Risk Presentation Aimed at Improving Older Drivers’ Understanding of Their Problems via Simulator-Based Education Programs

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Abstract: This study examined simulator-based methods of illustrating risks to elderly drivers in order to improve their ability to anticipate hazards. Experiments were performed using hypothesized driving programs, in which participants learned the importance of considering other cars’ behaviors during lane changes, both their own and those of other drivers. The lane change risks that the elderly drivers were intended to learn to anticipate in their driving were presented using the simulator. The results showed that these presentation methods may be more effective than verbal explanations in helping elderly drivers with reduced metacognitive abilities understand risks. In particular, the most effective method of exposing drivers to the experience of risk promoted the consideration of one’s surroundings in scenarios where another car changes lanes. Among the programs that reminded participants of the need to consider the car behind them when changing lanes, the trailing perspective review method was most effective. Based on our findings, this study presents implications that may be useful in developing driving simulator-based educational programs for elderly drivers.

Key Words: driver education program, image-based review, risk experiencing.

1. Introduction

The implementation of educational programs to help old drivers operate vehicles safely has become common with the growth of Japan’s old population. According to a national survey [1], the traffic-related death rate for drivers over 65 years old has risen to about 50% of the national total, an increase of approximately 120% from 10 years ago. To reduce the number of such accidents, drivers older than 70 are obliged to attend a remedial driver’s education program at a licensed driving school as a prerequisite to renew their drivers’ licenses.

One tool that may be effective in this remedial education program for old drivers involves the use of driving simulators. This was discussed in the recent report that stated the driving abilities shown by old drivers in the simulator correlate with their actual, on-the-road driving abilities [2]. In fact, such simulators are already in use in driver’s education programs across Japan, e.g., [3]. As for educating young drivers, some recent research addressed measuring the efficacy of using these simulators [4]–[6]. Chan et al. suggested that programs using driving simulators could improve hazard perception, speed management, and attention maintenance skills, especially in novice drivers [4].

However, it is doubtful that simulator-based education programs designed for young drivers would be effective for old drivers because of differences in risk comprehension abilities between old persons and young adults [7]. One of various factors that make the risk comprehension difficult for the old is their reduced metacognitive ability. The human aging process normally results in decreased metacognition, which is an ability that supports mental activities such as monitoring and coping with various situations [8]–[11]. Due to reduced metacognitive abilities, old drivers’ self-image of their driving performance often differs substantially from their actual driving behavior [10],[12]. Therefore, it may be difficult for some old persons to accept that they have unsafe driving behavior patterns, and the best methods of providing such learning content to old drivers, in ways that ensure those risks are understood, remains unclear. In order to assist the old in fully understanding their driving behavior risks, regardless of their level of metacognitive ability, the facts related to such risks need to be presented clearly. This can be done, for example, by providing information in ways that allow drivers to see their driving performance from various perspectives. Driving simulators enable us to demonstrate the discussed risks in ways that would be impossible in educational programs using real cars. Thus, the advantages obtained by using such simulators can be expected to contribute to improving understanding of driving risks, particularly for the old.

This study empirically examines the impacts of simulator-based methods of presenting potentially risky behaviors to older drivers ranging in age from 60 to 75 years old. In this paper, the term “risk presentation method” is defined as a way of presenting information on driving risks via the content matter of an education program. This study introduces two methods that may assist older drivers, whose metacognition might be reduced, in understanding the risks they face. One is a method that allows the participants to observe their own driving simulator data from perspectives other than the driver’s seat. The other is to expose the older drivers to risks or accidents while they are driving the simulator.

This study addressed the risks encountered when drivers were engaged in adjusting their behavior to conform to other cars. Such adjustments are often needed when merging at highway junctions and when changing lanes. The practice requires the driver to maintain constant attention and give due consideration to the intentions and behavior of other vehicles [13]. However, this is reportedly hard for old drivers [14]. In this study, risks associated with lane changes were targeted because of the frequency in which such situations arise. Drivers are
sometimes forced to change lanes several times in order to enter a certain lane or to reach a particular goal. Moreover, regardless of the old drivers’ intentions, it is impossible for them to avoid lane changes by other vehicles occurring on the road ahead, even if they avoid potentially unsafe situations such as driving on highways whenever possible [15]. Based on the concept that a simulator-based education process can help drivers heighten their safe driving awareness levels rather than focusing on improving their operation of actual vehicles, effects of risk presentation method were obtained in how much the methods facilitated attention and consideration for other vehicles during lane changes.

The goal of this study was to determine which risk presentation method was most effective for helping older drivers understand that their level of consideration for others was sometimes insufficient to keep them safe. With the oral explanation about the risks as the baseline, we compared the effects of two risk presentation methods. One was a review of participants’ driving performance from the perspective out of the driver’s seat. This method was expected to provide an objective image and would improve participant understanding of potentially insufficiently attentive attitudes in their driving, as well as communicating the crucial need to consider the behaviors and intentions of other drivers. In the other method, the participants were placed in driver simulator scenarios that included potential collision risks. This risk-experiencing method was expected to promote more intuitive understanding of the participants driving risks.

The present study carried out two experiments using the above-mentioned risk presentation methods. These two experiments used different driving scenarios, so that we could determine the common factors increasing the effects of the presentation methods and evaluate their implication. The scenarios themselves included differences in the person performing actions that could trigger an accident. In these experiments, the effects of the presentation methods were measured by comparing the participants’ driving data before and after the risk presentation. It was assumed that the driving performance changes would be reflected in the participants’ increased understanding of the importance of heightened awareness and consideration for others. The authors did not consider or use self-reported increases in awareness to estimate the effects of our risk presentation methods because it was considered unlikely that older participants would be able to accurately assess how much of the contents they had absorbed due to their reduced metacognition [9].

2. Experiment 1

2.1 Objectives

This experiment was aimed at finding out an effective risk presentation method for helping older participants comprehend the risks of insufficient consideration for other vehicles. In particular, we compared the effects of the oral-explanation and simulator-based risk presentation methods (the image-review, risk experience, collision/review combination). The hypothesis-sized education program in Experiment 1 showed drivers the importance of adjusting their vehicle’s position based on the motions of other cars. The dangerous component of the driving scenario occurs when another car changes lanes directly in front of the participant’s car. When this occurred, participants were required to increase the distance between their vehicle and the lane-changed car sufficiently to avoid a collision, even if the car ahead were to reduce its driving speed suddenly. The effects of the risk presentation methods were defined by comparisons of the distance between the participant vehicle and the car changing lanes before and after the risk presentations.

The authors hypothesized that the distance to the car changing lanes ahead was expected to increase significantly after the risk presentations using the simulator-based risk presentation methods.

2.2 Methods

2.2.1 Participants

This experiment recruited 32 young drivers and 32 drivers who were over 60 years old, as shown in Table 1. All participants were corresponding to the manual job offer calling for driving simulator operators. All test participants were required to have valid driver licenses and normal or corrected-to-normal vision. Participants were chosen from applicants who drove routinely (i.e., at least once a week). On the day of the experiment, all participants received an explanation about the experiment and gave written informed consent. They were then divided into four risk presentation method groups: oral-explanation, image-review, collision risk experience, and collision/review combination. Each group had eight young and eight older drivers. Ages were matched among the four presentation method groups. As shown in Table 1, the perception braking times of the older drivers were longer than those of the younger drivers ($F(1,56) = 5.33, p < .05$). No differences were confirmed between the presentation method groups consisting of both young and older participants.

2.2.2 Apparatus

This study used a static driving simulator (Mitsubishi Precision, DS-2000), which is a model commonly used in the driving schools where old drivers take remedial training prior to renewing their licenses. The simulator consists of a host computer system, a driving cabin, and a virtual visual and audio system. The host computer can simulate the driving environment and replay recorded driving data from various perspectives. The image ahead as seen from the driver’s perspective was projected on a monitor positioned 260 cm in front of the steering wheel in the driving cabin and 370 cm from the projector (EPSON EMP 835). The monitor was 182 cm high and 240 cm wide. Images from the rear-view and right side mirrors were also displayed on this monitor. A $22 \times 69$ cm rectangle showing the rear-view mirror view was displayed 21 cm from the top edge and 13 cm from the left edge of the monitor. A $32 \times 46$ cm rectangle

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showing a projected image of the right side mirror was situated 2 cm from the bottom edge and 6 cm from the right edge of the monitor. The simulator’s speaker system provided appropriate background sounds including engine and tire noises.

2.2.3 Driving scenarios

The simulated driving environment was set as a straight, left-hand road in an urban area. The road was four lanes wide with two lanes in each direction of travel. There were cars traveling ahead of and behind the participant’s car in both the left and right lanes. The roadway included two intersections equipped with crosswalks and traffic signals. The traffic signals remained green while the participant’s car was approaching. In each trial, the distance from the starting point to the goal was approximately 1,043 m. The distance from the starting point to the corner of the first intersection was about 805 m, and the distance from the starting point to the second intersection was 968 m. The end point of each trial was set beyond the second intersection.

There were three driving scenarios as follows:
Scenario 1) No cars change lanes as the participant travels from the starting point to the goal.
Scenario 2) A car about 480 cm long, traveling in the right lane, switches to the left lane in front of the participants’ car and travels through the first intersection (Fig. 1(a)). If the participant drives at 50 km/h, he or she is about 125 meters from the corner of the first intersection when the car in the right lane signals its lane change. When the lane change is complete, the participant’s car is about 90 m from the intersection, while the car that changed lanes is about 65 m from the intersection. At this time, if the participant did not slow down, the gap between the front of the participant’s car and the car that changed lanes will have decreased to about 20 m.
Scenario 3) This is the same as Scenario 2 until the lane change. After the lane change, the car that changed lanes begins to signal a left turn when it reaches a point 20 m from the corner. Then, the car decelerates rapidly and attempts a left turn at the first intersection (Fig. 1(b)). However, it stops without completing the turn in order to wait for pedestrians to cross the street. Since the participants were instructed not to change lanes, they will hit the car ahead if they are unable to stop in time.

2.2.4 Experimental procedure

After some practice driving, each participant’s stopping distance was estimated. First, the participant’s perception/braking response time was measured. On the road with two lanes in each direction of travel, the participants were asked to drive straight in the left of the two lanes at 50 km/h while several cars traveled in the right lane at 50 km/h. A pedestrian or a cyclist would suddenly appear 35 m in front of the participant’s car seven times. When the participants saw a pedestrian or cyclist ahead, they were instructed to step on the brake pedal immediately. Lane changes were prohibited. The perception/braking response time recorded from each participant, \( t_{\text{max}} \), was used for calculating the distance traveled from the time a hazard appears until the participant presses the brake pedal. The sum of this distance and the distance traveled from the time the participants start braking until they stop completely produces the stopping distance. The estimated stopping distance was calculated as

\[
s = v \cdot t_{\text{max}} + \frac{v^2}{2 \cdot 9.8 \cdot \mu},
\]

where \( s \) is the distance traveled from the time a hazard appears until the participants stop completely [m]. In the function, \( v \) is the initial speed [m/s] and \( t_{\text{max}} \) is the recorded perception/braking response time as noted above. Finally, \( \mu \) is the friction coefficient between the tires and a dry road when traveling 50 km/h. In this experiment, it was set at 0.7 [16].

After estimating the stopping distance, the experiment began. The experiment was conducted in three phases: a pre-risk presentation phase, a risk presentation phase, and a post-risk presentation phase. A total of 16 trials were carried out in this experiment.

(i) Pre-risk presentation phase

The pre-risk presentation phase consisted of eight trials. In six of these eight trials, Scenario 1 was provided. Participants in the oral-explanation and image review groups drove Scenario 2 in the other two trials. For the risk experience and collision/review combination groups, Scenario 2 was provided only once while Scenario 3 was run in the last trial.

Participants were instructed to drive at a speed of 50 km/h and brake whenever necessary. They were also asked to remain in the left lane.

(ii) Risk presentation phase

During the risk presentation stage, participants were asked to recall their driving in the pre-risk presentation stage and talk about their driving safety. The importance of anticipating the behavior of other drivers, such as lane changes near the intersection, was discussed. Then, an experimenter explained the need to respond to the driving behaviors of surrounding cars. For this explanation, the participant’s stopping distance, estimated on the basis of the perception/braking response time, was used. It was also explained that this distance varies depending on exogenous environmental factors as well as individual response time. In the scene where there was a risk of colliding with the car that changed lanes, participants were recommended to maintain a separation greater than their stopping distance. To compare the distance between the participant’s car and the car that changed lanes with the stopping distance, the image review and collision/review combination groups conducted onscreen reviews of two trials in each Scenarios of 2 and 3 recorded during the pre-risk presentation stage. In the display showing the participants’ car, the pitch angle to the road surface was set at 22° (Fig. 2(a)). For the individuals in the oral-explanation group, the distances were compared numerically. Participants in the risk experience group simply received an explanation about the importance of maintaining a safe distance from other
vehicles.

(iii) Post-risk presentation phase

Similarly to the pre-risk presentation phase, eight trials were provided. Scenario 1 was provided in six of these trials. In one trial, Scenario 2 was used. The order of these trials was randomized. All participants were provided with Scenario 3 as the last trial. While driving, participants were asked to reflect on the topics discussed in the risk presentation phase and add their own remarks.

2.2.5 Data analysis

This experiment was aimed at determining which risk presentation method was most effective in improving older drivers' safety. The two variable factors used in this experiment were age and the presentation method used to show participants the risks in their own driving behavior. The two age conditions comprised a younger and an older group. The four presentation methods were oral-explanation (oral), image review (review), risk experience (collision), and a collision/review combination (combination). The dependent variables were the difference in collision risk between the pre-risk presentation and the post-risk presentation phases. The difference between the recorded distance to the car ahead and the stopping distance calculated using individual perception/braking response times was defined as the collision risk. The recorded distance to the car that changed lanes was the average of the two trials in Scenarios 2 and 3. Two types of recorded distances were compared with the estimated stopping time. The first was the distance to the car that changed lanes when it reached the corner of the first intersection. The other was the average distance to the car ahead from the time the car changing lanes activated its turn signal, until it reached the corner of the first intersection. From the time the car changing lanes activated its turn signal until it began merging, the car ahead of the participant’s vehicle remained defined as the car in front. After the lane merge began, it was identified as the lane-changed car.

The influences of age and presentation method were analyzed using analysis of variance (ANOVA) on the differences between the collision risks before and after the risk presentation. A Tukey post hoc test was carried out for multiple mean comparisons.

2.3 Results and Discussion

First, Experiment 1 examined the effects of risk presentations on the collision risk with a car changing lanes when it reached the intersection. Figure 3 shows the differences in collision risk at the intersection before and after risk presentations. A 2 (age) × 4 (presentation method) ANOVA was performed on this difference and the interaction between age and instruction method was found to be significant, \( F(3, 56) = 7.39, p < .001 \). Post-hoc comparisons showed that for older participants, the collision risk decreased for the collision group compared to the oral, review, or collision-review groups. In contrast, for younger drivers, the collision risk decreased more for the review group than for the oral or combination groups.

The average distance to the car in front beginning at the time it activated its turn signal until reaching the corner of the intersection was also compared with the estimated stopping distances. A two-way ANOVA of age × presentation method was carried out on these distances before and after the risk presentations. Any effect relative to risk presentation method was not obtained.

In keeping with the authors’ hypothesis, the risk presentation methods were found to increase differences in collision risk at the intersection. In particular, it was found that experiencing collisions was effective for older drivers. All the older participants in the collision group collided with the car that had changed lanes at the intersection (Fig. 2(b)). The older participants were likely to be surprised by collision because they received greater crash sounds when they collided to the car in front. They may have also shocked at causing an accident in conflict with their confidence in their driving ability. However, the collision method was believed unlikely to have assisted older drivers in managing the potential risks resulting from the short distance to the lane-changed car. Without the
significant effects of the presentation method on the mean distance since the beginning of the lane change until its end, older participants appeared to just avoid collisions at the intersection. This risk aversive attitude might have been reflected in the greater amount of clear space ahead when approaching the intersection.

Contrary to our prediction, the distance ahead for the older participants in the combination group did not increase significantly after the risk presentation, even though they had all experienced collisions. Several reasons for this were hypothesized, one being that the subsequent image review may have mitigated their collision fear. It is also possible that the review provided a clear image about ways to avoid accidents through participant driving modification, and that knowledge might have decreased the participants’ risk-aversion attitudes by introducing a false sense of security.

However, it should be noted that a more appropriate way to measure the effects of the risk presentations might need to be developed for the scenario where participants are required to respond to the car ahead. This experiment measured the effects of the risk presentation methods by focusing on a comparison of the distance to a car that had changed lanes with the estimated stopping distance; but it is possible that keeping an excessively long distance between the participant’s vehicle and the car ahead could motivate surrounding drivers to make lane changes that could be unsafe during heavy traffic periods in urban areas. Further research will be needed to address this issue.

3. Experiment 2

Next this study focuses on confirming the impacts of risk presentation methods regardless of the learning contents. In Experiment 2, a different unsafe situation was used, which was having the participants change lanes. One cause of unsafe lane changes appears to be a lack of awareness of other cars driving behind the subject’s vehicle. In this experiment, participants were exposed to educational programs that improved their understanding of the importance of considering cars behind them.

Since the results of Experiment 1 already showed that, for older drivers, verbal explanation was less effective than the image review and risk experience methods, the verbal method was not utilized in this experiment. In addition, it should also be noted that Japanese traffic regulations assign more responsibility to the following car than the car ahead in the event of a collision, even when a sudden lane change by the preceding car from behind the subject’s vehicle. In this experiment, participants were asked to evaluate the safety of the participants’ lane changes immediately after their driving trials (self rating) and then again when they watched the reviewed images as if they were other participants’ driving data (another rating). After being informed that the images they had just reviewed were their own data, it was predicted that the participants would revise their initial impression that their consideration of other cars behind them had been sufficient. Based on these results, the authors will discuss how image reviews from bird’s-eye, trailing, and rear-view perspectives influence participants’ understanding of the importance of considering others during lane changes.

3.1 Objectives

In the second experiment, the participants learned the importance of paying attention to the oncoming car and maintaining that distance when changing lanes. The risk presentation method was a review of the participants’ lane change performance from bird’s-eye, trailing, or rear-view perspectives. To estimate the effects of the risk presentation, we measured any increase in the distance to the oncoming car in the other lane after the risk presentation compared to the participant’s behavior before the presentation. The effects were expected to partially reflect the newfound realization of their risk potential, which had been stimulated by viewing their own driving from a different driver’s perspective.

The hypothesis in Experiments 2 was that experiencing involvement in collisions would promote the effects of the presentation methods similar to the results obtained from Experiment 1. The rear-view image was effective because this method
shared a resemblance with the collision method used in Experiment 1. In addition, it was predicted that the image review from the trailing perspective would also be effective because participants could better evaluate the risks of collision by watching how the cars behind reacted to the participants' lane change.

3.2 Methods

3.2.1 Participants

Experiment 2 employed 24 young and 24 older drivers (Table 1). The applicants' qualifications were the same as in Experiment 1. All participants gave written informed consent similar to the test subjects of the first experiment. The young and older drivers were then divided into three groups based on the risk presentation method used. Ages were matched among three presentation-method groups.

3.2.2 Driving scenarios

The simulated roadway and vehicles were the same as those used in Experiment 1. The starting point was also in the left lane, with simulated cars positioned ahead and behind the participant's vehicle. There were also cars in the right lane that were programmed to remain in that lane and to maintain a constant distance from each other. The distances between the cars were set at 20, 30 or 40 m. Because it was believed that being prepared from the beginning of the trial might affect participant driving behavior, large red or white traffic cones were placed on the sidewalk 400 m from the starting point to indicate where the lane changes should begin in each trial. The lane change execution area was defined from the traffic cones and the corner of the first intersection, and was the only zone in which participants were allowed to change lanes. The length of the lane-change zone was also 400 m.

Participants were instructed to drive the simulated vehicle (approximately 375 cm long) at a speed of 50 km/h and brake whenever necessary. The participants were also instructed to remain in the left lane until the traffic cones appeared on the sidewalk. When the traffic cones were red, they were asked to change to the right lane in the lane-change zone (Fig. 5). Participants were also instructed to complete the lane change before reaching the traffic signal at the first intersection. After changing lanes and passing through the first intersection, they would see several vehicles stopped ahead in the right lane that were waiting to turn right at the second intersection. The participants were instructed to stop at the back of the line, which was the goal position in the lane change trials. In contrast, when the traffic cones were white, the participants were instructed to remain in the left lane and proceed straight ahead. This trial condition's goal was in the left lane beyond the second intersection.

3.2.3 Procedure

The same driving simulator was employed as in Experiment 1. A driving practice and measurement of each participant's perception/braking response time followed.

The experiment consisted of a pre-risk presentation phase, a risk presentation phase, and a post-risk presentation phase. There were 22 total trials in this experiment, with the pre-risk and post-risk presentation phases having 11 trials each.

(i) Pre-risk presentation phase

Participants were instructed to change lanes or drive straight depending on the color of the traffic cones placed on the sidewalk. In nine of the 11 trials, red traffic cones appeared, directing the participants to change lanes. After each driving trial, the participants rated themselves on the safety of their lane change using a seven-point scale, ranging from “1” (extremely dangerous) to “7” (extremely safe) to “1” (extremely dangerous). In the other two of the 11 trials, the traffic cones on the sidewalks were white.

(ii) Risk presentation phase

In the risk presentation phase, the recorded trials that included lane-change scenes were reviewed on the driving simulator screen. In total, five trials were reviewed. Two of the reviewed trials consisted of the participant's data when the distance between the cars traveling in the right lane was 30 m, and one was when the distance was 20 m. The other two trials utilized data recorded from other participants. The images were replayed from one of three perspectives for each group. The bird's-eye perspective was the same as used in Experiment 1 (Fig. 2a). The trailing-view perspective corresponded to the participants' car as seen from a vehicle traveling 25 m behind it (Fig. 4a). The rear-view perspective was a 180° perspective as seen from the rear window of the participant's car (Fig. 4b).

The participants were first instructed to watch the lane change image reviews, after which they were asked to assess the safety of each lane change using the seven-point scale. This safety score was “other-rated” because the participants had not yet been informed that the reviewed images would include their own data. Those participants who awarded the driving they watched low scores on the safety scale were asked to discuss the problems observed in the lane changes they reviewed. At this time, the participants were told that all the reviewed images were data collected from other participants.

After reviewing all five trials, the participants were informed that they had reviewed their own driving data as well. They were then asked to consider the difference between the degree of safety evaluated immediately after each lane-change trial in the pre-risk presentation phase, and that of the same trials reviewed in the risk presentation phase. The importance of sufficiently confirming whether cars were present in the right lane was also discussed.

(iii) Post-risk presentation phase

The same eleven trials as in the pre-risk presentation phase were conducted. Participants were required to change lanes in nine of the eleven trials in which the red traffic cones appeared. They were not asked to evaluate their own driving safety. In the final two trials, the scenario with white cones was provided and the participants did not need to change lanes. In this phase, participants were asked to change lanes while reflecting on the discussions held in the risk presentation phase.

3.2.4 Data analysis

The authors defined a behavioral indicator of increased consideration for cars in the right lane traveling in the participant's vicinity. This was the difference in the distance between the participant's car and the car behind it in the right lane, com-
pared before and after the risk presentations. This distance was measured when the participant began turning the steering wheel and when the lane change was completed. The impacts of two independent variables were measured. One was age, i.e., young and older groups. The other was the risk presentation perspective: bird’s eye, trailing, and rear views. Both were related to the subject variables.

Next, we examined the effects of age and presentation method factors on the differences between the participants collected self- and other-ratings safety scores. The two trials the participants reviewed were those in which the cars in the right lane maintained a regular 30 m separation from each other. The mean self-rated scores for these two trials obtained during the pre-risk presentation phase were compared with the other-rated scores for the same trials assessed during the risk presentation phase. Following ANOVA, a Tukey post hoc test was performed for multiple mean comparisons, if necessary.

### 3.3 Results and Discussion

First, the risk presentation effects on the distance to the oncoming car in the right lane when the steering wheel began turning were clarified. The difference between these distances before and after the risk presentation is shown in Fig. 6. A $2$ (age) $\times$ $3$ (presentation method) ANOVA was performed. The results showed an interaction between two factors with $F(2, 42) = 8.56, p < .001$. Post hoc comparisons revealed that for older drivers the group that viewed the trailing perspective showed a greater distance increase than the bird’s-eye or rear-view perspective groups. As for the young participants, the distance increased more after the instruction for the bird’s-eye perspective group than for the trailing-view perspective group.

Secondly, the impacts of age and presentation method on the distance to the oncoming car when participants had completed lane changes were examined. A $2$ (age) $\times$ $3$ (presentation method) ANOVA was performed on the distance differences between the pre- and post-risk presentations. Interactions between age and presentation method were significant with $F(2, 40) = 3.91, p < .05$. Post-hoc comparisons showed that, when presented with risks from the bird’s-eye perspective, the difference was less for the older drivers than for young drivers.

The differences between self-rated and other-rated safety appraisal scores of the lane changes viewed are shown in Fig. 7. A two-way ANOVA of age $\times$ presentation method was performed and yielded age as the main effect $F(1, 42) = 5.28, p < .05$. Older drivers showed greater differences in their self-rated and other-rated safety scores. In order to focus on the impact of the presentation method, a one-way presentation method ANOVA was performed for each (older and young) group. For the older group, the main effect of the presentation method was marginally significant, with $F(2, 21) = 3.09, p = .067$. Post hoc tests showed that the safety score gap between self-ratings and other-ratings was greater for the trailing-view perspective group than the bird’s-eye perspective group. Analysis of the young group did not yield a significant presentation method effect.

Older drivers increased the distance to the car approaching from behind when they began turning the steering, especially after watching the event from the trailing-view perspective. This can be interpreted as showing that the trailing-review method induced greater attention to oncoming cars when older drivers tried to change lanes. This enhanced understanding of the importance of maintaining an awareness of the cars behind them seems to be related to the larger difference in safety scores between the self- and other-ratings.

The larger difference in the self- and other-rated scores was revealed when older participants self-appraised their lane changes as highly safe, but as highly unsafe if viewed while under the impression that another person was driving. Thus, it does not appear that safety standards have become excessively lax among the older participants. Rather, they seemed to be completely unaware that their driving performance did not match their safety standards. Reviewing images from the trailing-view perspective was seen to be effective in helping participants become more aware of the discrepancies in their standards once they were told that they had appraised the same driving data in their self- and other-ratings. Realizing this discrepancy, the older participants in the trailing-view group might
have easily come to the conclusion that they needed to be more aware of approaching cars when making lane changes than they had been before.

Note that some older participants who had received a review from the bird’s-eye perspective shortened the distance to the car approaching behind at the end of the lane changes while they lengthened the distance at the beginning of the lane changes after risk presentation. One possible reason is that participants focused more on the trajectory smoothness of the lane change because the bird’s-eye view enabled them to clearly see their driving motions. This concern might have resulted in the shorter distance to the oncoming car at the end of the lane change. Considering these cases, the effects of the presentation methods were felt to depend on which risks the participants focused on, in particular for the old drivers who have difficulty to pay attention to several points in parallel. It was suggested that the most important point should be clearly identified when information is given to the old people [17]. Thus, the finding in this experiment implies that it is desirable to present the learning content to older drivers in a way that forces them to focus on the most important risks to be learned.

4. General Discussion

The present study investigated different effective methods of presenting risks using driving simulators to improve older drivers’ anticipation of hazards. The present study covered lane-changing situations in which drivers were compelled to increase their consideration of other vehicles. In Experiment 1, reviewing images of the participant’s driving behavior was found to be more effective than verbal explanations in helping older drivers understand the need to consider the intentions of a car that had changed lanes. However, experiencing a collision with the car ahead of them was the most effective way of bringing them to the realization that their awareness of a potential collision had been insufficient.

The target risk in Experiment 2 was a lack of awareness of a car approaching from behind when they changed lanes. For older drivers, reviewing images from the trailing-view perspective had the greatest effect on keeping their attention on cars approaching from behind before initiating a lane change.

While this study did not investigate why experiencing collisions and image-based reviews, especially from the trailing-view perspective, had more significant impacts on older drivers, we can engage in some speculations. Considering the points common to these methods, both seemed to provide a subjective image of the case when they hit the car in front of them. Those images were taken from the perspective of the person primarily responsible for the accidents. Because old drivers are likely to appraise their driving as highly safe [13],[18], being an “offender” appears to conflict with their internal convictions about their driving ability. Compared to the objective bird’s-eye view, the trailing view conveys a truer feeling of being an offender, which might have led participants to try to reduce their conflicting feelings [19]. In addition, it is possible that the simulated experience of causing accidents stimulated their recognition of the possibility that accidents could occur while driving in the real world, thus motivating them to avoid such accidents. That stimulated motivation is likely to encourage older drivers to consider risks relative to other cars and put what they learned while driving on the simulator into actual use.

Here, the authors would like to consider the impacts of the present study on academic research and industry. This study’s contribution is that it compares and reports on the effects of presentation methods that may support the education of old drivers concerning risks, particularly since it is reportedly difficult for old persons to learn those risks [7]. The presentation methods were selected in consideration of the reduced metacognition that accompanies aging. Additionally, presenting risks based on each participant’s driving may enable instructors to focus on different deficits depending on individual driving abilities or propensities. Considering these individual differences, such as the ability to recognize hazards, were great, especially among older drivers [13], presentations that focus on the individual may be especially effective for the old. Thus, this study focused on methods of presenting risks that are expected to increase the impact of remedial driver’s education programs for older drivers. While previous studies have reported the effects of educational programs using driving simulators [4]–[6], applying the risk presentation methods shown to be effective in this study can increase the usefulness of such programs. Moreover, it was expected that application of the implications of this study will increase the impact of current police-run driving simulator-based education programs for the old. Currently, several automobile organizations in our country also offer training programs for old drivers [20],[21]. Most of these organizations have driving simulators, which would allow our results to be incorporated in their training programs. Effective services that help many old drivers maintain driving safely will contribute to maintaining the number of active drivers in an aging society.

5. Conclusion

This study addressed simulator-based risk presentation methods used in education programs for old drivers. The findings of two experiments indicated that old drivers gained a much greater appreciation for the driving risks presented in situations where their actions resulted in a collision.

Finally, we need further studies to confirm the positive effects of using virtual collision experience or trailing-view replays in remedial driver education programs for the old. Although most researchers have confirmed the effects of educational programs on improving the driving performance of old participants [22]–[27], some previous research has cast doubt on the overall efficacy of such driving training programs, with a few even reporting that old drivers continued to exhibit unsafe behavior after participating in the programs [28]–[30]. Therefore, it will be necessary to assess the effects of the authors’ driving simulator-based programs through actual on-road testing.

Furthermore, the retention of the effects resulting from such risk presentations remains unaddressed. Considering the typical limited period of an emotional state [31], the effects of the collision or trailing-view review methods may fade relatively quickly if emotional factors, such as a psychological shock or a feeling of risk aversion, contributed to the positive effects. Further studies will be required to fully understand the sustainability of impacts produced by presenting old drivers with the risks their driving can cause.

References


