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Presenter Information

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TRAINING WORKING MEMORY OF OLDER DRIVERS:

THE EFFECT ON WORKING MEMORY AND SIMULATED DRIVING PERFORMANCE

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Summary: This study aimed to investigate in older drivers whether a working memory (WM) training would enhance WM, and whether improvement of WM transfers to enhanced driving ability. 54 older drivers participated in the study, but due to drop-out, 38 participants (mean age 70.34) remained in the sample. Participants were randomly assigned to a control (N=19) or an experimental condition (N=19). Each participant conducted a WM training during 25 days. During the pre-test and post-test, WM and driving ability were assessed. Results indicate that the training lead to an improvement of WM. In addition, there was an improvement of several driving measures, that was however independent of the level of WM improvement. These findings will be discussed.

INTRODUCTION

Driving is a complex, goal directed task that places high demands on perceptual, cognitive and motor abilities (Groeger, 2000). With age, there is a decline of these abilities. For example, increasing age is characterized by problems of working memory (Borella et al, 2008). Working memory (WM) is the ability to temporarily store or manipulate information (Baddeley, 1992). Previous research has indicated the relation between WM and driving in older drivers: a better WM was related to a larger gap acceptance decision time for turning left in female older drivers (Guerrier et al, 1999) and a better score on a summarized on road driving measure (consisting of speed control, lateral position and reactions to signals, Adrian et al, 2011).

Since driving cessation leads to a decline in out-of-home activities, social isolation and even depression (Marottoli et al, 1997), it is crucial to keep drivers safe drivers for as long as possible. Fortunately, even people with an advanced age, have considerable plasticity in their cognitive functioning (Kramer and Willis, 2002). Therefore, cognitive training could serve this purpose. Several studies have shown that cognitive training targeting older people can improve cognitive ability (Ball et al, 2002; Ball et al, 2007; Karbach and Kray, 2009; Rebok et al, 2014; Schmiedek et al, 2010). Recently, some studies have investigated whether a cognitive training targeting WM improves WM and found positive and even long-lasting effects of 8 months (Borella et al, 2010; 2013). In addition, their WM training had effect on other cognitive abilities like processing speed (Borella et al, 2010) and inhibitory control (Borella et al, 2013). Interestingly, a limited number of studies have shown transfer of cognitive training effects to driving ability, as an improvement of cognitive ability lead to an improvement of driving ability (Ball et al, 2010; Ball et al, 2013; Cassavaugh and Kramer, 2009; Edwards et al, 2009a,b; Roenker et al, 2003). To our knowledge, only one study has investigated whether a WM training improves driving ability of older drivers and found a positive effect on accelerator response to lead-vehicle braking (Cassavaugh and

Kramer, 2009). Interestingly, positive transfer effects of WM training have been shown in other domains of behavior. For example, after following a WM training, adults showed a decrease of alcoholic drinks intake and children with ADHD showed an improvement (i.e., decrease) of motor activity (Houben et al, 2011; Klingberg et al, 2002). The aim of the present study was to investigate whether a WM training leads to an improvement of WM in older drivers, and whether this improvement of WM transfers to improvement of driving. Based on previous research as mentioned above, we hypothesized that the WM training would not only improve WM, but also driving performance on specific measures like speed, lateral control and turning left.

METHOD

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. In total, fifty-four participants volunteered. However, sixteen participants dropped out due to simulator sickness or personal circumstances (i.e., hospitalization). Participants had a mean age of 70.34 years and on average had an MMSE score of 28.74. Participants were randomly assigned to a control (N=19) or an experimental condition (N=19).

Driving simulator scenario

The experiment was conducted on a STISIM M400 fixed-base driving simulator with a force-feedback steering wheel, an instrumented dashboard, brake and accelerator pedals and with a 135 degree field of view. The visual environment of this simulator is presented on three computer screens (each with 1280 x 800 pixels resolution and 60Hz refresh rate). Two practice rides preceded the main ride to get acquainted with the driving simulator. In the first ride (2.1 km) almost no curves, no signs, and no other road users were introduced to acquaint drivers with the experience of driving in a simulator. The second ride (5.5 km) was similar to the main rides (see below) to acquaint drivers with several traffic situations. The main ride included several situations that are known to be difficult for the older driver, for example right of way decisions and gap acceptance while turning left at an intersection. The situations were presented in the scenario in a randomized fashion. The scenario solely consisted of inner-city (50 km/hour) segments. The scenario did not contain any curves in order to decrease the risk of simulator sickness (Romoser, 2008).
A total of six specific driving measures were considered for analyses: mean driving speed (km/h), standard deviation of lateral lane position (SDLP, m), crashes (number), making a complete stop at a stop sign (yes or no), giving right of way (yes or no), and left turn gap acceptance decision (s).

WM task

WM was measured with the Automated Operation SPAN (AOSPAN) task (Unsworth et al, 2005) and is an adapted version of the original Operation Span (OSpan) task of Turner and Engle (1989). This task included three practice sessions and one experimental session. The first practice section was a 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. In the second practice session, participants practiced the math portion of the task. They first saw a math operation. The participants were instructed to solve the operation as quickly as possible. On the next screen a digit was presented and the participants were required to indicate whether it was the correct or false solution of the math operation. After the math practice, the program calculated each individual's mean time required to solve the equations. This time (plus 2.5 SD) was then used as a time limit for the math portion of the experimental session for that individual. In the final practice session, the participants performed both the letter recall and math portions together, just as they would do in the experimental session. The participants first saw the math operation and afterwards the letter to be recalled. If the participants took more time to solve the math operations than their average time plus 2.5 SD, the program automatically moved on and counted that trial as an error. This served to prevent the participants from rehearsing the letters when they should be solving the operations. After participants completed all practice sessions, the program progressed to the experimental session, which consisted of three sets of each set size, with set sizes ranging from 3 to 7. This made for a total of 75 letters and 75 math problems. The order of set sizes was random for each participant. Participants were encouraged to keep their math accuracy at or above 85% at all times. The AOSPAN score (i.e., the sum of all perfectly recalled sets) was used as a measure of WM.

WM training

The WM training was based on Klingberg et al. (2002) and Houben et al. (2011), since they found improvements in daily life. The training consisted of three tasks: a visuo-spatial WM task, a backward digit span task and a letter span task. The training was conducted via the internet, and participants performed it at home. The training consisted of 25 sessions, spread over a period of 25 days (i.e., 1 session a day). The training took approximately 20 minutes per session. Participants were allowed to miss a maximum of 5 sessions. A one-day session consisted of the above mentioned 3 tasks. The first task was the visuo-spatial span, a measurement of visuo-spatial WM. In this task, a 4-by-4 grid was presented where on each trial a number of squares in the grid would sequentially and randomly turn blue. Participants were instructed to reproduce the sequence in the correct order by indicating the squares that had changed color. The second task was the backward digit span, a measurement of verbal WM. On each trial, a series of digits was presented. After presentation of the complete digit set, participants needed to indicate which digits appeared in the opposite order. The third task was the letter span, a measurement of verbal WM. On each trial, a series of letters was presented with the letters being connected to a central circle. After presentation of the complete letter set, participants needed to indicate which letter appeared at the indicated location.
Importantly, to serve as a training task, the task became more difficult if participants showed an improvement in WM, with higher levels of difficulty corresponding to more stimuli. The number of stimuli was originally set at three. After each second trial, the number of stimuli was determined: in case two consecutive trials were correct, participants received an additional stimulus; in case only one of the trails was correct, they received the same number of stimuli; in case both trials were incorrect, the number of stimuli was lowered by one. Participants in the control condition received a maximum of 3 stimuli, while participants in the experimental condition, could receive a maximum of 15 stimuli. In addition, participants in the control

condition, started each session with 3 stimuli, while participants in the experimental condition started each session with the number of stimuli of the previous session.

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 et al., 2008). Repeated measures analyses of (co)variance (AN(C)OVAs) were conducted for each of the dependent measures. In the ANOVA for WM ability, AOSPAN score served as the dependent variable, Measurement (i.e. pre-test, post-test) served as within-subjects variable and Condition (control condition, experimental condition) served as between-subjects variable. Since there was no significant main effect or interaction effect of Condition in the results of WM (see Results), in the analyses of driving abilities the between-subject variable Condition was replaced by the improvement in WM on the AOSPAN (i.e. AOSPAN score pre – post; negative values indicating improvement, positive values indicating decline). In the ANCOVAs for driving ability, the driving measure served as the dependent variable, Measurement (i.e. pre-test, post-test) served as within-subjects variable, and the pre-post AOSPAN score difference on the AOSPAN served as covariate. 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.

RESULTS

For the WM task, there was a significant main effect of Measurement ($F(1,35)=17.06$, $p<.001$), indicating that during the post-test participants remembered more letters in the correct order (i.e., improved WM) than during pre-test. Cohen's d was 0.49, indicating a small effect size. There was no significant main effect of Condition ($F(1,35)=0.00$, $p=.96$), indicating that WM was comparable for the control condition and the experimental condition. In addition, there was no significant interaction between Measurement and Condition ($F(1,35)=0.01$, $p=.91$), indicating that the pre-post improvement of WM (i.e., main effect Measurement) was comparable for the control condition and the experimental condition.

Since there was no significant main effect of Condition in the analysis of WM, the between-subject variable Condition was replaced by the improvement of WM on the AOSPAN (i.e., AOSPAN score pre – post; negative values indicating improvement, positive values indicating decline). For the driving measures, there was a significant main effect of Measurement for gap acceptance ($F(1,22)=17.98$, $p<.001$) and mean speed ($F(1,35)=5.27$, $p=.03$), indicating that at post-test participants accepted smaller gaps and drove faster, than at pre-test. Cohen's d was 0.71 for gap acceptance, indicating a medium effect size, and Cohen's d was 0.34 for mean speed, indicating a small effect size. In addition, there was a marginally significant main effect of Measurement for lateral position ($F(1,35)=3.87$, $p=.06$) and crashes ($F(1,35)=3.89$, $p=.06$), indicating that at post-test participants had better lateral control and less crashes, than at pre-test. Cohen's d was 0.20 and 0.27, indicating small effect sizes. There were no significant

interactions between Measurement and WM improvement for the specific driving measures under investigation (p>.05).

CONCLUSION

This study aimed to investigate whether a WM training leads to an improvement of WM in older drivers and whether improvement of WM transfers to improvement of driving. The results showed that there was an improvement of WM and that, independent of the amount of improvement in WM, there was an improvement on four measures of driving ability (i.e., mean driving speed, gap acceptance, lane keeping and crashes) at post-test in both conditions. Such training might thus serve as a method to remediate deficits of WM and driving ability in the elderly. Even a training with a limited difficulty level (memory span of 3 stimuli) might then have substantial effects. However, since both the experimental and the control group showed an improvement of WM and driving ability, it is impossible to determine whether these improvements are due to the training or whether they are due to a learning effect (performing the task for the second time). Therefore, additional data of a passive control group is currently collected. In case improvements are due to the training, future research is necessary to investigate the duration of these training effects.

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