2013•2014
FACULTEIT BEDRIJFSECONOMISCHE WETENSCHAPPEN
master in de mobiliteitswetenschappen

Masterproef

Cognitieve training bij oudere bestuurders

Promotor :
Prof. dr. Tom BRIJS

Steffen Briers

Proefschrift ingediend tot het behalen van de graad van master in de mobiliteitswetenschappen

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The effect of a working memory training on cognitive ability and driving ability of older drivers

School for mobility sciences
Master in de mobility sciences

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1. SUMMARY

Since cognitive ability is important for driving, this study investigated whether strengthening cognition, more specific working memory, influences cognitive and driving ability in a positive way. The present study focused on older drivers since with age there is a decrease in cognitive ability. Twenty drivers (aged 65+) were allocated to a control or an experimental group and performed a working memory training at home for 25 consecutive days.

Before and after the training, participants were measured on working memory, response inhibition and visual attention in a cognitive test battery. Afterwards, their driving ability was measured in a driving simulator.

Results showed that training improved working memory, inhibition and visual attention for all participants. Further, the training improved driving ability of all participants in the experimental group, showing a decreased gap acceptance during post-test. However, these results can be influenced by learning-effect. Especially for crashes, the experimental group showed better results in the post-test than the control group, indicated by a larger decrease of crashes. These results and their implications will be discussed.

Keywords: Working Memory, Driving Simulator, Older Drivers, Driving ability, Cognitive ability

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Figures: 6

2. INTRODUCTION

Mobility enables people to conduct the activities of daily life, stay socially connected with the world and therefore increase quality of life. Personal mobility is equated with the automobile. People nowadays have an active way of living, reflected by the increased number of driver licenses held and the higher amount of annual kilometers driven *(Eby, et al., 2009).* In addition, life expectancies are increasing in most developed countries around the world. Taken this together with the baby boom between 1946 and 1964, there is an enormous increase in the population of older drivers (aged 65 and older). Unfortunately, this rising population is also accounted in a higher number of (fatal) accidents for older drivers compared with middle-aged drivers. One reason for this high number of fatalities is due to a decreased number of kilometers driven by older drivers. Another reason is the higher frailty of the human body of older drivers. This frailty not increases the crash risk but the fatality of these crashes, contributing to the fact that they are not so much a risk to others, but more to themselves *(Cuenen, et al, Submitted).* Although the stereotype of the impaired older driver exists among a lot of persons, it's not the case that all older drivers are unsafe drivers. Indeed, research has indicated that age alone, as the mere passage of time, is not an adequate predictor of driving ability *(Anstey, et al., 2012; Barrash, et al., 2010; Cuenen, et al., Submitted).* In contrast, cognitive abilities seem to be a good predictor of driving abilities. Driving is a complex, goal-directed task that places high demands on perceptual, cognitive and motor processes. The typical driving environment nowadays contains a large amount of information that must be identified, processed, and acted upon to remain safe. Numerous sources of information are competing for the driver's attention. Faster processing speed means more efficient thinking and learning. However, with age, there is a decrease in motor functions, visual abilities and cognitive abilities. Older drivers are more likely to fail to yield the right of way- (*Hakamies-Blomqvist, 1993; Zhang, et al., 1998)*, turn improperly, ignore traffic lights, merge into traffic improperly. As a consequence they are more involved in multivehicle accidents *(Langford & Koppel, 2006; Rothe, et al., 1990; Yan, et al., 2007).* With regard to cognitive abilities, there is especially a decrease in executive functions, which control and manage strategic, self-regulated and goal-oriented cognitive processes. Executive functioning is an umbrella term that refers to a collection of cognitive functions including inhibition, memory, attention, task switching, problem solving, mental flexibility and planning *(Huizinga, et al., 2006; Chan, et al., 2008; Barnes, et al., 2011; Houben, et al, 2011; Baddeley, 1986; Norman & Shallice, 1986).* Some studies already investigated and found a relation between executive functioning (i.e. attention, inhibition and memory) and driving ability *(Jongen, et al.,2011; Mäntylä, et al., 2009*). Studies also demonstrated a causal connection between cognitive control and driving performance using prefrontal trans-cranial brain stimulation *(Beeli, et al., 2008).*

Strengthening executive functions helps to restore control over behavior. Improved performance is associated with neuronal changes from the intracellular level to functional organization of the cortex *(Buonomano & Merzenich, 1998)* and prevents age-related cognitive decline *(Cuenen, et al., Submitted).* Smith et al *(2009)* investigated the efficacy of a novel brain plasticity–based computerized cognitive training program in older adults and evaluated the effect on untrained measures of memory and attention and participant-reported outcomes. Significant improvement favoring the experiment group on a performance measure directly related to the trained tasks was measured and consistent with the generally large effect sizes seen on directly trained tasks in other training programs *(Ball, et al., 2002; 2007).* Unique to this study, performance improvements generalized to untrained standardized measures of memory and attention, implying that robust gains occurred across systems serving auditory-based cognition.

Working memory (WM) is a central component of general cognition *(Cowan, et al., 2005; Engle, et al., 1999; Oberauer, et al., 2005).* To facilitate understanding of the WM training literature, we first develop a perspective of what WM is. In many studies, WM is explicitly defined as a storage system that is responsible for retaining small amounts of information over brief intervals of time (*Klingberg, 2010; McNab, et al., 2009; Olesen, et al., 2004)*. According to Baddeley *(1992)*, WM comprises multiple specialized components of cognition that allow humans to comprehend and mentally represent their immediate environment to retain information about their immediate past experience, to support the acquisition and new knowledge, to solve problems, and to formulate, relate, and act on current goals. These specialized components include both a supervisory system (the central executive) and specialized temporary memory systems, including a phonologically based store (verbally coded information) and a visuospatial store (visual and/or spatial information). Due to the central role that WM plays in general cognition, it has become the focus of a rapidly growing training literature that seeks to affect broad cognitive change through prolonged training on WM tasks. Despite the importance of working memory during driving, few studies up to today have examined the effect of working memory training on driving to our knowledge. Ross et al *(2014)* focused on the influence of working memory capacity on driving behavior of young novice drivers combined with cognitive load. This study focused on the influence of working memory capacity on driving behavior of young novice drivers combined with cognitive load.

In contrast with driving ability, many modern training programs are thus designed to specifically target WM *(Houben, et al., 2011; Klingberg, 2010; Sternberg, 2008).* In turn, it is assumed that, if a person's WM can be strengthened, a constellation of related abilities will benefit. This assumption has been reinforced by several studies that have concluded that trained participants are better equipped to reason with novel information *(Jaeggi, et al., 2008; Klingberg, et al., 2005; 2002),* have improved attention *(Chein & Morrison, 2010; Klingberg, et al., 2005; 2002),* and, in certain cases, display decreases in ADHD-related symptoms *(Beck, et al, 2010; Klingberg, et al., 2005; 2002; Mezzacappa & Buckner, 2010)* and alcohol abusive drinking *(Houben, et al, 2011).* Driven by these encouraging results, WM training has rapidly gained prominence within the psychological literature. Smith et al. *(2009)* investigated the efficacy of a novel brain plasticity–based computerized cognitive training program in older adults and evaluated the effect on untrained measures of memory and attention and participant-reported outcomes. Significant improvement favoring the experiment group on a performance measure directly related to the trained tasks was measured and consistent with the generally large effect sizes seen on directly trained tasks in other training programs *(Ball, et al., 2002; 2007).* Unique to this study, performance improvements generalized to untrained standardized measures of memory and attention, implying that robust gains occurred across systems serving auditory-based cognition.

Training programs attempt to clarify the meaning of "transfer of training" to other tasks or situations. Near-transfer refers to increased performance on tasks at the pre-test that is highly similar to the tasks on which post-test occurred (i.e. participants do the same test for a second time) *(Shipstead, et al., 2012).* By far-transfer, we refer to post-training performance improvements on tasks which are not of the same nature or appearance as the tasks on which participants have been trained. The point that is critical to far-transfer is the assumption that two different tasks share an underlying processing component (e.g. both tasks require working memory) that is tapped regardless of performance circumstances or visual context *(Shipstead, et al., 2012*).

Therefore the present study has three aims: First, to investigate the relation between specific driving measures of older drivers and working memory. Second, to investigate the near transfer effect of working memory training on cognitive ability, and third, the far transfer effect on driving ability.

3. METHODS

2.1 Subjects

Senior drivers participating in the study were aged higher than 65 years and in possession of a driver's license. Further inclusion criteria were no Cerebro Vasculair Accident (CVA) or a stroke in the last 4 months and ownership/experience of a computer so that they could perform the computerized task at home independently. Recruitment occurred through the senior association in Lummen, via local media and oral presentation in public places. Participants were assigned randomly to the training condition or the control condition. Participants were tested while wearing their normal visual correction. They received a €30 gift certificate as compensation for participating. The study was conducted at the Care Service Centre OCMW Lummen.

2.2 Procedure

The study is divided in three phases. First, each participant is assessed in a pre-training evaluation (lasting approximately two hours), with a general questionnaire, Mini-Mental State Examination (MMSE), three PC-based cognition tests, simulator assessment and finally a demo of the working memory training. Between the pre- and post-training, all participants have to fulfill at least 20 days of working memory training tasks at home. At last, each participant returns to the research centre to be assessed with the post-training tests (lasting approximately two hours), which is equivalent with the pre-test. However the demo is deleted. Order of the PC-based cognition tests and simulator assessment is counterbalanced between subjects. All participants gave informed consent.

2.3 Questionnaires

General questionnaire is a list of general questions about the participant's age, education, medication use, driving habits and recent accidents.

Mini-Mental State Examination (MMSE) by Folstein, Folstein & McHugh *(1975)* is used as a quick and easy measure of cognitive functioning, but also to estimate the severity of cognitive impairment (Mild Cognitive Impairment). The MMSE is comprised of 7 items assessing orientation to time and place, attention and concentration, immediate and delayed recall, language and constructional ability. In less than 10 minutes it samples functions including memory and orientation *(Folstein, et al., 1975)*. Possible scores range from 0 to 30, with higher scores reflecting a better psychological ability.

2.4 Cognitive tests

The Useful Field of View-test (UFOV) by Ball et al. *(2006)* and Edwards et al. *(2005)* included 3 subtests varying difficulty to assess participants' cognitive abilities: The first subtest focused on visual processing speed, the second subtest on divided attention, and third subtest on selective attention. The UFOV test is PC-based, with stimuli presented on a monitor and responses made on the participant's command by the test administrator using a computer mouse. The UFOV screening task predicts driving safety and performance on other everyday tasks. The subtests are predictive of driving and other complex behaviors. Because the subtests are complex, they tap multiple attention components *(Edwards, et al., 2005; Cosman, et al., 2012)*. Scores are expressed in milliseconds.

The stop signal task (STT) by Lappin & Eriksen *(1966)* can be used as a standard laboratory measure of inhibitory control *(Jongen, et al., 2011; Logan & Cowan, 1984)*. Participants need to press the button (left or right) in response to visual stimuli (respectively X or O) and in some occasions (when hearing a beep tone) they need to inhibit their response. The stop signal reaction time (SSRT) is calculated by subtracting the stop signal delay from the reaction time *(Verbruggen & Logan, 2008)* and is expressed in milliseconds. The shorter the SSRT, the higher inhibitory control is thought to be.

The Automated Operation span task (AOspan) by Unsworth et al. *(2005)* can be used as a standard laboratory measure of working memory consists of three sections. The first practice section was simple letter span. A letter appeared on the screen, and the participants were required to recall the letters in the same order in which they were presented. Next, participants practiced the math portion of the task. The participants were instructed to solve a math operation (i.e., (1*2) + 1 = ?) as quickly as possible and then click the mouse to advance to the next screen, in which a random digit was presented and the participants were required to click either a "true" or "false" box, depending on their answer. In the final practice session, the participants performed both the letter recall and math portions together. As in the Turner and Engle Ospan, the participants first saw the math operation, and after they clicked the mouse button indicating that they had solved it, they saw they letter to be recalled. After participants completed all of the practice sessions, the program progressed to the experimental trials, which consisted of three sets of each set size ranging from 3 to 7. These sizes were used because studies showed that these produced the best distribution of scores (i.e. neither on ceiling nor on floor). This made for a total of 75 letters and 15 math problems. Note that the order of set sizes was random for each participant. Because we wanted to only use those participants who were attempting to solve both the math operations and remember the letters, we imposed an 85% accuracy criterion for all participants. The Operation span score, which will be used in the analysis, was the sum of all perfectly recalled sets. Three types of errors were reported: “Math errors”, “speed errors” and “accuracy errors”.

2.5 Driving simulator

The experiment was conducted on a fixed-based low-fidelity driving simulator (STISIM M400; Systems Technology Incorporated) with a force-feedback steering wheel, brake pedal and accelerator (see picture). The visual virtual environment was presented on a field of view on 3 pc screens, with rear view and side-view mirror images. The projection screen offered a resolution of 1024×768 pixels on each screen and a 60 Hz refresh rate. Data were collected at frame rate.

FIGURE 1: STISIM M400 simulator

2.6 Scenarios

There were two main rides, preceded by practice rides to get acquainted with the driving simulator. There was a main ride without social pressure and a main ride with social pressure (car following the driver closely). The rides, performed in daylight, consisted of inner-city (50 km/h) sections. Four traffic situations that are known to be difficult for the older driver were presented in the two experiment scenarios (left turns, right of way, road hazards and yellow light running).

1. Left turn was measured in the scenario by gap acceptance. A voice pointed out that the participant had to turn left at the following intersection. The participant was instructed to stop at the intersection and indicate when he interpreted that he was able to safely make a left turn, taken into account a stream of oncoming traffic on the major road in the opposite lane with a speed equaling the speed limit. The first part of the stream consisted of very small gaps (less than 3s; very unlikely to be accepted by the participants) and was followed by the second part of the stream that, similar to Yan, et al. *(2007)* and Cuenen, et al. *(Submitted)*, consisted of gaps uniformly increasing in duration from 3s to 16s. Participants used the horn to indicate when they turned to the left instead of actually turning left in order to decrease the risk of simulator sickness.
2. Right of way and complete stop was measured in the scenario by registration if the participant stopped at the intersection indicated previously with a yield sign or STOP sign.
3. Road hazards were measured in the scenario by crashes with crossing obstacles. Pedestrians crossed the road with or without the presence of a pedestrian crossing. Road hazards were calibrated such that crashes could be avoided by braking (when driving at speed limit).
4. Yellow light running was measured in the scenario by registration if the participant did not stop at the intersection when the traffic lights turned yellow. A vehicle could appear in front of the car before reaching the intersection with traffic lights. These vehicles were presented on the roadway in order to increase the chance that they also did not stop for a yellow light (just like the car in front of them). Their presence required no passing or braking on the part of the driver.

The scenarios did not contain any curves in order to decrease the possibility of simulator sickness *(Romoser, 2009)* .

2.7 Driving measures

A total of 7 driving measures/parameters were recorded.

1. Mean driving speed (km/h)
2. Standard Deviation of Lateral Position (SDLP) (m)
3. Left turn gap acceptance decision (s)
4. Giving way (yes or no)
5. Complete stop (yes or no)
6. Number of collisions
7. Yellow light running (with or without car in front) (yes or no)

The first two measures are obtained across separate road segments without any events. Gap acceptance *(Cassavaugh, et al., 2009; Yan, et al.; 2007)* and complete stop *(Bao & Boyle, 2008)* were retrieved from the literature.

2.8 Computerized training program

Each participant had to fulfill a WM training at home for at least 20 days. The WM training consisted of three tasks: a visuo-spatial WM task, a backward digit span task and a letter span task *(based on Klingberg, et al., 2002)*.
During the visuospatial WM task, a sequence of squares in a 4x4 grid changed in color (blue) on the computer screen. Participants had to reproduce this sequence by clicking on the squares that had changed color (blue) in the correct order using the computer mouse.

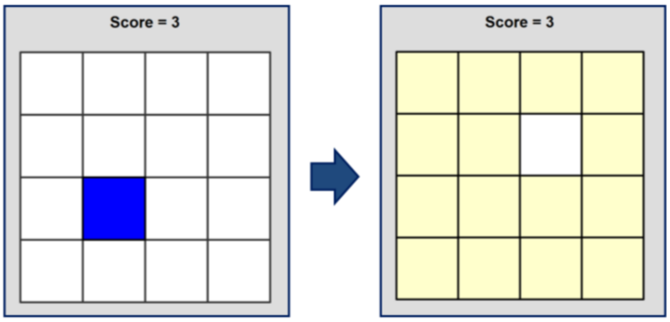

FIGURE 2: Visuospatial WM task (computerized task) (source: Maastricht University)

During the backward digit span, a sequence of numbers was presented on the computer screen, which participants had to reproduce in reversed order, using either the computer mouse or the number keys on the keyboard.

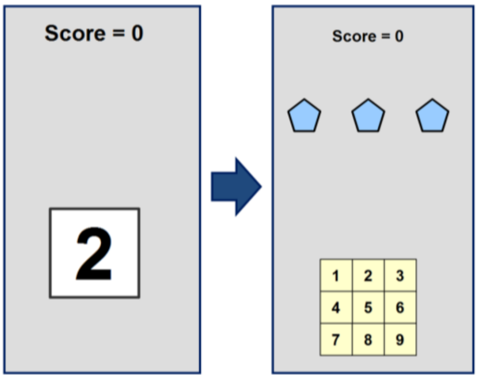

FIGURE 3: Backward digit span (computerized task) (source: Maastricht University)

Finally, in the letter span task, a sequence of letters was presented on the computer screen in the form of a flower. Each leaf was highlighted blue with a letter in the core of the flower. Participant had to reproduce the leaf indicated by the computer with the corresponding letter using the keyboard. All three tasks consisted of 30 trails. For all WM tasks, difficulty was adjusted by changing the number of stimuli to be remembered. Subjects completed 20 to 25 trials on each WM task every day, and the daily training time was approximately 20 min. Time between pre-test and post-test was 4 weeks.

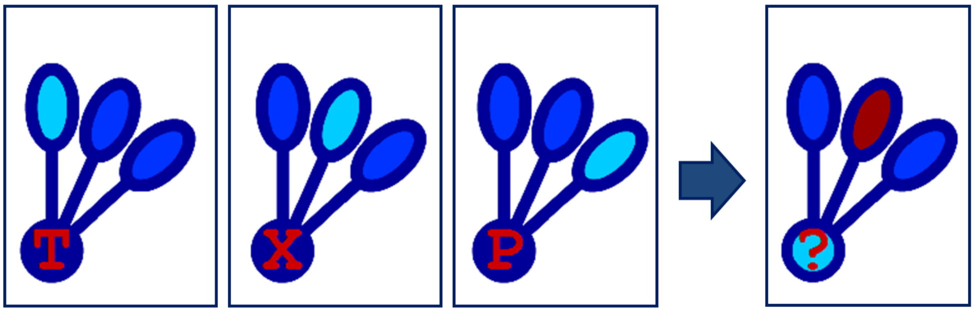

FIGURE 4: Letter span task (computerized task) (source: Maastricht University)

In the training condition, the difficulty level of all three WM tasks was automatically adjusted on a trial-by-trial basis, starting with the highest result in the previous session. All participants started out each task with a sequence of three items. When participants correctly reproduced this sequence two times in a row, one item was added to the sequence on the next trial. When participants were not able to correctly reproduce the sequence on two consecutive trials, the sequence in the next trial contained one item less. In the control condition, the difficulty level of the WM tasks was not adjusted and remained on the initial easy level (three items in a sequence).

2.9 Data analysis

Analyses were done using SPSS.
Descriptive statistics were conducted to analyze the scores on dependent measures (i.e., the neuropsychological test battery and driving measures). Exploratory analyses were conducted to identify outliers (i.e. individuals with a z-score higher than three of lower than minus three) per dependent measure. To reduce the influence of these outliers, each one was replaced by a value three standard deviations from the mean *(Miyake, et al., 2000).*
First, a preliminary analysis was conducted on the dependent measures to investigate if there was a difference between the results from the experiment condition and the control condition on the pre-test. This was done by an independent sample t-test for continuous measures (SSRT, UFOV, AOSPAN, MMSE, age, SDLP, speed and gap acceptance) and the chi-square test for categorical measures (crash, complete stop, right of way and yellow light running).
Second, we conducted a Pearson correlation analysis to investigate the relation between working memory and driving ability at pre-test.
Third, we performed an effect analysis to measure the effect of working memory training by using the repeated measures ANOVA. For the cognitive measures, Measurement (i.e. pre-test, post-test) served as a within-subjects (WS) variable and Condition as a between-subjects (BS) variable. For the driving measures, WS and BS factors were the same, but in addition the Scenario (i.e. with tailgater, without tailgater) was also used as a WS variable. However, the results of the WS factor Scenario will not be discussed in the present paper. Significant interactions between the WS variable Measurement and the BS variable Condition were further investigated, by dividing participants into the control and experimental condition. First, a repeated measures analysis of variance (ANOVA) with Measurement (and Scenario) as within-subjects variables was conducted for each Condition to assess the main effect of Measurement. Second, separate univariate analyses of variance (ANOVAs) for each level of Measurement were conducted with Condition (2: control condition, experimental condition) as between-subjects factor to assess the main effect of Condition.
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.

4. RESULTS

3.1 Participants

The sample size was influenced by drop-out. From the 26 participants agreed to participate in study and completed the pre-test, three participants didn’t complete the training at home and three participants exhibited symptoms of simulator sickness. A total of 20 participants remained for analysis (EG = 9; CG = 11) and were between 65 and 80 years of age (mean: 70.2, SD: 3.3). The EG included 2 women and 6 men (mean age 71.1, SD 3.8), and the CG included 3 women and 8 men (mean age 69.4, SD 4.8). Participants were cognitively healthy without any indication for dementia (MMSE score of at least 25), since they all scored between 26 and 30 on the MMSE test (mean: 28.5, SD: 1.2). Mean score for the EG was 28.7 (SD: 1.1) and 28.3 for the CG (SD: 1.3).

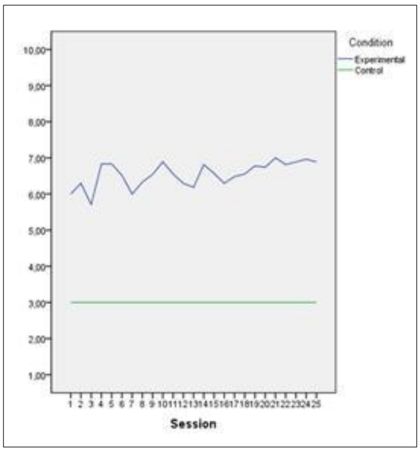

FIGURE 5: Results sessions WM training

3.2 Working memory training

All participants performed a working memory training at home during 25 days between the pre- and the post-test. In case of absence, participants could miss maximum five sessions before being excluded from the study. Participants completed an average of 24.1 sessions (SD: .85). The EG completed an average of 24.2 sessions (SD: .83) and the CG completed an average of 24.0 sessions (SD: .89). The number of sessions did not significantly differ between the two conditions (p=.58).

During the training, performance of the EG significantly improved compared to the CG on the whole training (p=.00). All participants scored an average end level of 4.6 on all tasks (SD: 2.06), with an average of 6.57 (SD: 1.47) for the EG and an average of 3.0 (SD: .00) for the CG, see figure 5. In addition, performance of the EG significantly improved compared to the CG on each training subtask.

For the first task (visuospatial), all participants scored an average of 3.9 (SD: 1.5), with an average of 5.1 (SD: 1.5) for the EG and an average of 3.0 (SD: .0) for the CG. For the second task (backward digit), all participants scored an average of 4.4 (SD: 1.96), with an average of 6.2 (SD: 1.7) for the EG and an average of 3.0 (SD: .0) for the CG. For the third and final task (letter span), all participants scored an average of 5.4 (SD: 3.0), with an average of 8.35 (SD: 2.0) for the EG and an average of 3.0 (SD: .0) for the CG.

3.3 Preliminary analysis

With regard to the neuropsychological test battery, both EG and CG scored equally for the AOSPAN-test, the UFOV test and the SSRT test on the pre-test, indicating that at baseline there were no significant differences between the two conditions (p>.05).

With regard to the driving measures on the simulator, EG and CG performed equally at the pre-test on the complete stop, traffic lights, right of way, gap acceptance for both scenarios (p >.05). However, there were significant differences between the two groups on the number of crashes (only scenario 2), speed (only scenario 2) and SDLP (both scenarios), see table 1 for the descriptives.

Table 1 describes the means and standard errors for the dependent per measurement and condition.

TABLE 1 Descriptive Analysis (Cognitive and Driving Measures)

	Control condition Pre-test	Control condition Post-test	Experimental condition Pre-test	Experimental condition Post-test	Pre-test	Post-test
Cognitive measure	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**
SSRT (ms)	233.31 (13.99)	191.69 (13.77)	199.45 (15.47)	180.90 (15.22)	216.38 (10.43)	186.30 (10.26)
AOSPAN (number)	15.73 (3.98)	24.09 (5.91)	12.56 (4.40)	28.44 (6.53)	14.14 (2.97)	26.27 (4.40)
UFOV1(ms)	24.27 (11.77)	18.73 (4.63)	37.10 (13.01)	28.22 (5.12)	30.68 (8.77)	23.47 (3.45)
UFOV2(ms)	83.00 (38.59)	31.73 (23.90)	122.74 (42.66)	90.00 (26.42)	102.87 (28.76)	60.86 (17.82)
UFOV3 (ms)	113.10 (35.83)	83.90 (24.98)	155.29 (42.83)	95.29 (29.86)	134.19 (27.92)	89.59 (19.46)
Driving measure	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**
Crashes (number)	0.32 (.15)	0.27 (.11)	1.00 (.17)	0.43 (.13)	0.66 (.11)	0.35 (.09)
SDLP (m)	0.20 (.02)	0.20 (.02)	0.26 (.02)	0.24 (.02)	0.23 (.01)	0.22 (.01)
Gap acceptance (s)	5.81 (.36)	4.97 (.37)	5.71 (.42)	5.21 (.43)	5.76 (.28)	5.09 (.29)
Speed (km/h)	40.35 (.94)	41.31 (1.39)	43.33 (1.04)	44.03 (1.54)	41.84 (.70)	42.67 (1.04)
Complete stop*	0.66 (.10)	0.61 (.09)	0.75 (.11)	0.69 (.10)	0.71 (.07)	0.65 (.07)
Giving right of way*	0.82 (.05)	0.84 (.06)	0.86 (.06)	0.89 (.06)	0.84 (.04)	0.87 (.04)
Yellow light running*	0.67 (.08)	0.72 (.07)	0.90 (.09)	0.90 (.08)	0.79 (.06)	0.81 (.06)

*(1=yes/0=no)

3.4 Correlation analysis

Table 2 shows the correlation on the pre-test between WM and inhibition and visual attention. However, there were no significant correlations (p>.05). In addition, the table shows the correlation between WM and driving on the pre-test. There were only significant correlations between WM and speed for both scenarios, indicating that a good WM corresponds with a lower speed when there is no tailgater (p=-.036) and a higher speed when there is a tailgater (p=.01). Other significant correlations were found between WM and complete stop (p=.014) without tailgater; WM and giving right of way (p =-.028) with tailgater and marginally significant correlation with WM and traffic lights (p=-.072) with tailgater, indicating that a good WM corresponds with less yellow light running, more frequent giving right of way and more stops at a stop sign.

TABLE 2: Correlation Analysis (Cognitive and Driving Measures)

Cognitive measure pre-test		*AOSPAN pre-test (P)*
SSRT		-0.364
UFOV1		-0.124
UFOV2		-0.254
UFOV 3		-0.475
Driving measure pre-test		***AOSPAN pre-test (P)***
Crashes		
	Tailgater	-0.261
	No tailgater	-0.227
SDLP		
	Tailgater	-0.262
	No tailgater	-0.248

Yellow light running		
	Tailgater	-0.072
	No tailgater	0.124
Gap acceptance		
	Tailgater	-0.177
	No tailgater	-0.600
Speed		
	Tailgater	0.01*
	No tailgater	-0.036*
Complete stop		
	Tailgater	-0,153
	No tailgater	0,014*
Giving right of way		
	Tailgater	-0.028*
	No tailgater	0.416

(*p≤.05, two-tailed; **p≤.01, two-tailed; ***p≤.001, two-tailed)

3.5 Effect analysis

3.5.1 Cognitive measures

See table 1 and 4 for results.

For SSRT, there only was a significant main effect of measurement, indicating that during post-test (M=186.30, SD=10.26) participants had an improved inhibitory control (i.e. lower SSRT) compared to the pre-test (M=216.38, SD=10.43).

For AOSPAN, there only was a significant main effect of measurement, indicating that during post-test (M=26.27, SD=4.40) participants had an improved working memory (i.e. higher AOSPAN score) compared to the pre-test (M=14.14, SD=2.97).

For UFOV 1, there was no significant main effect or interaction effect (p>.05). For UFOV 2, there only was a marginally significant effect of measurement, indicating that during post-test (M=89.60, SD=19.46) participants had an improved divided attention (i.e. lower UFOV2 score) compared to the pre-test (M=134.19, SD=27.92). For UFOV 3, there only was a significant main effect of measurement, indicating that during post-test (M=89.60, SD=19.46) participants had an improved divided attention (i.e. lower UFOV3 score) compared to the pre-test (M=134.19, SD=27.92).

3.5.2 Driving measures

See table 4 for the results.

For SDLP, right of way, complete stop, mean speed and yellow light running, there were no significant main effects or interaction effect (p >.05). For crashes, there was also marginally significant interaction between measurement and condition for crashes (see figure 6).

For gap acceptance, there was a marginally significant effect of measurement, indicating that during post-test (M=5.09) participants needed a smaller gap (i.e. smaller distance between vehicles) compared to the pre-test (M=5.76).

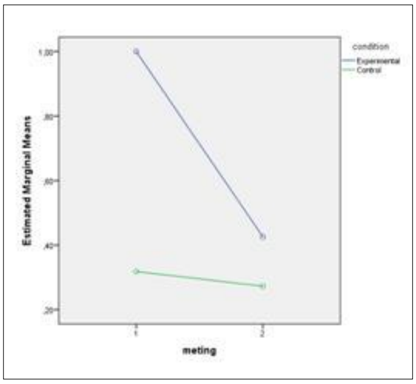

FIGURE 6: Effect analysis crashes

Table 4 depicts additional ANOVA analyses on the interaction between measurement and condition for crashes, indicating a higher decrease in crashes on the post-test regarding the pre-test for the EG than for the CG. In table 3 the first part shows the difference of between the CG and the EG for the pre-test and the post-test. The second part shows the difference in means between the pre-test and the post test is given for the CG and the EG.

In the first part there is no significant main effect of measurement, but only those in the EG indicating a decrease in crashes. In the second part there is a significant main effect of condition, but only at the pre-test, indicating less crashes in the CG than the EG.

TABLE 3: Effect Analysis Crashes

Condition	Measurement (Mean)		p
	Pre-test	**Pos-test**	
Control	M= .32	M= .27	.810
Experimental	M= 1.00	M= .43	.016*
Measurement	**Condition (Mean)**		**p**
	Control	**Experimental**	
Pre-test	M= .32	M= 1.00	.008*
Post-test	M= .27	M= .43	.380

*<.05, **<.01

Corrected F and probability values per dependent cognitive measure and driving measure.

TABLE 4: Effect Analysis (Cognitive and Driving Measures)

Cognitive measure		*F*	*p*
SSRT			
	Measurement	5.128	0.036*
	Measurement x condition	0.755	0.396
	Condition	1.981	0.176
AOSPAN			
	Measurement	19.271	0.000***
	Measurement x condition	1.855	0.190
	Condition	0.007	0.933
UFOV			
UFOV 1			
	Measurement	1.339	0.262
	Measurement x condition	0.071	0.792
	Condition	0.896	0.356
UFOV 2			
	Measurement	4.206	0.055
	Measurement x condition	0.205	0.656
	Condition	1.285	0.272
UFOV 3			
	Measurement	10.572	0.005**
	Measurement x condition	1.260	0.279
	Condition	0.337	0.570
Driving measure		***F***	***P***
Crashes			
	Measurement	5.444	0.031*
	Measurement x condition	3.964	0.062
	Scenario	1.112	0.306
	Scenario x condition	9.546	0.006**
	Measurement x scenario	0.062	0.806
	Measurement x scenario x condition	0.011	0.919
SDLP			
	Measurement	3.196	0.091
	Measurement x condition	2.538	0.129
	Scenario	1.776	0.199
	Scenario x condition	7.950	0.011*
	Measurement x scenario	0.081	0.779
	Measurement x scenario x condition	2.035	0.171

Traffic lights			
	Measurement	0.362	0.555
	Measurement x condition	0.362	0.555
	Scenario	0.438	0.516
	Scenario x condition	0.004	0.948
	Measurement x scenario	6.647	0.019*
	Measurement x scenario x condition	0.387	0.542
Gap acceptance			
	Measurement	5.888	0.032*
	Measurement x condition	0.385	0.546
	Scenario	2.372	0.149
	Scenario x condition	0.001	0.981
	Measurement x scenario	0.029	0.868
	Measurement x scenario x condition	3.140	0.102
Speed			
	Measurement	1.309	0.267
	Measurement x condition	0.031	0.861
	Scenario	91.696	0.000***
	Scenario x condition	0.031	0.862
	Measurement x scenario	0.095	0.761
	Measurement x scenario x condition	1.532	0.232
Complete stop			
	Measurement	0.466	0.503
	Measurement x condition	0.005	0.946
	Scenario	0.535	0.474
	Scenario x condition	0.005	0.943
	Measurement x scenario	0.046	0.833
	Measurement x scenario x condition	4.557	0.047*
Giving right of way			
	Measurement	0.204	0.657
	Measurement x condition	0.002	0.964
	Scenario	0.136	0.716
	Scenario x condition	0.769	0.392
	Measurement x scenario	0.769	0.392
	Measurement x scenario x condition	0.136	0.716

(*p ≤ .05, two-tailed; **p ≤ .01, two-tailed; ***p ≤ .001, two-tailed)

5. DISCUSSION AND CONCLUSIONS

The present study investigated WM training on cognitive ability and driving ability in a sample of older drivers (aged 65+). The study had three aims: First, to investigate the relation between specific driving measures of older drivers and working memory. Second, to investigate the near transfer effect of working memory training on cognitive ability, and third, the far transfer effect on driving ability.

For the first aim, results showed that WM had no influence on visual attention or on inhibition. For the driving measures, a good WM corresponds with a lower speed when there is no tailgater and a higher speed when there is a tailgater. Interestingly, a good WM also corresponded with less yellow light running, more frequent giving right of way and more stops at a stop sign.

For the second aim, results showed that WM training improved WM, showing that the training had direct (i.e. near transfer) effects on working memory. In addition, the training improved inhibition (SSRT) and visual attention (UFOV3 and UFOV2 (marginally significant)), showing that the training effect generalized to other cognitive abilities. Interestingly, the improvement from training was evident for both experimental condition (increasing level of difficulty) and control condition (same level of difficulty) hence, even a limited amount of training was sufficient to improve cognitive ability. Though improved performance on the training task does not necessarily signal an increase in WM capacity *(Barnett & Ceci,* *2002; Klingberg, 2010).* Learning effect could influence the results which occur in situations where response improves each time a person takes a test due to experience. Though, learning effect cannot be seen as a major factor of such force increment due to the relatively long period (20-25 days) of between the pre- and post-test *(Chang, et al., 2002).* Houben et *al. (2011)* found that working memory training improved both working memory and response inhibition, but also reduced behavior of alcohol intake. Same effect was measured by Klingberg et al. *(2005)* that found that WM training also transferred to other executive functions including response inhibition. Their findings demonstrated that strengthening executive functions was an effective strategy to reduce alcohol use and ADHD-related symptoms *(Klingberg, et al., 2005).*

For the third aim, linking the working memory training with driving ability, the results showed a significant main effect for gap acceptance (smaller GAP), suggesting that higher WM indirectly improves driving maneuvers (i.e., taking a left turning with oncoming traffic) for all participants (EG and CG). Another far transfer effect was measured for crashes, where EG scored (marginally significant) better on the number of crashes (lower number of crashes on post-test for EG), suggesting that in order to improve driving ability (i.e. crashes) an extensive amount of WM training is necessary.

In conclusion, the training had near transfer effects to other cognitive functions (i.e., working memory, inhibition and visual attention) and far transfer effect to driving ability (i.e., gap and crashes).

6. LIMITATIONS

The important limitation of this paper is the sample size. A large number of older drivers (65+) are not raised with computer knowledge and thereby not in possession of a computer with internet connection hence, they did not meet the inclusion criteria. Also, several participants dropped out due to simulator sickness and/or personal circumstances (e.g., hospitalization, vacation plans).

In addition to the small sample size, the results of the study cannot be generalized to the broad population of 65+ drivers, since they were all cognitively healthy (MMSE above 25). Future research should therefore investigate the effects of working memory training on persons with dementia.

Performing the training at home had the benefit that participants did not had to come 25 days to the research institute and had the comfort to do the task at a random hour of the day. However, participants indicated problems with the software during the process (e.g., slow). Another limitation with a home based task is that participants could cheat the test by writing down the numbers or letters while performing the task. They could also be distracted by phone calls or visitors.

The pre- and post-test was physically and mentally very hard for the participants. Some participants had to make a lot of effort to do the cognitive tasks (especially AOSPAN) and were subjected to simulator sickness, when performing the driving task. Future research could also look for a link between simulator sickness and the difficulty of the cognitive tasks.

The inclusion of a no-contact group in a pretest-posttest control group design is a common violation. The primary reason for using a pretest-posttest design is that it protects against threats to internal validity: Researchers who properly utilize this design can safely assume that the changes in performance occurring between the pretest and the posttest were caused by the experimental manipulation. No-contact control groups only interact with the experimenters at pretest and posttest. The use of these groups does not constitute a valid pretest-posttest experiment, because participants might to behave in accordance with the perceived expectations of the experimenter. In this case, members of a no-contact group can readily recognize that they are not receiving treatment and are thus not expected to show improvements *(Campbell et al., 1963).* However, implementing this group would be an alternative to make sure that there was improvement.

7. RECOMMENDATIONS

This study shows that WM training could be a good tool to increase working memory, inhibition and visual attention; improve turning left properly, but importantly to decrease the number of crashes in which older drivers are involved. The observed WM training could be used as a remediating intervention for individuals for whom low WM capacity is a limiting factor for driving performance or in other everyday life activities. However, the government should provide training programs equipped with WM tasks, but also other cognitive tasks, to elderly associations in order to increase cognitive functioning and driving ability in order to decrease the number of crashes related to lack of inhibition, attention or working memory (i.e. motor and visual skills). Future research should also investigate to what extent the durability of the training effects influence cognitive abilities.

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