■ORIGINAL ARTICLE

Learning Effects of Multiple Driving Simulator Runs in Older Adults

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Abstract: Driving simulators (DS) have been used in medical institutions to evaluate a participant's driving abilities. Despite the empirical fact that the learning effects of multiple DS runs have been observed in clinical practice, few studies have examined the learning effects. The learning effects of multiple DS runs were examined among 25 older adults and 27 young participants. The participants drove the same course thrice without receiving any advice on the operation. The older adults had significantly more accidents than the young ($p < 0.05$) in all the trials. The number of accidents was significantly higher ($p < 0.05$) among older adults in the first trial than in the second. No significant difference was observed in the number of accidents between the second and third trials ($p = 0.94$). No significant difference in the number of accidents was found among all trials in the younger age groups. Among the different types of accidents noted, "Rear-end collisions due to inadequate deceleration" were observed more frequently among the older adults. "Collisions with a wall or vehicle due to improper maneuvering when turning right or left" were observed more frequently among young drivers. The results suggest that, the older adults may reveal their true driving abilities after at least three trials in the course used in this study. Furthermore, the results suggest that the quality of accidents differ between the older adults and the young.

Keywords: older drivers, driving simulator, learning effect

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Introduction

Mobility support is one of the important roles of occupational therapists. Among the various means of transportation, driving a car greatly affects quality of life [1]. Recently, driving simulators (DS) have been used in medical institutions to evaluate a participant's driving abilities. DS can easily evaluate safe driving performance, such as maneuvering a car (operating the steering wheel, gas pedal, and brakes), hazard prediction, and compliance with laws and regulations. Although previous studies have found that DS can predict accidents and on-road driving performance [2–5], the findings are contradictory [6–7]. Possible reasons for these contradictory findings include differences in the attributes of the participants, type of DS used, indicators of on-road driving performance, and amount of prior practice. Despite the empirical fact that the learning effects of multiple DS runs have been observed in clinical practice, few studies have examined the learning effects.

To the best of our knowledge, only Kawano et al. (2012) [8] reported that habituation occurs during the third execution of a given course. However, the qualitative characteristics of driving performance on a DS were not analyzed by the authors. Additionally, the DS used in their study differed from those frequently used in Japanese medical institutions. Therefore, in this study, we quantitatively and qualitatively examined the effects of multiple DS sessions on the performance of participants using the DS that is frequently used by occupational therapists in Japan.

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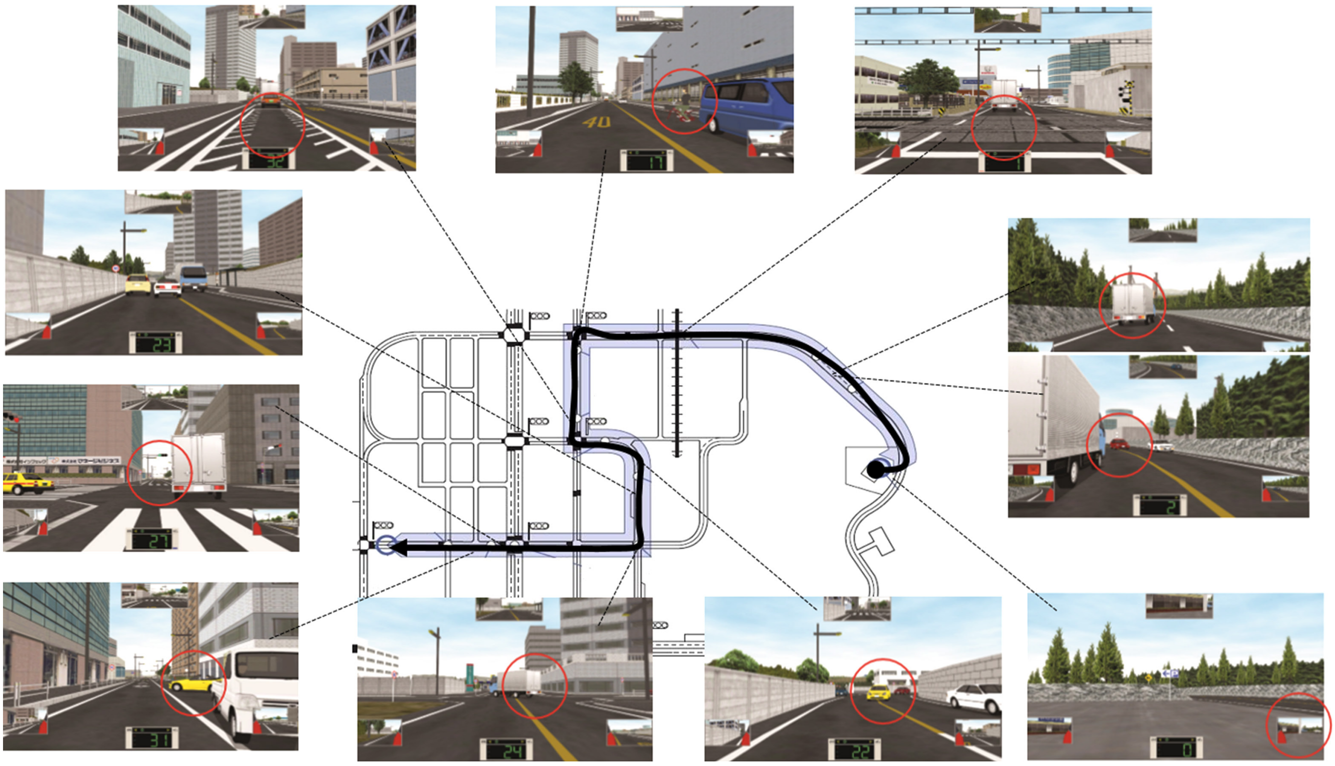

Fig. 1. Outline of the course. Edited by authors from [9].

Methods

Participants

Consent to participate in the study was obtained from 43 older adults with valid driver's licenses. Participants were recruited from community health promotion classes, public lectures, and the Silver Human Resource Center through oral and poster presentations. Of these, 18 participants who could not complete the scheduled number of DS trials (three trials) because of DS sickness were excluded (16 participants stopped after the first trial, while the other two stopped after the second trial) (DS sickness rate: 41.9%). Ultimately, 25 participants were included in the analysis. The mean age of the participants was 75.0 ± 6.0 years (range, 65–89 years; median, 74 years), and 20 were men. The mean score of mini-mental state examination (MMSE) was 27.5 ± 2.0 points (range, 23–30 points; median, 27 points). Additionally, 21 participants had valid licenses for more than 40 years, whereas the other four drivers had been driving for 20–30 years. Twenty-one participants drove daily, and the remaining four drove 3–5 days per week.

The comparison group consisted of 27 young adults with valid driver's licenses. A total of 57 second- and third-year university students were recruited to participate in the study, and 27 of them cooperated and consented to participate in the study. The mean age of the these participants was 20.3 ± 0.7 years (range, 19–21 years; median, 20 years), and eight were men. All participants had obtained their driver's licenses less than two years ago and drove only a few times a year. Additionally, none of the participants had any prior DS experience.

DS

The DS used in this study was Honda Safety Navi® (HONDA GIKEN, Japan). The course used was the KIKEN YOSOKU TAIKEN Course 6 (intermediate level, daytime, estimated distance of 1.2 km, and estimated driving time of 3 min). The course with the shortest driving time was selected taking into consideration the endurance of the older participants. The course content included entering the roadway from a parking lot; driving downhill, including straight lines and curves; overtaking stopped vehicles (with oncoming traffic); railroad crossing; sudden appearance of a bicycle from behind the car when turning left; turning left on a narrow road; dealing with oncoming traffic on a narrow road; and continuing straight after taking a right turn (with approaching vehicles and road crossers) (Fig. 1) [9].

Procedure

Prior to starting the session, the participants were told that if they felt sick, they could alleviate the symptoms by taking their eyes off the screen or taking a deep breath, and that if they judged that it was difficult to continue, they could immediately stop the DS by reporting it. The DS included a fan blowing air from the left side and rear. After explaining about the steering wheel, accelerator, brake, blinkers, and how to read the screen (side and rearview mirrors and speedometer), the participants were given the following instructions, "We will not provide any advice in case of any accidents while operating the DS. Please familiarize yourselves with the operations. We plan to conduct the trial three times with a break of approximately 15 min. If you feel sick, please let us know and we will stop." Subsequently, a DS session was initiated.

Analysis

The number of accidents automatically measured by the DS was used as an indicator of the repeated learning effect. Inter-trial and intergroup comparisons included the number of accidents. Normality and equal variance for the number of accidents could not be confirmed; therefore, the Friedman test was used for comparisons between trials, and the Scheffé's method was used for multiple comparison methods. The Mann-Whitney U test was used for intergroup comparisons. The significance level was set at 5%. The effect size (r) was calculated for the amount of effect.

Results

The number of accidents in the older participants was 42, 17, and 15 in the three trials, respectively. The number of accidents in younger participants was 17, 6, and 5 in the three trials, respectively. The Friedman test revealed a significant difference in the number of accidents between trials between the groups (older participants: $X^2(2) = 19.1$, $p < 0.001$; younger participants: $X^2(2) = 6.0$, $p < 0.05$). Scheffé's method revealed that older participants had fewer accidents in the 2nd or 3rd trials than in the 1st trial (1st vs. 2nd trial: $X^2(2) = 12.9$, $p < 0.01$, r = 0.61; 1st vs. 3rd trial: $X^2(2) = 15.6$, $p < 0.01$, r = 0.67; 2nd vs. 3rd trial: $X^2(2) = 0.13$, $p = 0.94$, r = 0.11). Younger participants performance did not differ significantly between the trials. However, a moderate difference effect was observed between the 1st and 2nd trials and between the 1st and 3rd trials (1st vs. 2nd trial: $X^2(2) = 4.30$, $p = 0.12$, r = 0.38; 1st vs. 3rd trial: $X^2(2) = 4.76$, $p = 0.09$, r = 0.41; 2nd vs. 3rd: $X^2(2) = 0.01$, $p = 0.9$, r = 0.05). The Mann-Whitney U test revealed that older drivers had more accidents than younger participants in all trials (1st trial: Z = 2.89, $p < 0.01$, r = 0.56; 2nd trial: Z = 2.93, $p < 0.01$, r = 0.57; 3rd trial: Z = 2.37, $p < 0.05$, r = 0.46) (Fig. 2).

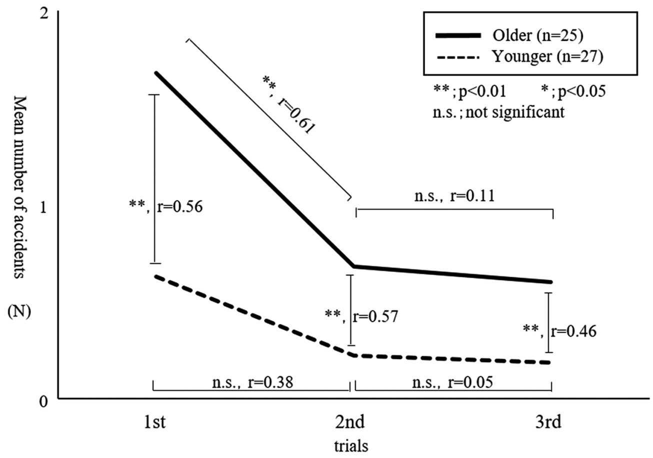

Fig. 2. The mean number of accidents

Regarding the qualitative parameters of the accidents, over 90% of the accidents in older participants group were observed in the first half of the course (between the starting point and railroad crossing), whereas most of the accidents in younger participants group occurred in the second half of the course. The ratio of the number of accidents in the first half of the course to the total number of accidents in the three trials were 97.6%, 94.1%, and 100%, respectively, in the older participants, and 52.9%, 50.0%, and 20.0%, respectively, in the younger participants (Fig. 3–5).

Overall, 102 accidents were noted and these were classified into the following four categories: (1) collision with a wall or vehicle owing to improper maneuvering when driving straight or turning, (2) collision with a wall or vehicle owing to improper maneuvering when turning right or left, (3) rear-end collisions owing to inadequate deceleration, and (4) rear-end collisions owing to improper entry into the road. Irrespective of the number of trials, older participants were most commonly involved in type 3 and rarely in type 2 collisions. In contrast, type 2 accidents were observed most frequently in younger participants, whereas type 3 accidents were rare. Type 4 accidents were observed in a certain number of older participants irrespective of the trial, whereas they decreased in younger participants in each successive trial (Fig. 6).

Discussion

This study is the first reports that show the learning effects of multiple driving simulator runs in older drivers using Honda Safety Navi® which is the most frequently used in Japanese medical institutions. The number of accidents decreased with successive trials for both the older and younger participants. In this study, a repeated learning effect was expected in the third trial. Kawano

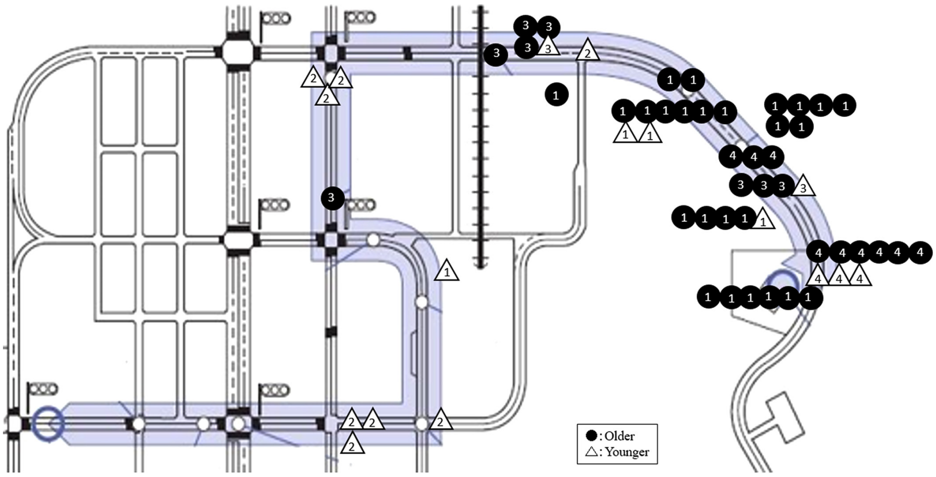

Fig. 3. Accidents observed in the 1st trial. Categories of accidents; 1; collision with a wall or vehicle owing to improper maneuvering when driving straight or turning, 2; collision with a wall or vehicle owing to improper maneuvering when turning right or left, 3; rear-end collisions owing to inadequate deceleration, and 4; rear-end collisions owing to improper entry into the road.

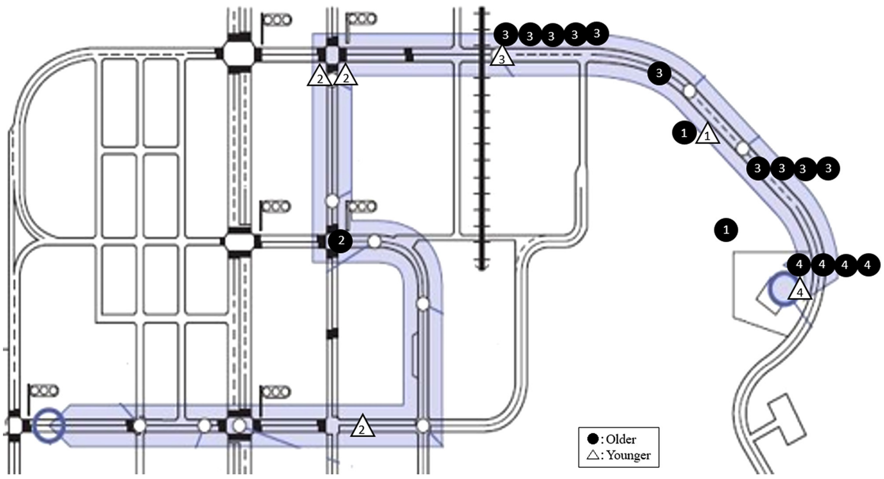

Fig. 4. Accidents in the 2nd trial.

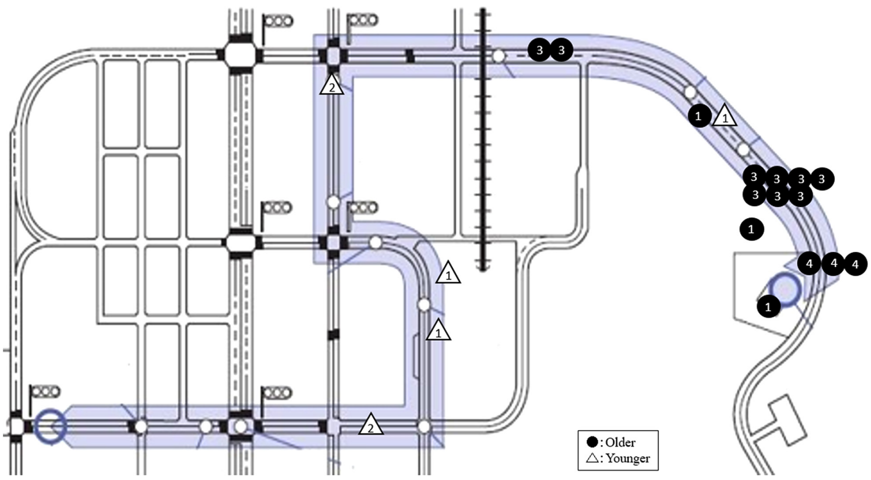

Fig. 5. Accidents in the 3rd trial.

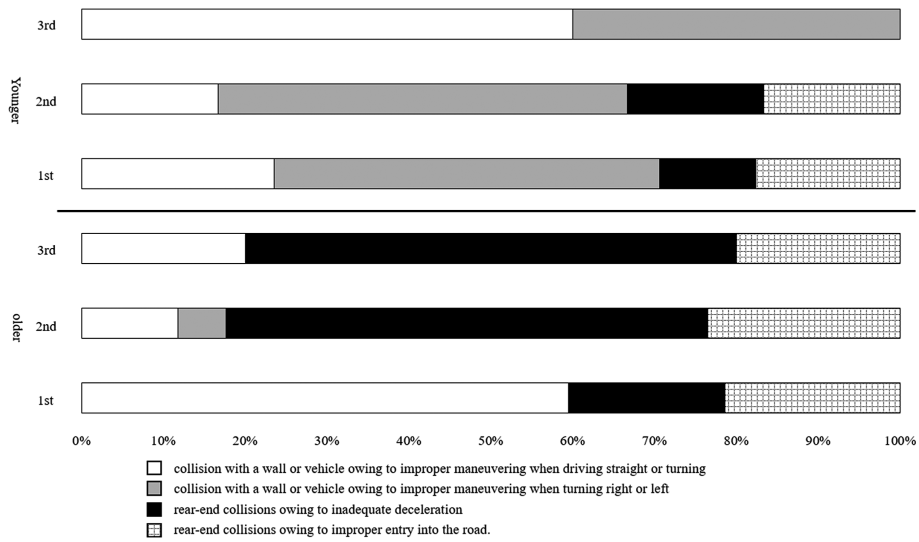

Fig. 6. The proportion of accidents across trials.

et al. (2012) [8] examined the effects of repeated sessions of DS on maintenance of speed (100 km/h) and lane position, and reported that older drivers become accustomed by the 4th trial. Despite differences in the experimental procedures, their results were similar to those of the present study.

DS is a visuomotor learning task that involves several brain regions, including the cerebellum, visual cortex, motor cortex, parietal lobe, hippocampus, and cingulate gyrus [10]. The refinements in this DS-related neural network are influenced by individual functional and age differences; older drivers take longer than younger drivers. Therefore, the possibility cannot be ruled out that a participant's performance may improve, albeit slightly, after the fourth trial in the DS course used in this study. Unsafe driving performance in the initial DS trials may be the result of a combination of both unfamiliarity with the DS operation and the participants actual driving ability. However, it is expected that after multiple trials (e.g., the fourth trial), the unfamiliarity component will decrease and the performance will more likely reflect the participants actual driving ability.

Two results were apparent in the analysis of the accident characteristics. First, accidents in older participants were predominant in the first half of the course (especially type 3 accidents were common in the 2nd and 3rd third trials), whereas accidents in younger participants (especially type 2 accidents) were predominant in the second half of the course (between the railroad crossing and the finish line). The first half of the course was characterized by driving downhill, adjusting the speed, dealing with stopped vehicles and oncoming traffic, and driving around curves in an unfamiliar DS environment. Older participants may have responded to the high cognitive load of operating the DS against the rapidly changing screen from the 2nd trial using inadequate deceleration [11]. By contrast, younger participants may have judged that they could cope with rapid changes on the screen without slowing down, although their DS operations were poor. This speculation is consistent with the finding that information processing speed decreases with age [12]; however, an in-depth analysis of the relationship between speeding locations and accidents is required. As in the first half of the course, in the second half the driver was required to deal with stopped vehicles and oncoming traffic, and to make multiple right and left turns on a flat road without curves. A sensory understanding of the steering wheel rotation angle and the left-right turn angle of the vehicle body depends on the driving experience; consequently, several accidents may have been observed in younger participants with less driving experience. In contrast, the older participants, even in an unfamiliar DS environment, were able to turn right and left without collisions at moderate speeds based on their previous experiences.

The second important accident characteristic was that a certain number of rear-end collisions due to improper entry into the road were observed in older participants, irrespective of the number of trials. Such accidents were not observed in the 3rd trial among the younger participants. In terms of traffic accident statistics, both novice and experienced drivers experienced the highest number of accidents due to unsafe driving, and the ratio of unsafe driving to all violations that led to traffic accidents was higher among experienced drivers [13]. Although the relevance of the results of this study is a matter of speculation, it is interesting to note that there were differences between the groups in accidents related to safe driving awareness when entering the road. In the future, it will be necessary to measure and verify rearview-checking during DS sessions.

Limitations

This study has several limitations. First, the causes of accidents remain unclear. It is not clear whether the accidents were caused by unfamiliarity with the movements of the car on the screen in response to the DS-specific steering wheel and brake operations or by a lack of safety awareness, such as insufficient rear-checking when starting, or whether they were the result of the interaction of the two. The background factors of the repeated learning effect should continue to be analyzed by increasing the amount of data, including changes in the experimental methods, such as increasing the number of repetitions to four or more. Second, because the sample size was small and the age range of the older participants was large, the possibility cannot be ruled out that the number of repetitions until habituation may have differed between individuals of 65–74, 75–80, and ≥ 80 years of age. Third, it should be noted that the present findings are limited to HONDA Safety Navi®, KIKEN YOSOKU TAIKEN Course 6 (intermediate, daytime).

Ethical consideration

All participants gave their informed consent to participate in this study. Experimental procedures followed the ethical standards of the Declaration of Helsinki. This study was approved by the Research Ethics Committee of Hokkaido Chitose College of Rehabilitation (Approval No. 18008).

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Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, and/or publication of this article.

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