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The effect of a simulator based training on specific measures of driving ability in older drivers.

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Abstract: Since driving is important for quality of life, it is important to keep older drivers safe drivers for as long as possible. Therefore, this study investigated whether driving simulator based training can enhance specific measures of driving ability in older drivers. Forty older drivers participated in the study, but due to drop-out, 30 participants (mean age 69.93) remained in the sample. Participants were randomly assigned to an experimental (N=15) or an active control group (N=15). During the training session, participants in both groups drove in the simulator, in order to have equal driving experience in the simulator. In addition, participants in the experimental group received driving-specific feedback on their driving ability, while participants in the active control group received general information about traffic and conducted a traffic-related quiz. During the pre-test and post-test, specific measures of driving ability were assessed in the driving simulator (i.e., mean driving speed, standard deviation of lateral position, complete stops at stop signs, giving right of way to traffic at the right side and crashes). Results indicated that both groups had improved lateral control and less crashes after following a driving simulator based training. In addition, after following a driving simulator based training, participants in the experimental group gave more right of way to traffic at the right side and participants in the active control group drove faster (without exceeding the speed limits). These results demonstrated that driving multiple times in a simulator, improves performance on some measures of driving ability like lateral control. However, in order to improve on measures of driving ability like giving right of way to traffic at the right side, driving-specific feedback is necessary.

Older drivers; Driving simulator; Training; Feedback

1. Introduction

The number of older drivers is increasing. Previous research has indicated that older drivers have problems with some driving situations, e.g., giving right of way at intersections (Eby, Molnar, & Kartje, 2009). Problems with driving situations like giving right of way could be due to several reasons (e.g., not having the knowledge of giving right of way, insufficient visual abilities). Although not all problems can be solved by driver training (e.g., insufficient visual abilities), some of these problems could be tackled by driver training (e.g., knowledge), which may result in a postponement of driving cessation. Since driving cessation leads to a decline of out-of-home activities, social isolation and even depression, a postponement of driving cessation would benefit the quality of life among older people (Marottoli et al., 1997). Several studies have investigated the effect of cognitive training on driving ability of older people since cognitive abilities are important for driving ability and are trainable, indicating considerable plasticity even at old age (Kramer & Willis, 2002). These studies have shown that cognitive training can improve cognitive ability (Ball et al., 2002; Ball, Edwards, & Ross, 2007; Cuenen et al., 2016; Karbach & Kray, 2009; Rebok et al., 2014; Schmiedek, Lövdén, & Lindenberger, 2010) and even some measures of driving ability of older people (Ball, Edwards, Ross, & McGwin Jr, 2010; Ball, Ross, Roth, & Edwards, 2013; Cassavaugh & Kramer, 2009; Cuenen et al., 2016; Edwards, Delahunt, & Mahncke, 2009; Edwards, Myers, et al., 2009; Roenker, Cissell, Ball, Wadley, & Edwards, 2003). However, the studies showing transfer effects from cognitive training to driving ability, often found only small effects on a limited number of driving measures. As a consequence, there is debate about the transfer effects of cognitive training (Melby-Lervåg & Hulme, 2013; Shipstead, Redick, & Engle, 2012). Several studies found improvement on the trained tasks after following cognitive training, but not on untrained tasks. This was found for studies only investigating effects on cognitive measures (Lange & Süß, 2015; Zinke, Zeintl, Eschen, Herzog, & Kliegel, 2012) and for studies also investigating effects on driving measures (Gaspar, Neider, Simons, McCarley, & Kramer, 2012; Mayhew, Williams, & Pashley, 2014). According to the law of identical elements and the practice-specificity approach of learning abilities, the best training conditions are those allowing learning of the same underlying processes that will be used in the transfer task (Schmidt & Lee, 2005; Thorndike & Woodworth, 1901). Therefore, if the final purpose is to transfer to the road, they must be acquired in a driving-specific context. Hence, a training more directly targeting driving ability might be more successful in improving driving ability (Gaspar et al., 2012; Mayhew, Robertson, & Vanlaar, 2014). Indeed, recent research has investigated the effect of driving simulator-based training in older drivers and found promising on road effects on driving ability after training (Casutt, Theill, Martin, Keller, & Jäncke, 2014; Lavallière, Simoneau, Tremblay, Laurendeau, & Teasdale, 2012; Roenker et al., 2003; Romoser & Fisher, 2009). Casutt et al. (2014) compared the effects of driving simulator based training and cognitive training on older drivers' overall driving score during an on-road test and found improvements only in those who followed driving simulator based training. Romoser and Fisher (2009) and Lavallière et al. (2012) compared the effects of driving simulator based training with and without feedback on older drivers' visual search. They found that the visual search of participants who received driving-specific feedback was twice as good after the training, while there was no improvement in participants who did not receive feedback.

With the exception of the study of Roenker et al. (2003), these studies investigated the effect on overall driving ability (Casutt et al., 2014) or on only one measure of driving ability, i.e., visual search (Lavallière et al., 2012; Romoser & Fisher, 2009). Although overall measures of driving ability do incorporate different aspects of driving, they do not provide a detailed enough view of driving ability. Since driving is a complex task, it can be expected that not all driving measures will be affected by a training. Indeed, Roenker et al. (2003) investigated the effect of driving simulator based training on specific measures of on-road driving ability of older drivers and found that participants, with a decreased useful field of view, showed improvements in turning into the correct lane and proper signal use. They found no improvement in other driving measures like maintaining lane position and speed, accelerating and decelerating smoothly and selecting gaps.

Given that older drivers are the fastest growing segment of the driving population and that it is important to keep older drivers safe drivers for as long as possible, it is surprising that only a limited number of studies investigated the effect of driving simulator based training on the driving ability of older drivers (Casutt et al., 2014; Lavallière et al., 2012; Roenker et al., 2003; Romoser & Fisher, 2009). Therefore, the aim of the present study was to gain more insight into the effect of driving simulator based training on specific measures of driving ability of older drivers and to contribute to the limited research conducted in this area. Contrary to an overall driving measure or solely one specific measure of driving ability, several specific measures of driving ability were assessed like mean driving speed, standard deviation of lateral position, complete stops at stop signs, giving way to the right, and crashes. Since previous research (Lavallière et al., 2012; Romoser & Fisher, 2009) found beneficial effects of providing driving-specific feedback, we randomly assigned participants to a group with driving-specific feedback (i.e., experimental group) and a group without driving-specific feedback (i.e., active control group).

We have three research hypotheses: The first hypothesis is related to the number of driving measures that could be affected by the training. We hypothesize that driving simulator based training will improve performance on some driving measures, but not on all, since previous research found improvement on solely a few measures of driving ability (Roenker et al., 2003). The second hypothesis is related to the groups (i.e., experimental group, active control group) that were included in the study. We hypothesize that both groups will improve on some specific driving measures since both groups actively trained in the simulator and learning theories state that participants' performance improves with practice (Boot, Blakely, & Simons, 2011; Collie, Maruff, Darby, & McStephen, 2003). Third, we hypothesize that there will be additional improvements on some specific driving measures in the group receiving driving-specific feedback (i.e., experimental group) compared to the group receiving no driving-specific feedback (i.e., active control group) since previous research found beneficial effects of providing driving-specific feedback (Lavallière et al., 2012; Romoser & Fisher, 2009). Although, the few studies that conducted an evaluation of a driving simulator based training used other driving measures than the measures used in this study (Casutt et al., 2014; Lavallière et al., 2012; Romoser & Fisher, 2009) or a group of older drivers that experienced a decline in functional abilities (i.e., UFOV reduction of 30% or greater; Roenker et al., 2003), we expect an improvement in giving right of way in our study, since this is the focus of our driving simulator based training.

2. Method

2.1. Participants

Participants aged 65 years or older who were still active drivers, had not had a stroke or sequel in the last six months and had a Mini-Mental State Examination (MMSE) score of 25 or above were recruited. The MMSE is a brief test that examines the mental status of an individual. It comprises items assessing orientation to time and place, registration and recall, attention, language and constructional ability (Folstein, Folstein, & McHugh, 1975). Possible scores range from 0 to 30, with higher scores reflecting better mental status. Recruitment occurred through the community via (local) media and via oral presentations and flyers distributed in senior associations. Given the possibility of simulator sickness, participants were closely watched for signs of this type of sickness. If a participant showed any signs of simulator sickness, the simulation was immediately terminated and the participant was excluded from further participation. In total, forty participants volunteered. However, ten participants dropped out due to simulator sickness (n=9) or personal circumstances (n=1). After successful completion of the pre-test (i.e., no simulator sickness), participants were randomly assigned to an experimental group receiving driving-specific feedback (N=15) or an active control group receiving no driving-specific feedback (N=15). The study was approved by the ethical review committees of Hasselt University.

2.2. Driving simulator

The experiment was conducted on a driving simulator with a force-feedback steering wheel, an instrumented dashboard, brake and accelerator pedals and with a 135 degree field of view (see Figure 1). STISIM version 3 was used as software. The visual environment of this simulator was presented on three computer screens (each with 4800 x 900 pixels resolution and 60Hz refresh rate).

Fig. 1: Driving simulator.

During the pre-test and post-test, two practice rides served to get acquainted with the driving simulator and preceded the main ride. In the first practice ride (3 km) almost no curves, no signs, and no other road users were introduced to acquaint drivers with the experience of driving in a simulator (i.e., speed, lane position). The speed limit increased from 50 km/hour to 70 km/hour to 90 km/hour to 120 km/hour. The second practice ride (3 km) consisted solely of an inner-city section (50 km/hour). Turning left at an intersection and changing lanes in order to pass a road obstacle were introduced to acquaint drivers further with the experience of driving in a simulator (i.e., steering, signal use, looking behavior). The main ride (11 km) consisted of inner-city (50 km/hour) and outer-city sections (70 km/hour and 90 km/hour). The ride did not contain any curves in order to decrease the risk of simulator sickness (Romoser, 2008). The ride included two situations where drivers need to give right of way, since these situations are known to be difficult for older drivers. One situation where drivers need to give right of way was at an intersection with an explicit right of way (i.e., stop sign). Here, drivers need to make a complete stop (0 km/h) and give right of way to traffic at the left and right side. Cross traffic from the left and right side occurred when the driver approached the intersection (see Figure 2). A second situation where drivers need to give right of way was at an intersection with no explicit right of way. Here, drivers need to give right of way to traffic at the right side. A motorcycle from the right side crossed the intersection when the driver approached the intersection (see Figure 3).

Fig. 2: An intersection with an explicit right of way.

Fig. 3: An intersection with no explicit right of way.

Importantly, in the pre-test and post-test main ride, participants encountered situations that were identical (i.e., directly trained) to situations in the training session, and situations that were comparable though not identical (i.e., indirectly trained) to situations in the training session. For example, during the training session they encountered a two-lane intersection, while during the pre- and post-test, they also encountered a four-lane intersection.

A total of five specific driving measures, based on a literature study, were considered for analyses: mean driving speed (km/h), standard deviation of lateral lane position (SDLP, m), crashes (number), making a complete stop at an intersection with a stop sign (yes (coded as 1) or no (coded as 0)) and giving right of way to traffic at the right side at an intersection with no explicit right of way (yes (coded as 1) or no (coded as 0)). The first two driving measures (i.e., mean driving speed and standard deviation of lateral position (SDLP)) were chosen since they represent longitudinal and lateral control measures. A measure of longitudinal control (i.e., mean driving speed) was selected since older drivers compensate for age-related increases in response time, for example by adopting slower speeds (Fisher, Rizzo, Caird, & Lee, 2011). A measure of lateral control (i.e., SDLP) was selected since this measure is an index of road-tracking precision (Ramaekers, 2003), which is considered a reliable characteristic of individual driving performance (O'hanlon & Ramaekers, 1995; Vuurman, Theunissen, Van Oers, Van Leeuwen, & Jolles, 2007; Wester, Böcker, Volkerts, Verster, & Kenemans, 2008) and provides a sensitive measure of driver impairment (De Waard, 1996; Ramaekers, 2003). The other two driving measures were selected since they represent situations that are often mentioned in the literature as difficult for the older driver: Giving right of way to traffic at the right side at an intersection with no explicit right of way and complete stop at a stop sign. These measures were used to assess whether drivers would comply with Belgian traffic regulations stipulating that drivers must give right of way to traffic at the right side at an intersection with no explicit right of way and make a full stop (i.e., mean driving speed = 0 km/h) at a stop sign (Bao & Boyle, 2008; Jongen et al., 2012). It has to be noted that the legislation of giving right of way to traffic at the right side at an intersection has changed in Belgium in the year 2000. Before the change in legislation, drivers only needed to give right of way in inner-city road sections if the car at the right side was moving. If the car at the right side stopped, they 'lost' their right of way. Since the year 2000, drivers always need to give right of way in inner-city sections, regardless of whether the car at the right side is moving or not.

All driving measures were averaged measures, with the exception of crashes where the total number of crashes during the ride was calculated. Mean driving speed and SDLP were measured across separate road segments without any events (Trick, Toxopeus, & Wilson, 2010).

2.3. Driving simulator based training

The driving simulator based training was based on components of the study of Romoser and Fisher (2009). During the training session, participants of the experimental group viewed a replay of their own ride that they made during the pre-test. During this replay, they received both reinforcing and corrective feedback from the researcher tailored to the participant's (un)safe driving behavior during specific traffic situations. In addition, they saw a replay of a comparable ride including pre-recorded commentaries from a certified driver instructor. These were commentaries on how to react best in the specific driving situations (e.g., when entering a four-lane road one needs to drive in the lane at the right side). Afterwards, they drove in the simulator on their own for approximately 40 minutes. There was no researcher helping them/providing feedback, since they received feedback prior to driving in the simulator. First, they drove through two practice rides. Afterwards, they drove through four short scenarios that incorporated situations where they needed to give right of way.

Participants of the active control group received no driving-specific feedback, instead, they received general traffic information about possible decreases in functional abilities (i.e., cognitive, motor and visual abilities) due to aging, and information about some driving measures like driving speed and following distance. Importantly, with the exception of the information about speed, there was no information given about driving measures that were investigated during the pre- and post-test. Hence, this information should not lead to an improvement in driving performance. Afterwards, they filled in a traffic-related quiz. This quiz consisted of 15 multiple choice questions about general topics (e.g., the visual field when driving at a speed of 100 km/h, the safest place in the car, the country with the highest number of people that drive under influence, the definition of an 'anti-lock braking system'). At the end, they received feedback about the correct answers on the questions of the quiz including a brief explanation. Finally, they also drove the two practice rides and the four short scenarios in the simulator during approximately 40 minutes, in order to have equal driving experience as the experimental group in the simulator. Hence, the only difference between the two groups is the driving-specific feedback given prior to driving in the simulator, with participants in the experimental group receiving this kind of feedback and participants in the active control group not receiving this kind of feedback.

2.4. Procedure

First, participants gave informed consent. Then, all participants were screened for cognitive status with the MMSE. After successful completion of the pre-test (i.e., no simulator sickness), participants were randomly assigned to either an experimental group or an active control group. During the pre- and post-test, participants of both groups drove in the driving simulator. In between, participants of both groups completed driving simulator based training. After the post-test, participants received a gift certificate. Order of the driving situations within a scenario was counterbalanced between and within participants during the pre- and post-test. A one-week interval was set between pre-test and training, and between training and post-test.

2.5. Data analysis

The data was processed using SPSS. Before analyses, outliers were treated for each variable. Outliers larger than three standard deviations were replaced with the maximum score within the three standard deviation range (Wood, Anstey, Kerr, Lacherez, & Lord, 2008).

Univariate analyses of variance (ANOVA) were conducted to check for pre-test differences between the two groups on age, MMSE, and the five driving measures (i.e., mean driving speed, SDLP, complete stops at stop signs, giving right of way to traffic at the right side, and crashes). Repeated measures ANOVA were conducted for each of the driving measures. The specific driving measures served as the dependent variables, Test (i.e., pre-test, post-test) and Situations (i.e., directly trained, indirectly trained) served as within-subjects variables, and Group (experimental group, active control group) served as between-subjects variable.

Significant three-way interactions between the within-subjects variables Test and Situation and the between-subjects variable Group were further investigated. Separate repeated measures ANOVA for each level of Situations (i.e., directly trained, indirectly trained) were conducted with Test (i.e., pre-test, post-test) as within-subjects variable and Group (i.e., experimental group, active control group) as between-subjects variable to assess the two-way interaction effect of Test x Group.

Significant two-way interaction effects between the within-subjects variable Test and the between-subjects variable Group were further investigated. Separate repeated measures ANOVA for each level of Test (i.e., pre-test, post-test) were conducted with Group (i.e., experimental group, active control group) as between-subjects variable to assess the main effect of group.

For one driving measure (i.e., crashes) the within-subjects variable ‘Situations’ was not applicable. The Greenhouse–Geisser epsilon correction factor was applied to compensate for possible effects of non-sphericity in the measurements compared. Only the corrected F and probability values are reported. An alpha level of .05 was maintained for all statistical tests. Effect sizes were reported with Cohen’s d. A Cohen’s d of 0.2 indicates a small effect size, 0.5 indicates a medium effect size, and 0.8 indicates a large effect size.

3. Results

3.1. Participants

Participants had an age between 65 and 79 years (experimental group 65-79 years, active control group 65-76 years). They had a mean age of 69.93 years (experimental group 71.27 years, active control group 68.60 years) and on average had a MMSE score of 28.80/30 (experimental group 28.53/30, active control group 29.07/30). Among the participants, 19 were male (experimental group 10 male participants, active control group 9 male participants) and 11 were female (experimental group 5 female participants, active control group 6 female participants). At pre-test, participants did not significantly differ in these demographic measures (all p-values $\geq .05$).

3.2. Driving ability during pre-test and post-test

See Table 1 for the descriptive statistics of the (directly and indirectly trained) driving measures for the pre-test and post-test, separately for each group. Participants did not significantly differ on the majority of driving measures (i.e., speed, SDLP and crashes) during pre-test (p-values ≥.05).

Table 1.
Means and standard deviations (SDs) for the (directly and indirectly trained) driving measures, in the experimental group (EG) and active control group (ACG) for the pre-test and post-test.

Driving measure (not averaged)	**Pre-test**				**Post-test**			
	EG Mean (SD)		*ACG Mean (SD)*		*EG Mean (SD)*		*ACG Mean (SD)*	
Crashes (number)	0.93 (0.88)		0.93 (1.22)		0.07 (0.26)		0.13 (0.52)	
Driving measure (averaged)	**Pre-test**				**Post-test**			
	Directly trained situations		Indirectly trained situations		Directly trained situations		Indirectly trained situations	
	EG Mean (SD)	*ACG Mean (SD)*	*EG Mean (SD)*	*ACG Mean (SD)*	*EG Mean (SD)*	*ACG Mean (SD)*	*EG Mean (SD)*	*ACG Mean (SD)*
Mean driving speed (km/h)	56.43 (6.26)	59.54 (5.26)	59.87 (5.14)	62.30 (4.09)	56.70 (5.99)	60.04 (5.30)	58.70 (4.55)	65.58 (4.42)
SDLP (m)	0.19 (0.06)	0.20 (0.06)	0.20 (0.12)	0.21 (0.07)	0.17 (0.03)	0.17 (0.04)	0.15 (0.04)	0.17 (0.04)
Complete stops at stop signs (0= no/ 1=yes)	0.73 (0.46)	0.60 (0.51)	0.73 (0.46)	0.40 (0.51)	0.73 (0.46)	0.53 (0.52)	0.80 (0.41)	0.60 (0.51)
Giving right of way to traffic at the right side (0=no/1=yes)	0.80 (0.41)	0.73 (0.46)	0.53 (0.52)	0.87 (0.35)	1.00 (0.00)	0.94 (0.22)	1.00 (0.00)	0.94 (0.22)

3.3. Repeated measures ANOVA

See Table 2 for the results of the repeated measures ANOVA.

There was a significant three-way interaction between Test, Group and Situations for only two driving measures (i.e., mean driving speed and giving right of way to traffic at the right side). These interactions were further investigated.

For mean driving speed, there was only a significant main effect of Test for those in the active control group during situations that were indirectly trained, indicating a higher driving speed at post-test (without exceeding the speed limits) compared to pre-test ($F(1,14)=6.05$, $p=.028$). In other words: those who did not receive driving specific feedback during the training session, drove faster after the training session (without exceeding the speed limits) in situations that were indirectly trained compared to those who did receive this feedback. Cohen's d was 0.77, indicating a medium effect.

For giving right of way to traffic at the right side, there was only a significant main effect of Test for those in the experimental group during situations that were indirectly trained, indicating more giving right of way to traffic at the right side at post-test compared to pre-test (F(1,14)=12.25, p=.004). In other words, those who did receive driving-specific feedback during the training session gave more right of way to traffic at the right side after the training session in situations that were indirectly trained compared to those who did not receive this feedback. Cohen's d was 1.29, indicating a large effect.

In addition to these interactions, there was a significant main effect of Test for SDLP and crashes, indicating that all participants had an improved lateral control and had less crashes after the training session. Cohen's d was 0.74 for SDLP, indicating a medium effect, and 1.09 for crashes, indicating a large effect.

Table 2.

Corrected F and probability values per driving measure.

Driving measure	***F***	***p***
Mean driving speed		
Test	0.77	.39
Situations	31.43	.00**
Test x Group	2.02	.17
Test x Situations	0.60	.45
Situations x Group	1.38	.25
Test x Group x Situations	5.84	.02*
Group	6.68	.02*
SDLP		
Test	8.99	.006**
Situations	0.06	.80
Test x Group	0.001	.98
Test x Situations	0.49	.49
Situations x Group	0.24	.63
Test x Group x Situations	0.06	.81
Group	0.56	.46
Complete stop at stop signs		
Test	0.29	.59
Situations	0.11	.75
Test x Group	0.03	.86
Test x Situations	0.84	.37
Situations x Group	0.97	.33
Test x Group x Situations	0.30	.59
Group	4.18	.05
Giving right of way to traffic at the right side		
Test	15.68	<.001**
Situations	0.56	.46
Test x Group	2.48	.13
Test x Situations	0.56	.46
Situations x Group	5.04	.03*
Test x Group x Situations	5.04	.03*
Group	0.22	.65
Crashes		
Test	24.49	<.001**

Test x Group	0.03	.87
Group	0.01	.91

*<.05, **<.01

4. Discussion

Since it is important to keep older drivers safe drivers for as long as possible, this study aimed to investigate whether driving simulator based training can improve specific measures of driving ability in older drivers.

The results showed that there was an improvement of SDLP and crashes after following a driving simulator based training in both groups. Hence, as expected and in line with learning theories, participants' performance improved by driving multiple times in a driving simulator.

In addition to these learning effects and in line with our hypothesis, the results also showed that driving simulator based training with driving-specific feedback (i.e., the experimental group) leads to an improvement of giving right of way to traffic at the right side. Since previous research demonstrated the importance of driving-specific feedback (Lavallière et al., 2012; Romoser & Fisher, 2009), the improvement is probably due to the feedback participants received during the training session before driving in the simulator (i.e., when driving in inner-city sections you need to give right of way to traffic at the right side). As mentioned in the Method section (i.e., 2.2 Driving simulator), there was a change in legislation on giving right of way in 2000. Although this change in legislation occurred 18 years ago, older people are often not aware of this change in legislation since they already obtained their driving license long before that moment, and they are not obligated to follow traffic education sessions in Belgium. Remarkably, the improvement occurred only in situations that were indirectly trained in the simulator (e.g., a four-lane intersection) and not in situations that were directly trained in the simulator (e.g., a two-lane intersection). When comparing the situations that were trained directly and indirectly in more detail, we have to conclude that the situations that were indirectly trained could be perceived as more complex (e.g., four-lane intersection vs. two-lane intersection). Hence, the situations that were indirectly trained in the simulator possibly received more attention since these were perceived as more complex. However, since we did not measure this, we can only speculate about this reason. In addition, it has to be noted that the baseline performance of the experimental group on giving right of way situations that were directly trained in the simulator was a lot higher compared to giving right of way situations that were indirectly trained in the simulator. Hence, the size of possible improvement was a lot lower. As a result, it could be due to a ceiling effect that we did not find a significant effect among the situations that were directly trained in the simulator.

Surprisingly, the results also showed that driving simulator based training without driving-specific feedback (i.e., the active control group) leads to an increase in mean driving speed (without exceeding the speed limits). We did not expect a change in driving performance in the active control group, without a change in driving performance in the experimental group since this group received no driving-specific feedback and previous research indicated that feedback is important in order to have an effect (Lavallière et al., 2012; Romoser & Fisher, 2009). Remarkably, the change occurred only in situations that were indirectly trained in the simulator. This might be due to the general information about traffic this group received during the training session before driving in the simulator. Possibly, the increase in mean driving speed can be attributed to the fact that during this general information, it was highlighted that "it is not only important not to exceed the speed limit, but also important not to drive too slow since this can hinder other road users". When taking a closer look at the results, it seems that the information on driving speed made older drivers more aware of their driving speed and prompted them to adjust their speed accordingly, since they drove faster during the post-test compared to the pre-test without exceeding the speed limits.

With the exception of this information about driving speed, there was no information given about the other driving measures, which could explain why there was only an effect in the active control group on driving speed in situations that were indirectly trained in the simulator.

Since the few studies that conducted an evaluation of a driving simulator based training used other driving measures (Casutt et al., 2014; Lavallière et al., 2012; Romoser & Fisher, 2009) or a group of older drivers that experienced a decline in functional abilities (Roenker et al., 2003), we did not have specific expectations about which aspects of driving performance would improve, except for giving right of way, since this was the focus of our driving simulator based training.

Taken together, we can conclude that: (1) driving simulator based training with driving-specific feedback (i.e., the experimental group) leads to an improvement of giving right of way to traffic at the right side, (2) that driving simulator based training without driving-specific feedback, but with general traffic information about speeding, following distance and possible decreases in functional abilities due to aging (i.e., the active control group) leads to an increase in mean driving speed (without exceeding the speed limits), and (3) that driving simulator based training both with and without driving-specific feedback leads to an improvement in SDLP and crashes. Hence, as expected, driving simulator based training had an effect on some, but not all driving measures. This is in line with previous research who also found improvements on only some driving measures after following driving simulator based training (Roenker et al., 2003). Possibly, given the complexity of driving, some aspects of driving are more difficult to train than others. Since training often has an influence on some but not all driving measures, training should be offered to participants having difficulties with driving measures where training has an influence on. The finding of several studies that training does not improve all driving measures is not problematic since drivers who can benefit from training merely have problems with only a selection of driving measures instead of problems with (almost) all driving measures where driving cessation should be more appropriate than training. However, it is important that training is tailored to the needs of the individual, tackling especially those aspects that are needed the most. Also drivers who do not yet experience difficulties with driving can benefit from specific training tackling aspects where most older drivers experience difficulty with since the driving environment is constantly changing to conditions of modern life.

5. Limitations and future research

Some limitations have to be noted. First, both groups improved on SDLP and crashes. In order to distinguish training effects from test-retest effects, future research should incorporate a no-training control group (i.e., a group with only a pre- and post-test). In addition, future research should pay attention to the information the active control group receives, since this group improved in driving speed by only receiving general information about driving speed.

Second, although driving-specific feedback in the current study seems to have beneficial effects on giving right of way to traffic at the right side, it is not clear whether the benefits are due to the customized feedback and/or due to the pre-recorded commentaries of the certified driving instructor. Future research should therefore not only evaluate the programs overall effect, but also evaluate the effect of the separate components. This should not only been applied to driving simulator based training, but also to other types of driver training, since, although simulators offer several advantages, due to simulator sickness, not all drivers can be trained in a driving simulator (Fisher et al., 2011). In addition, the present study included solely one training session, while other studies incorporated several training sessions (i.e., ten sessions

(Casutt et al., 2014)). Therefore, future research should investigate the number of training sessions, so that training is efficient and participants do not follow too few or too many sessions. Third, the present study only investigated immediate training effects. As a consequence, the longer-term effects remain unclear. Future research should therefore examine the sustainability of effects. Previous studies investigating the effects of driving simulator based training on the driving performance of older drivers found effects maintained for two years (Romoser, 2012). Fourth, the possibility of a self-selection bias has to be kept in mind. Especially those drivers that think of themselves as good drivers could be more willing to volunteer to participate in a study investigating driving performance. Indeed, results cannot be generalized to the whole population of older drivers, since the sample size of this study was quite small and participants were only screened for mental impairments, not for visual or motor impairments. In addition, participants were all cognitively healthy as indicated by the scores on the MMSE. Therefore, results of this study in some way could be an underestimation of the program's true effectiveness.

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