m)	-30.8	-31.5	0.01
Lane change: Average speed (SD)	4.5	7.5	0
Lane change: Average speed (CV)	0.74	0.15	0
Lane change: Acceleration (m/s^2)	0.81	0.077	0.015
Lane change: Acceleration (SD)	1.3	1.7	0.015
Lane change: Acceleration (CV)	6.5	0.78	0.003

Table 3: Comparison of driving behaviors in the driving tasks between the two age groups of healthy subjects (Mann–Whitney U test; SD: Standard Deviation; CV: Coefficient of Variation).

When changing lanes, the older group showed a significantly lower average speed (p=0.003), left-sided vehicle positioning (p=0.01), a higher standard deviation for speed (p=0.000) and acceleration (p=0.000), and a higher variation of the average speed (p=0.000). Their acceleration (p=0.015) and coefficient of variation of the acceleration (p=0.003) were lower.

Comparison between the older healthy subjects and stroke patients

Tables 4 and 5 compare the older group of healthy subjects (aged ≥ 55 years) with the stroke patients based on attention and other measures as well as for specific driving behaviors. No significant differences were found in age, MMSE scores, or years of driving experience between the groups. Compared with the older healthy subjects, the stroke patients showed significant differences in braking reaction time for a suddenly crossing vehicle, TMT (A) and (B).

	Healthy, age ≥ 55 years	Stroke	p-value
Age	67	64.5	0.112
MMSE	29	27.5	0.076
Driving experience (year)	43	43	0.805
Braking reaction time (ms)	925.5	1133.3	0.028
TMTA (s)	45.6	103.5	0
TMT(B (s)	99.8	159.5	0.002
TMT(B/A) (s)	2.08	1.31	0.013

Table 4: Comparison of attention measures and driving behaviors between healthy subjects aged ≥ 55 years and stroke patients (Mann–Whitney U test; MMSE: Mini Mental State Examination; TMT: Trail Making Test).

The stroke patients had significantly lower TMT (B/A) values and significantly higher values for the other parameters. The stroke patients showed a significantly greater deceleration when turning right (p=0.038); and, when changing lanes, their vehicle´s positioning was significantly closer to right side (p=0.042), and they had a lower standard deviation of average speed (p=0.012), and less variation in the average speed (p=0.002).

	≥ 55 years of age	stroke	P-value
Turn right:acceleration (m/s^2)	-0.77	-2.8	0.038
Lane change:vehicle positioning (1/10 m)	-31.5	-30.9	0.042
Lane change: average speed (SD)	7.5	5.2	0.012
Lane change: average speed (CV)	0.14	0.096	0.002

Table 5: Comparison of driving behaviors in the specific driving tasks between the healthy subjects aged ≥ 55 years and the stroke patients (Mann–Whitney U test; SD: Standard Deviation; CV: Coefficient of Variation).

Discussion

Relationship between attention and driving behaviors

The aim of this study was to investigate the relationship between attention and driving behaviors. The results show that attention had deteriorated in the older subjects, and that reduced attention was correlated with poorer driving behaviors, particularly road edge excursion. In our study, longer times for TMT (A) (which indicates poorer selectivity/visuoperceptual function in attention), TMT (B) (which indicates poorer allotment of attention), and TMT (B–A) (which indicates poorer visuoperceptual functions and working memory) were positively correlated with road edge excursion frequency; and road edge excursion was positively correlated with standard deviation and coefficient of variation in the SRT task. Thus, a general deterioration of attention likely results in road edge excursion. Deterioration of visuoperceptual functions, the selectivity to react to a specific stimulus amongst many stimuli, the allotment of attention to more than one stimulus, and working memory for temporarily holding and manipulating information are likely to lead to road edge excursion, a hazardous driving behavior. It has been suggested that steering a vehicle is controlled by two visual processes: a compensatory process for maintaining lane position, and an anticipatory process for previewing the curvature of the upcoming road [25]. In addition, the validity and predictive value of the SRT task, which indicates persistence of attention, were negatively correlated with crash frequency. Persistence of attention probably influences all driving behaviors because of its close relationship with arousal levels. There have been reports that TMT times are correlated with automobile crashes in the elderly [4]. Thus, deterioration of attention due to aging would be expected to cause road edge excursion. It would also be expected that monitoring of hazardous objects becomes insufficient in some elderly people, potentially leading to a crash when attention is temporarily discontinued because of a reduction in persistent attention.

Characteristics of driving behaviors in right turn, left turn, and changing lane tasks

In this study, the driving environment presented in DS included two lanes on each side of the road and a speed limit of 60 km/h; and the task involved right turns, left turns, and changing lane. This driving environment simulated road environment frequently encountered in urban areas.

In the driving environment presented in the present study, subjects aged ≥ 55 years had a significantly higher frequency of road edge excursions, slower braking reaction times when a vehicle suddenly crossed in front, and a slower average speed. Considering that reducing the speed of driving is an important aspect of safe driving [8] and that road edge excursion and a slow reaction time in response to a sudden appearance of other vehicles constitute hazardous driving behaviors and often occur in the elderly, older subjects were likely to avoid the hazard by reducing their driving speed. The higher road edge excursion frequency observed in the older subjects was probably not due to poorer physical function because no differences in simple reaction times of the SRT task were observed between older and younger drivers. However, there were differences between the older and younger subjects in the attention tests, and so we suppose that a general deterioration in attention makes cooperating with the traffic flow and staying in lane difficult.

Driving behaviors such as vehicle positioning may be affected by difficulties in perceiving external information during driving, such as the information required to properly navigating right and left turns or entry into the passing lane in the lane-changing task. During right and left turns, the driver rotates the steering wheel in the direction of travel, and as the orientation of the vehicle body changes, the driver has to rotate the steering wheel in the opposite direction. In the results of this study, the traffic line of the vehicle was longer in the older drivers, and the vehicle shifted more to the right or left lanes during left and right turns, respectively. We speculate that the older drivers delayed rotating the steering wheel in the opposite direction after the turn. Drivers tend to see vehicles, bicycles, and other objects in the direction where the external environment changes at intersections [26], and that visual information is immediately applied to the steering [27]. We suspect that the older subjects delayed correction of steering because of poor acquisition of external environmental information due to insufficient visuoperceptual functions. This observation indicates that reduced attention may also lead to road edge excursions at intersections. In addition, when the older subjects changed lanes, the standard deviation and the variation of speed and acceleration were significantly higher. Changing lanes is considered to be the most hazardous driving behavior, and the procedure involves serious risk, which is correlated with deterioration of attention [28]. We speculate that the older subjects performed the changing lane task, which requires entering a lane in time with the traffic flow, by slowing down until other vehicles were out of range and therefore travelled a longer distance before entering the passing lane. This driving behavior probably represents the avoidance of other vehicles in the DS. However, in actual traffic conditions, this behavior is likely to lead to hazardous consequences, such as a collision with a following vehicle or a collision resulting from forcibly changing lane when there is less space between vehicles. Driving characteristics identified in the older drivers were their difficulty in staying in the lane as well as maintaining speed when there were other vehicles traveling in the same direction. Deterioration in the allotment of attention for simultaneously paying attention to other vehicles and maintaining speed appears to be the main cause of this driving behavior.

In this study, the subjects who caused a crash in the DS were all ≥ 55 years of age. In agreement with previous studies, these findings suggest that, when using a DS, crash rate increases with age from the age of 55 years.

Comparison between healthy subjects ≥ 55 years of age and stroke patients

Compared with healthy subjects, stroke patients had significantly slower TMT (A) and (B) times and braking reaction times for a suddenly crossing vehicle, but no differences were observed in driving behaviors. In the changing lane task, which requires traveling in cooperation with the traffic flow, the stroke patients made an effort to keep in lane, and there was little difference in maintaining the speed compared with the older healthy subjects. This observation appears to be mainly due to the stroke patients having better flexibility of thought. Compared with the healthy subjects aged ≥ 55 years, the stroke patients showed no difference in TMT (B-A), but lower TMT (B/A), which is correlated with flexibility of thought not represented in (B–A) [2,22]. Because flexibility of thought is correlated with the basic and inference ability as the underlying process required for problem solving [29], we suppose that, despite their reduced motor speed, visuoperceptual functions, and information-processing speed, the stroke patients achieved a proper driving behavior by slowing down. Hazardous driving behavior occurs because of an improper perception of the driver. It has been demonstrated that is important to anticipate the situation and decelerate while entering an intersection or navigating a curve [8,27,30]. As stroke patients decelerated more successfully during a right turn than healthy subjects, their driving behavior also indicates that their ability to foresee an upcoming situation was appropriate. The results of this study support previous findings that there was no difference in crash rates between stroke patients and healthy subjects [31], leading us to expect no differences in driving behaviors. However, because the stroke patients showed hazardous driving behaviors similar to those of the older healthy subjects and required time to avoid a hazard, their level of attention and the traveling environment will need to be evaluated in detail.

Conclusion

In this study, we demonstrated the relationship between attention and automobile driving behaviors in 47 healthy individuals and 8 stroke patients using attention tests and a DS task. The results showed that attention deteriorates with age, which in turn significantly increases road edge excursions. We also demonstrated that reduced attention is associated with difficulties in steering in one´s lane and maintaining speed in a changing environment, such as when making right or left turns, or changing a lane. Although we did not observe any clear difference in reduced attention between healthy subjects and stroke patients, the influence of attention on the control of speed and steering has been quantified. As reduced attention and road edge excursions may lead to a crash, it is necessary to improve understanding of the characteristics of driving behaviors and evaluate human and environmental factors in detail.

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