Steunpunt rapport Werkpakket 4 Ontwikkeling van verkeersveiligheidsmaatregelen

Project 4.1. Rijsimulator gebaseerde en cognitieve trainingen met als doel oudere bestuurders veilige bestuurders te laten blijven.

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Dit rapport kwam tot stand met de steun van de Vlaamse Overheid, programma ‘Steunpunten voor Beleidsrelevant Onderzoek’. In deze tekst komen onderzoeksresultaten van de auteur(s) naar voor en niet die van de Vlaamse Overheid. Het Vlaams Gewest kan niet aansprakelijk gesteld worden voor het gebruik dat kan worden gemaakt van de meegedeelde gegevens.

Het Steunpunt Verkeersveiligheid 2012-2015 voert in opdracht van de Vlaamse overheid beleidsondersteunend Wetenschappelijk onderzoek uit over verkeersveiligheid. Het Steunpunt Verkeersveiligheid is een samenwerkingsverband tussen de Universiteit Hasselt, de KU Leuven en VITO, de Vlaamse Instelling voor Technologisch Onderzoek.

Inhoudstafel

Lijst van figuren in de synthese

Lijst van tabellen in de synthese

Gebruikte afkortingen

VV	Verkeersveiligheid
IMOB	Instituut voor mobiliteit
VITO	Vlaamse Instelling voor Technologisch Onderzoek

Samenvatting

Door de vergrijzing stijgt het aantal oudere bestuurders. Aangezien mobiliteit essentieel is voor de levenskwaliteit, is het belangrijk om te onderzoeken hoe oudere bestuurders zo lang mogelijk veilige bestuurders kunnen blijven. Dit rapport geeft de resultaten weer van drie trainingen die als hoofddoelstelling hadden rijvaardigheid van ouderen te verbeteren: twee cognitieve trainingen en één rijsimulator gebaseerde training. De cognitieve trainingen richtten zich op inhibitie en werkgeheugen, aangezien deze vaardigheden belangrijk zijn voor veilig rijden en met (normale) veroudering afnemen. Deelnemers hadden een gemiddelde leeftijd van 70 jaar en werden willekeurig toebedeeld aan een experimentele groep of een controle groep. Het trainingseffect op rijvaardigheid werd onderzocht in een rijsimulator. Om een zo gedetailleerd mogelijk beeld te krijgen van de trainingseffecten, werd gekeken naar specifieke rijmaten zoals snelheid, slingergedrag en voorrang verlenen. Zowel vlak voor als onmiddellijk na de trainingssessie werd rijvaardigheid onderzocht. Resultaten gaven aan dat cognitieve trainingen vooral voor een verbetering in cognitieve vaardigheden, maar niet in rijvaardigheid, zorgden. De rijsimulator gebaseerde training zorgde voor verbetering in verschillende specifieke maten van rijvaardigheid. Het meermaals rijden in de simulator op zich zorgde al voor verbetering in verschillende rijmaten. Verbetering van andere rijmaten (vb. voorrang verlenen aan rechts) trad echter alleen op in geval van rij-gerelateerde feedback. Hoewel verder onderzoek nodig is, kan geconcludeerd worden dat een context-relevante training veelbelovend is om vaardigheden van ouderen te verbeteren. Als het doel is om rijvaardigheid te verbeteren, is een training die rijvaardigheid *direct* traint (vb. met een rijsimulator gebaseerde training) aan te bevelen boven een training die rijvaardigheid *indirect* traint (vb. met een cognitieve training).

Summary

The number of older drivers is increasing due to the aging of the population. Since mobility is important for quality of life, it is necessary to investigate how to keep older drivers safe drivers for as long as possible. This report illustrates the results of three training programs that were aimed at improving driving ability of older drivers. These three training programs consisted of two cognitive trainings and one driving simulator based training. Cognitive trainings were related to working memory and inhibition, since these abilities are important for safe driving and decrease with (normal) aging. Participants had a mean age of 70 years and were randomly assigned to an experimental group or a control group. The effect on driving ability was investigated in a driving simulator. In order to obtain a detailed view about training effects, specific driving measures like speed, standard deviation of lateral position and giving way were investigated. Driving ability was investigated both before and immediately after the training session. Results indicated that cognitive training specifically had an effect on cognitive abilities, with only limited effects on driving ability. Driving simulator based training had several effects on specific measures of driving ability. Driving multiple times in the simulator improved several specific driving measures. However, driving-related feedback was necessary to improve some other specific driving measures (e.g., giving right of way). Although further research is necessary, it can be concluded that a context-relevant training is promising to improve abilities of older people. Hence, if the goal is to improve driving ability, a training targeting driving ability *directly* (e.g., with a driving simulator based training) can be recommended above an *indirect* training of driving ability (e.g., with a cognitive training).

1 Synthese

1.1 Inleiding

1.1.1 Ouderen en mobiliteit

Ouderen van tegenwoordig zijn niet meer de ouderen van vroeger. Ouderen zijn actiever, waardoor er meer (vrouwelijke) autobestuurders zijn, die meer en langere verplaatsingen maken (Eby et al., 2009). Kijkend naar de verkeersongevallenstatistieken is het duidelijk dat, indien ongevallen met doden of zwaargewonden uitgedrukt zijn per afgelegde kilometer of per verplaatsing, er een U-vormige curve ontstaat. Naast de piek bij de jonge bestuurders (18-24 jaar), is er opnieuw een stijging van verkeersongevallen bij de oudere bestuurder (65+). Men loopt vooral een risico op (zware) verkeersongevallen indien men een hoge leeftijd heeft (75+) en nog slechts weinig kilometers aflegt per jaar (<3000 km; Langford et al., 2006). In tegenstelling tot jonge bestuurders hebben oudere bestuurders vaak verkeersongevallen door het maken van fouten i.p.v. overtredingen (risicogedrag). Ongevallen gebeuren vaak op kruispunten waarbij meerdere auto's betrokken zijn.

Rijden is een complexe taak waarbij functionele vaardigheden nodig zijn (Groeger, 2000). Functionele vaardigheden bestaan uit visuele, cognitieve en motorische vaardigheden. Visuele vaardigheden zijn nodig om het verkeer te kunnen 'waarnemen'. Voorbeelden hiervan zijn scherptezicht, dieptezicht en contrastgevoeligheid. Cognitieve vaardigheden zijn nodig om te kunnen 'beslissen' in het verkeer. Voorbeelden hiervan zijn aandacht, inhibitie en werkgeheugen. Motorische vaardigheden zijn nodig om te kunnen 'handelen' in het verkeer. Voorbeelden hiervan zijn spierkracht, balans en flexibiliteit. Met veroudering kan er een achteruitgang optreden in deze functionele vaardigheden, wat een reden kan zijn van betrokkenheid bij verkeersongevallen. Deze achteruitgang in functionele vaardigheden is weliswaar niet voor elk individu hetzelfde. Het moment waarop achteruitgang optreedt, de oorzaak van de achteruitgang en de ernst van de vooruitgang verschilt per individu (Eby et al., 2009; Fildes, 2008; Langford, 2008). Veel ouderen zijn zich bewust van deze achteruitgang en passen hun rijgedrag aan: niet meer rijden tijdens de spitsuren, in het donker of bij slechte weersomstandigheden. Daarnaast rijden ze vaak trager, houden ze een grotere afstand van hun voorligger en vermijden ze verkeerssituaties waar ze moeite mee hebben. Ouderen hebben vaak moeite met de volgende verkeerssituaties: voorrang verlenen op kruispunten, links afslaan op kruispunten en reageren op verkeerstekens en onverwachte gebeurtenissen (Eby et al., 2009).

Aangezien mobiliteit verbonden is aan autonomie en daardoor gerelateerd is aan de kwaliteit van leven en gezondheid, is het essentieel om oudere bestuurders veilige bestuurders te laten blijven voor zo lang mogelijk (Eby et al., 2009). Stoppen met rijden kan zorgen voor een daling in dagelijkse activiteiten, sociale isolatie en zelfs depressie (Marottoli et al., 1997; Ragland et al., 2005). Indien ouderen stoppen met rijden, moeten ze zich op andere manieren gaan verplaatsen, vb. als zwakke weggebruiker (voetganger/fietser). Helaas is het risico op ongevallen als zwakke weggebruiker nog hoger dan als autobestuurder. Dit wordt mede veroorzaakt doordat ouderen vaak zeer kwetsbaar zijn, waarbij ze vlug (ernstige) verwondingen oplopen (Eby et al., 2009). Iemand laten stoppen met rijden is dus pas verantwoord na een uitgebreide meting waaruit blijkt dat men geen baat meer heeft bij een interventie vb. training van rijvaardigheid. Als men over het algemeen nog voldoende goed rijdt, maar moeilijkheden heeft met bepaalde situaties, vb. links afslaan, is een training aangeraden.

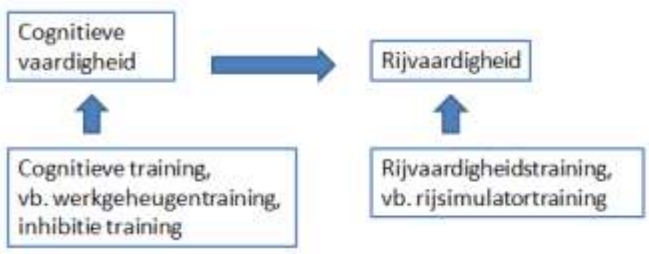
Dit rapport had als hoofddoelstelling om de effecten van verschillende soorten trainingen (nl. cognitieve training en rijsimulator gebaseerde training) op de rijvaardigheid van ouderen te onderzoeken. Daarnaast had het rapport als doelstelling om de effecten van cognitieve training op cognitieve vaardigheden te onderzoeken. Het is van belang om effecten van trainingen te onderzoeken, omdat trainingen naast gewenste effecten ook onbestaande of ongewenste effecten met zich mee kunnen brengen. Indien een training gewenste effecten heeft op de betreffende vaardigheden, kan het functioneren als instrument om achteruitgang in deze vaardigheden tegen te werken en ouderen op die manier zo lang mogelijk zelfstandig en veilig mobiel te laten blijven.

1.1.2 Training

Een training kan zowel preventief als curatief ingezet worden. Preventief indien er nog geen achteruitgang is, curatief indien er wel reeds achteruitgang is.

Daarnaast kan training zowel direct als indirect gericht zijn op rijvaardigheid, zie figuur 1. Bij een directe training van rijvaardigheid wordt rijvaardigheid zelf getraind, m.b.v. training op de openbare weg, op een gesloten parcours, in een rijsimulator, of op een computer. Bij een indirecte training van rijvaardigheid worden de onderliggende functionele vaardigheden getraind, d.m.v. een cognitieve training (Ball et al., 2010; Cassavaugh en Kramer, 2009), of een motorische training (Marmeleira et al., 2009; Sayers en Gibson, 2012). Een indirecte training waarbij de onderliggende functionele vaardigheden getraind worden kan enkel succesvol zijn in het verbeteren van de rijvaardigheid als de variantie verklaard door functionele vaardigheden voldoende hoog is.

Ondanks dat ouderen moeilijker leren dan jongeren, is training mogelijk, want ouderen hebben ook nog voldoende plasticiteit in hun cognitief functioneren (Kramer en Willis, 2002).



Figuur 1: Weergave training opties

1.1.2.1 Cognitieve training

Cognitieve vaardigheden zijn nodig voor het uitvoeren van complexe taken zoals rijden. Verschillende studies hebben de relatie tussen rijden en cognitieve vaardigheden zoals aandacht bij ouderen aangetoond (Adrian et al., 2011; Cuenen et al., 2015; Dawson et al., 2010; Jongen et al., 2012; Wood et al., 2008). Helaas zegt de 'frontale veroudering hypothese' dat met een stijging in leeftijd cognitieve vaardigheden verminderen (Dempster, 1992; West, 1996).

Verschillende studies hebben aangetoond dat cognitieve training bij ouderen de cognitieve vaardigheid kan verbeteren (Ball et al., 2002; Ball et al., 2007; Karbach en Kray, 2009; Rebok et al., 2014; Schmiedek et al., 2010). Een cognitieve training kan bijvoorbeeld mentale flexibiliteit verbeteren (Karbach en Kray, 2009). Daarnaast kan een cognitieve training ook ongetrainde cognitieve vaardigheden verbeteren. Bijvoorbeeld, een training van mentale flexibiliteit verbeterde niet alleen de prestatie op een mentale flexibiliteit taak, maar ook prestatie op o.a. werkgeheugentaken en intelligentietaken (Karbach en Kray, 2009). Daarnaast heeft een beperkt aantal studies aangetoond dat cognitieve training positieve effecten heeft op rijvaardigheid (Ball et al., 2002; Ball et al., 2007; Ball et al., 2010; Ball et al., 2013; Cassavaugh en Kramer, 2009; Edwards et al., 2009a,b; Rebok et al., 2014; Roenker et al., 2003; Ross et al., 2013).

1.1.2.1.1 Werkgeheugen

Met veroudering treden er problemen op met werkgeheugen (Borella et al., 2008). Werkgeheugen is de capaciteit om tijdelijk informatie op te slaan en te manipuleren (Baddeley, 1992). Eerder onderzoek heeft de relatie tussen werkgeheugen en rijden bij ouderen aangetoond: Een beter werkgeheugen is verbonden aan een langere beslissingstijd om links af te slaan bij vrouwelijke oudere bestuurders (Guerrier et al., 1999) en een betere score op een gesommeerde rijmaat bestaande uit snelheid, slingergedrag en reacties op signalen (Adrian et al., 2011).

Recent werd onderzocht of een werkgeheugentraining, werkgeheugen kan verbeteren en uit deze onderzoeken volgden positieve effecten die tot zeker 8 maanden aanhielden (Borella et al., 2010; Borella et al., 2013). Daarnaast had de werkgeheugentraining een effect op andere cognitieve vaardigheden zoals inhibitie (Borella et al., 2013).

Tot nu toe heeft slechts één studie onderzocht of een werkgeheugentraining de rijvaardigheid van oudere bestuurders kan verbeteren. Deze studie vond positieve effecten op reactie op het remmen van een voorligger (Cassavaugh en Kramer, 2009). Er dient opgemerkt te worden dat deze studie de rijvaardigheid onderzocht onder gemanipuleerde omstandigheden (nl. volgen van een voorligger) i.p.v. meer neutrale rijomstandigheden.

Interessant, op andere gebieden van gedrag had een werkgeheugentraining positieve effecten: Na het volgen van een werkgeheugentraining vertoonden volwassenen een daling in excessief alcoholgebruik (Houben et al., 2011), en vertoonden kinderen met ADHD een verbetering van motoractiviteit (Klingberg et al., 2002).

1.1.2.1.2 Inhibitie

Volgens de 'inhibitie gebrek hypothese' (Hasher en Zacks, 1988; Lustig et al., 2007), hebben ouderen vooral problemen met inhibitie. Inhibitie is de vaardigheid om automatische reacties te onderdrukken wanneer dit nodig is (Bunge en Crone, 2009; Miyake et al., 2000).

De relatie tussen inhibitie en rijden is slechts beperkt onderzocht. De Raedt en Ponjaert-Kristoffersen (2000) vonden dat inhibitie gerelateerd is aan een gesommeerde rijmaat bestaande uit snelheid, slingergedrag en reacties op signalen, maar dit was niet gevonden door Adrian et al. (2011). Daigneault et al. (2002) vonden dat inhibitie gerelateerd is aan ongevallenbetrokkenheid.

Aangezien deze studies hebben aangetoond dat inhibitie belangrijk is voor de rijvaardigheid van ouderen en het geweten is dat inhibitie afneemt met veroudering, is het verrassend dat het effect van een inhibitietraining op de rijvaardigheid van ouderen nog niet onderzocht is. Tot nu toe is het effect van een inhibitietraining slechts bekeken op gezondheidsgebied zoals problematisch drinkgedrag, eetgedrag en gokgedrag. Na het volgen van een inhibitietraining, hadden jonge volwassen minder excessief alcoholgebruik en hoog calorierijk voedsel en verkozen ze lagere inzetten tijdens het gokken (Houben, 2011; Houben et al., 2011; Houben en Jansen, 2011; Jones en Field, 2013; Stevens et al., 2015).

1.1.2.2. Rijsimulator gebaseerde training

Er zijn slechts enkele studies die positieve effecten op rijvaardigheid vonden dankzij een cognitieve training. Hierdoor is er debat over de effecten van cognitieve training op alledaagse activiteiten zoals rijden (Mayhew et al., 2014; Reijnders et al., 2013). Verschillende studies vonden namelijk verbetering in de getrainde taken na een cognitieve training, maar niet op ongetrainde taken, vb. rijtaken (Gaspar et al., 2012; Lange en Süb, 2015; Mayhew et al., 2014; Zinke et al., 2012). Volgens de 'wet van identieke elementen' en de 'oefening-specificiteitsbenadering van leervaardigheden' zijn de beste trainingsomstandigheden degene die het toestaan om dezelfde onderliggende processen aan te leren die gebruikt zullen worden in de taak waar men een effect op wilt hebben (Schmidt en Lee, 2005; Thorndike en Woodworth, 1901). Met andere woorden: als het doel is om een effect op rijvaardigheid te hebben, moeten vaardigheden verkregen worden in een rij-specifieke context. Een training die rijvaardigheid direct i.p.v. indirect traint zal dus meer effect hebben. Recente studies hebben aangetoond dat een context-specifieke training inderdaad succesvoller kan zijn in het verbeteren van rijvaardigheid (Gaspar et al., 2012; Mayhew et al., 2014). Recente studies onderzochten daarom het effect van een rijsimulator gebaseerde training voor ouderen en vonden veelbelovende effecten op rijvaardigheid zowel onmiddellijk na de training (Akinwuntan et al., 2005; Casutt et al., 2014; Lavallière et al., 2009; Romoser en Fisher, 2009), als verschillende jaren later (Devos et al., 2010; Romoser, 2012).

1.2 Methode

In het kader van Werkpakket 4 Ontwikkeling van verkeersveiligheidsmaatregelen voor Steunpunt Verkeersveiligheid werden drie aparte studies uitgevoerd. Twee studies onderzochten het effect van een cognitieve training op rijvaardigheid, respectievelijk een werkgeheugentraining en een inhibitietraining. Een derde studie onderzocht het effect van een rijsimulator gebaseerde training op de rijvaardigheid.

1.2.1 Onderzoeksvragen

Cognitieve trainingen:

- Zorgt een cognitieve training (werkgeheugen en inhibitie) voor een verbetering in cognitieve vaardigheden?
- Vertaalt deze verbetering van cognitieve vaardigheden zich in een verbetering van rijvaardigheid?

Rijsimulator gebaseerde training:

- Zorgt een rijsimulator gebaseerde training voor een verbetering in rijvaardigheid?

1.2.2 Deelnemers

Deelnemers van 60 jaar of ouder die nog actief reden met de auto, geen beroerte hadden in de afgelopen 6 maanden en geen cognitieve achteruitgang hadden werden gerekruteerd. In het geval van de cognitieve trainingen was het bezit van en ervaring met een computer ook vereist. Werving gebeurde via de gemeenschap via (lokale) media en mondelinge presentaties en flyers verdeeld in ouderenorganisaties. Een steekproefgrootte van 15-25 personen per groep werd gekozen.

1.2.3 Meetinstrument en afhankelijke maten

Rijvaardigheid kan op verschillende manieren gemeten worden: m.b.v. vragenlijsten, een computertaak, een rit in een rijsimulator, een rit op de weg of een rit op een gesloten parcours. Ieder meetinstrument heeft zijn voor- en nadelen. In de studies die in dit rapport besproken zullen worden is rijvaardigheid gemeten m.b.v. een rijsimulator (zie figuur 2) aangezien het de mogelijkheid biedt om risicovolle situaties in een gestandaardiseerde, veilige en gecontroleerde omgeving te onderzoeken (Lee et al., 2003). Daarnaast is er recent positief bewijs voor simulatorvaliditeit gegeven (Fisher et al., 2011) en staat een rijsimulator toe om specifieke rijmaten te onderzoeken zoals snelheid en slingergedrag. Er is gekozen voor specifieke rijmaten, aangezien recent onderzoek het belang aantoonde voor het gebruik van specifieke rijmaten t.o.v. een gesommeerde rijmaat (Aksan et al., 2015; Anstey en Wood, 2011; Cuenen et al., 2015; Mullen et al., 2008). Een gesommeerde maat van rijvaardigheid is de algemene beoordeling over rijvaardigheid van een evaluator gebaseerd op geobserveerde componenten tijdens de rit (Bédard et al., 2008; Jones Ross et al., 2014; Stav et al., 2008; Wood et al., 2008). Specifieke aspecten van rijden worden in één algemene rijmaat gesommeerd. Deze gesommeerde maat is vaak gebaseerd op overtredingen en strafpunten met als resultaat een categorische maat, zoals geslaagd/niet geslaagd (Bédard et al., 2008): Deelnemers slagen niet indien ze te veel strafpunten verzameld hebben of als ze een serieuze overtreding maken. Hoewel het gebruik van een gesommeerde maat van rijvaardigheid het voordeel geeft van een duidelijk beeld over rijvaardigheid (geslaagd of niet geslaagd) is het niet optimaal om het effect van een training op rijvaardigheid te bekijken. Het is namelijk mogelijk dat een cognitieve training slechts effect heeft op een selectie van rijmaten aangezien recent onderzoek heeft aangetoond dat het van de specifieke rijmaat in kwestie afhangt welke cognitieve vaardigheden van belang zijn (Aksan et al., 2015; Anstey en Wood, 2011; Cuenen et al., 2015; Mullen et al., 2008).

Onvermijdelijk zijn er ook nadelen verbonden aan de rijsimulator. Er is bewijs voor relatieve validiteit, maar niet voor absolute validiteit. Dit betekent dat de richting van verandering van een gesimuleerde rijmaat in dezelfde richting is als een corresponderende rijmaat in het dagelijks leven, maar dat het niet dezelfde numerieke verandering geeft. We kunnen daarom verwachten dat de training in het dagelijks leven een vergelijkbaar effect zal teweeg brengen in termen van richting, maar de grootte van verandering kan verschillen van die waargenomen in de simulator (Fisher et al., 2011). Een ander nadeel is dat mensen symptomen van simulatorziekte kunnen ervaren, welke vergelijkbaar zijn met wagenziekte, nl. duizeligheid en misselijkheid.

Figuur 2: Rijsimulator

Vooraleer deelnemers de experimentele rit reden, kregen ze twee oefenritten om te wennen aan de rijsimulator. Bedoeling was dat men reed zoals men in het dagelijks leven zou rijden. In de experimentele rit kwamen situaties voor waarvan bekend is dat ouderen hier moeite mee hebben, vb. voorrang aan rechts verlenen (Hakamies-Blomqvist, 1993), reacties op tekens, vb. volledig stoppen bij een stopbord (Bao en Boyle, 2008; Jongen et al., 2012) en links afslaan (Jongen et al., 2012; Yan et al., 2007).

De afhankelijke rijmaten bestonden uit: (1) gemiddelde snelheid (km/u), (2) slingergedrag (standaard deviatie van laterale wegpositie (SDLP), m), (3) voorrang van rechts geven (ja, gecodeerd als 1 of nee, gecodeerd als 0), (4) een volledige stop maken bij een stopbord (ja, gecodeerd als 1 of nee, gecodeerd als 0), (5) ongevallen (aantal) en (6) hiaatacceptatie bij links afslaan (s). Alle rijmaten waren gemiddeldes, m.u.v. ongevallen welke het totaal aantal ongevallen tijdens de rit illustreert. Gemiddelde snelheid en SDLP werden gemeten op wegsegmenten zonder gebeurtenissen (Trick et al., 2010).

Naast de rijmaten waren cognitieve maten ook afhankelijke maten bij de cognitieve trainingen, nl. werkgeheugen bij de werkgeheugentraining en inhibitie en aandacht bij de inhibitietraining. Verwacht wordt dat een inhibitietraining niet enkel effect heeft op inhibitie, maar ook op aandacht, aangezien verschillende cognitieve functies en hun onderliggende neurale circuits verbonden zijn met elkaar (McNab et al., 2008).

1.2.4 Procedure

Deelnemers gaven eerst hun toestemming. Na succesvolle voltooiing van de voormeting werden deelnemers willekeurig toegewezen aan een controlegroep of een experimentele groep. Voor en na de training werd rijvaardigheid gemeten. In het geval van de cognitieve trainingen werd voor en na de training ook cognitieve vaardigheid gemeten (zie figuur 3).

*Enkel bij de cognitieve trainingen

Figuur 3: Onderzoeksopzet

1.3 Analyse

Het effect van de trainingen is onderzocht met een herhaalde metingen variantieanalyse (ANOVA) per afhankelijke maat. De afhankelijke maat was telkens de specifieke rijmaat (en in het geval van de cognitieve training ook de cognitieve maten).

In de ANOVA, diende Meting (i.e., voormeting, nameting) als within-subjects variabele en Groep (i.e., controle groep, experimentele groep) als between-subjects variabele. De Greenhouse–Geisser epsilon correctie factor werd telkens toegepast om te compenseren voor mogelijke effecten van non-sphericity in de vergeleken metingen. Enkel de gecorrigeerde F en waarschijnlijkheidswaarden worden gerapporteerd. Een significantieniveau van .05 werd aangehouden voor de statistische testen. Een Bonferroni correctie werd toegepast om te controleren voor herhaalde vergelijkingen. Effect groottes voor het hoofdeffect van Meting werd gerapporteerd met Cohen's delta. Een Cohen's delta van 0.2 betekent een klein effect, 0.5 betekent een medium effect, en 0.8 betekent een groot effect.

1.4 Resultaten

Zorgt een cognitieve training (werkgeheugen en inhibitie) voor een verbetering in cognitieve vaardigheden?

Werkgeheugentraining: zowel deelnemers van de controle groep als de experimentele groep hadden tijdens de nameting een verbetering van werkgeheugen.

Inhibitietraining: zowel deelnemers van de controlegroep als de experimentele groep hadden tijdens de nameting een verbetering van inhibitie en aandacht.

Zie tabel 1 voor een overzicht van de resultaten.

Vertaalt deze verbetering van cognitieve vaardigheden zich in een verbetering van rijvaardigheid?

Werkgeheugentraining: zowel deelnemers van de controlegroep als de experimentele groep hadden tijdens de nameting een verbetering van rijvaardigheid: deelnemers kozen een kleiner hiaat bij het links afslaan en hanteerden een hogere gemiddelde snelheid. Daarnaast vertoonden deelnemers minder slingergedrag en hadden ze minder ongevallen, maar dit effect was slechts marginaal significant.

Inhibitietraining: zowel deelnemers van de controlegroep als de experimentele groep hadden tijdens de nameting een verbetering van rijvaardigheid: deelnemers kozen een kleiner hiaat bij het links afslaan.

Zie tabel 2 voor een overzicht van de resultaten.

Zorgt een rijsimulator gebaseerde training voor een verbetering in rijvaardigheid?

Zowel deelnemers van de controle groep als de experimentele groep vertoonden na de rijsimulator gebaseerde training minder slingergedrag en hadden minder ongevallen. Daarnaast hanteerden deelnemers in de controlegroep na de rijsimulator gebaseerde training een hogere gemiddelde snelheid en gaven deelnemers in de experimentele groep na de rijsimulator gebaseerde training meer voorrang aan rechts.

Zie tabel 2 voor een overzicht van de resultaten.

Tabel 1: Resultaten cognitieve trainingen op cognitieve vaardigheden

	Cognitieve training	
Cognitieve maat	***Werkgeheugentraining***	***Inhibitietraining***
Werkgeheugen	Nameting > voormeting	N.v.t.
Inhibitie	N.v.t.	Nameting > voormeting
Aandacht	N.v.t.	Nameting > voormeting

Tabel 2: Resultaten trainingen op rijvaardigheid

	Training		
	Cognitieve training (indirect)		**Rijvaardigheidstraining (direct)**
Specifieke rijmaat	***Werkgeheugentraining***	***Inhibitietraining***	***Rijsimulator gebaseerde training***
Gemiddelde snelheid	Nameting > voormeting		Controlegroep: Nameting > voormeting
Slingergedrag	Nameting < voormeting (marginaal significant, p<0.10)		Nameting < voormeting
Ongevallen	Nameting < voormeting (marginaal significant, p<0.10)		Nameting < voormeting
Volledig stoppen bij een stopbord			
Voorrang verlenen aan rechts			Experimentele groep: Nameting > voormeting
Hiaatacceptatie bij links afslaan	Nameting < voormeting	Nameting < voormeting	N.v.t.

1.5 Discussie en verder onderzoek

1.5.1 Cognitieve training

Na de cognitieve trainingen kozen deelnemers een kleiner hiaat bij het links afslaan en reden ze sneller, wat zorgde voor een vlottere doorstroming in het verkeer. Een mogelijke verklaring hiervoor is dat ze minder moesten compenseren voor achteruitgang in cognitieve vaardigheden omdat cognitieve vaardigheden als gevolg van de training verbeterd waren. Eerder onderzoek heeft aangetoond dat ouderen grote hiaten kiezen om links af te slaan en traag rijden om te compenseren voor een daling in cognitieve vaardigheden (Alexander et al., 2002; Fisher et al., 2011; McKnight, 1988).

Hoewel we na het volgen van de cognitieve trainingen enkel verbetering van cognitieve vaardigheid en rijvaardigheid verwachtten in de experimentele groep, zagen we een gelijkaardige verbetering in de actieve controle groep. Dit is niet verrassend als we kijken naar het gemiddeld niveau gehaald op de cognitieve trainingen door beide groepen. Hoewel het gemiddeld niveau significant hoger was voor de experimentele groep was het verschil in absolute zin klein. Er zijn twee mogelijke verklaringen voor de gelijkaardige verbetering in beide groepen. Een eerste mogelijke verklaring is dat deze gelijkaardige verbetering komt door de cognitieve training, waarbij een training met een beperkt moeilijkheidsniveau reeds voldoende is om verbetering in cognitieve vaardigheden teweeg te brengen. Een tweede mogelijke verklaring is dat deze gelijkaardige verbetering komt door een leereffect, omdat men de taken voor de tweede maal deed. Het is nodig om de resultaten te vergelijken met een groep die geen training volgde. Indien deze groep verbetert zal het eerder gaan om leereffecten. Indien deze groep niet verbetert zal het eerder gaan om trainingseffecten.

Indien het daadwerkelijk om trainingseffecten gaat, is het duidelijk dat de cognitieve trainingen vooral een effect hebben op cognitieve vaardigheden, maar minder op rijvaardigheid. Dit is in lijn met de kritiek dat cognitieve training wel cognitieve vaardigheid verbetert, maar in veel gevallen niet leidt tot een verbetering van alledaagse activiteiten zoals rijden (Mayhew et al., 2014; Reijnders et al., 2013). Deze trainingen kunnen dan ook vooral worden gebruikt om beperkingen in cognitieve vaardigheden van ouderen tegen te werken. Uit de resultaten blijkt dat specifieke problemen met snelheidscontrole en hiaatacceptatie wel aangepakt kunnen worden aan de hand van cognitieve training. Belangrijk hierbij is echter op te merken dat deze effecten slechts klein tot middelmatig in grootte waren. Een mogelijke verklaring voor deze kleine effecten is dat cognitieve vaardigheden slechts een relatief kleine hoeveelheid van de variantie in rijvaardigheid verklaren (Backs et al., 2011; Cuenen et al., 2015; Mullen et al., 2008; Shanmugaratnam et al., 2010).

Er dient opgemerkt te worden dat de trainingen gericht waren op één cognitieve vaardigheid. Mogelijk heeft een multifactoriële cognitieve training die een variëteit van cognitieve vaardigheden traint wel positieve effecten op rijvaardigheid (Schmiedek et al., 2010), omdat verschillende cognitieve vaardigheden samenhangen met verschillende rijmaten. Verder onderzoek moet dit uitwijzen.

Daarnaast bestonden de trainingen uit 25 sessies die individueel thuis uitgevoerd werden. Verder onderzoek moet uitwijzen hoeveel sessies aanbevolen zijn. Verder onderzoek moet ook uitwijzen welk format van de sessies (individueel vs. groep) aanbevolen is. Een recente meta-analyse raadt voor cognitieve trainingen een groep gebaseerde training aan bestaande uit maximum 3 sessies (Lampit et al., 2015).

1.5.2 Rijsimulator gebaseerde training

Na de rijsimulator gebaseerde training vertoonden deelnemers minder slingergedrag en hadden ze minder ongevallen. Daarnaast hanteerden deelnemers in de controlegroep na de rijsimulator gebaseerde training een hogere gemiddelde snelheid en gaven deelnemers in de experimentele groep na de rijsimulator gebaseerde training meer voorrang aan rechts. Hieruit kunnen we concluderen dat feedback op maat van het individu dus enkel een meerwaarde blijkt te hebben bij het voorrang van rechts verlenen. Het actief rijden in de simulator op zich lijkt al te zorgen voor een verbetering in slingergedrag en ongevallen.

Belangrijk om op te merken is dat de effecten niet enkel klein tot middelmatig waren zoals bij de cognitieve training, maar dat de effecten soms ook groot waren. De training had een groot effect op voorrang verlenen en ongevallen, twee rijmaten waar de cognitieve trainingen geen effect op hadden.

Personen die moeite hebben met slingergedrag, snelheidscontrole, voorrang verlenen aan rechts, en ongevallen kunnen vooral baat hebben bij deze rijsimulator gebaseerde training, waarbij feedback op maat nodig is om een effect te hebben op voorrang aan rechts verlenen.

1.5.3 Limitaties

Onvermijdelijk hadden deze studies enkele limitaties waardoor verder onderzoek nodig is:

(1) Aangezien het op dit moment niet duidelijk is of het over trainingseffecten of leereffecten gaat, is het nodig om een studie uit te voeren, met naast een experimentele groep en een actieve controlegroep ook een passieve controlegroep die geen training uitvoert (Brehmer et al., 2012; Chein en Morrison, 2010; Dahlin et al., 2008; Li et al., 2008; Schmiedek et al., 2010). Om een idee te verkrijgen over trainingseffecten/leereffecten is er bijkomende dataverzameling geweest van een passieve controlegroep in het kader van de werkgeheugentraining. Analyses tonen aan dat de experimentele groep de grootste verbetering had van werkgeheugen, de actieve controlegroep een minder grote verbetering en de passieve controlegroep een beperkte tot geen verbetering. Dezelfde trend lijkt te bestaan voor gemiddelde snelheid en reactie op stopborden, maar deze resultaten waren slechts marginaal significant. Deze resultaten laten zien dat een adaptieve training beter is dan een niet-adaptieve training of geen training. Voor hiaatacceptatie verbeterden alle groepen, wat wijst op een leereffect i.p.v. een trainingseffect.

(2) De studies werden uitgevoerd in een simulator. Alhoewel er bewijs is voor validatie van de simulator, is er enkel bewijs voor relatieve i.p.v. absolute validiteit. Daarom zouden de studies gerepliceerd moeten worden tijdens rijden in het dagelijks leven om de praktische relevantie van de resultaten te onderzoeken.

(3) De studies onderzochten enkel onmiddellijke trainingseffecten. De lange termijn effecten zijn hierdoor onbekend. Verder onderzoek moet de duur van effecten onderzoeken. Eerder onderzoek vond dat cognitieve trainingseffecten bleven aanhouden voor enkele maanden (Borella et al., 2013; Li et al., 2008) en dat rijsimulator gebaseerde trainingseffecten bleven aanhouden voor zelfs enkele jaren (Devos et al., 2010; Romoser, 2012).

(4) De steekproefgrootte van de studies is relatief klein, welke de generaliseerbaarheid van de resultaten beperkt. Een ander aspect dat de generaliseerbaarheid van de resultaten beperkt is de mogelijkheid van een zelfselectie bias. Vooral bestuurders die zichzelf goede bestuurders vinden zullen vrijwillig deelnemen in een studie die de rijvaardigheid onderzoekt. Hieraan verbonden, deelnemers in de studies behoorden niet tot de risicogroep aangezien ze een gemiddelde leeftijd van slechts 70 jaar hadden (i.p.v. 75+) en gemiddeld meer dan 3000 kilometers per jaar aflegden (Langford et al., 2006). Een laatste aspect dat de generaliseerbaarheid van de resultaten beperkt is dat de studies ouderen zonder cognitieve beperkingen onderzocht, waardoor zij niet representatief zijn voor de gehele populatie van oudere bestuurders, waarvan een gedeelte wel een achteruitgang in cognitieve vaardigheden ervaart, vb. dementie.

1.6 Conclusies

Deze studies dragen bij aan de bestaande wetenschappelijke literatuur over trainingseffecten bij oudere bestuurders. Deze studies waren namelijk de eerste studies die het effect van een cognitieve training gericht op werkgeheugen en inhibitie onderzochten op specifieke rijmaten van ouderen tijdens het rijden onder neutrale omstandigheden (nl. alledaagse situaties, onder normale weeromstandigheden).

Vooraleerst moet verder onderzoek uitwijzen of de effecten bij de cognitieve trainingen ontstonden door de training of doordat men de taken voor de 2^{e} maal deed. Er zijn indicaties dat de effecten deels te wijten zijn aan een leereffect. Het is namelijk normaal dat als men taken voor een tweede maal doet dit beter verloopt dan de eerste maal omdat men ervan geleerd heeft (Boot et al., 2011; Collie et al., 2003). Bijkomende effecten zijn waarschijnlijk wel ontstaan door de training.

Indien de effecten ontstonden door de training, liggen de resultaten in lijn met eerder onderzoek dat heeft aangetoond dat een cognitieve training slechts beperkte effecten heeft op rijvaardigheid (Gaspar et al., 2012; Mayhew et al., 2014). Een meer directe training van rijvaardigheid (rijsimulator gebaseerde training) had meerdere en grotere effecten. Indien men achteruitgang in de rijvaardigheid van ouderen wilt tegenwerken is daarom een meer directe training van rijvaardigheid aanbevolen.

Effectieve trainingen zijn op maat van het individu waarbij die vaardigheden waar men moeite mee heeft aangepakt worden. Een training op maat is enkel mogelijk indien gedetailleerde informatie beschikbaar is, met rijvaardigheidsscores op het niveau van specifieke rijmaten i.p.v. een gesommeerde rijmaat. Het is daarom van belang om het effect van een training te onderzoeken op specifieke maten van rijvaardigheid, aangezien een gesommeerde maat geen gedetailleerd beeld kan geven van trainingseffecten. Daarnaast is het mogelijk dat de ene training een effect kan hebben op bepaalde aspecten van rijvaardigheid, terwijl het geen effect heeft op andere aspecten van rijvaardigheid. Hierdoor kan dezelfde training niet als interventie gebruikt worden voor alle rijvaardigheidsproblemen, maar slechts voor een selectie van rijvaardigheidsproblemen. Op basis van de resultaten kan het volgende geconcludeerd worden: Personen die moeite hebben met snelheidscontrole zouden baat hebben bij een werkgeheugentraining en een rijsimulator gebaseerde training (zonder feedback op maat). Personen die moeite hebben met hiaatacceptatie bij links afslaan zouden baat hebben bij een werkgeheugentraining en inhibitietraining. Personen die moeite hebben met slingergedrag en ongevallen zouden vooral baat hebben bij een rijsimulator gebaseerde training (zonder feedback op maat). Personen die moeite hebben met voorrang verlenen aan rechts zouden vooral baat hebben bij een rijsimulator gebaseerde training waarbij men feedback op maat krijgt.

Verder onderzoek is weliswaar nodig om te bekijken hoe deze trainingen best opgebouwd worden. Bijvoorbeeld hoeveel sessies best aangeboden worden om een (langdurig) gunstig effect te verkrijgen, of deze sessies best individueel of in groep aangeboden worden, enz.

2 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. Fifty-four 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 an active 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.

2.1 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 inhibition (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.

2.2 Method

2.2.1 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. 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 an active control (N=19) or an experimental condition (N=19).

2.2.2 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 practice 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 practice ride (5.5 km) was similar to the main ride 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).

2.2.3 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.

2.2.4 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 active 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 active 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.

2.2.5 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 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 (i.e., active 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.

2.3 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 active 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 active 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 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 ($p>.05$).

2.4 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, lateral control 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 condition 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 no-training control condition 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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3 Inhibition and driving: the effect of an inhibition training on cognitive ability and driving ability of older drivers

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Summary

Since mobility is essential for quality of life, it is important to keep drivers safe drivers as long as possible. With age there is a decline in inhibition, that is important for driving. This study aimed to investigate in older drivers (1) the relation between inhibition and cognitive/driving ability, and (2) whether a computerized home-based inhibition training can improve cognitive ability and driving ability. Forty-two drivers (mean age 73.95 years) were randomly assigned to an active control (n=20) or an experimental condition (n=22). During the pre- and post-test, cognitive and driving ability were assessed. In between, participants conducted an inhibition training. Results indicate that inhibition corresponds with cognitive ability (i.e., attention) and driving ability (i.e., lateral control and crashes). With regard to the training, there was an improvement of cognitive ability (i.e., inhibition and attention) and of one driving measure (i.e., gap acceptance) for both conditions during post-test. Although additional data indicates that this latter effect could be a test-retest effect, there seems to be at least a genuine training effect for cognitive ability. Possibly, even an inhibition training with a limited difficulty level might serve as a method to remediate deficits of cognitive ability in older drivers.

3.1 Introduction

The frontal aging hypothesis states that there is a decline in cognitive abilities with increasing age (Dempster, 1992; West, 1996). To postpone or counteract impairments in cognitive abilities, they have to be trained. Fortunately, even older people can benefit from training since they have still considerable plasticity in their cognitive functioning (Kramer and Willis, 2002). Several studies with older people have shown that cognitive training can improve cognitive abilities targeted by the training like speed-of-processing (Ball et al., 2007) and task switching (Karbach and Kray, 2009). Interestingly, the effect of a cognitive training sometimes seems to transfer to untrained cognitive abilities. For example, a task switching training not only improved performance on a task switching task, but also improved performance on an interference control task, working memory tasks and fluid intelligence tasks (Karbach and Kray, 2009).

It is promising that decreases in cognitive abilities can be postponed or counteracted by training since cognitive abilities are important in daily life activities, such as driving. Several studies indicated a relation between driving ability and cognitive abilities like attention in older drivers (Adrian et al., 2011; Cuenen et al., 2015; Dawson et al., 2010; Jongen et al., 2012; Wood et al., 2008). In the last couple of years, studies investigated to what degree improvement of cognitive ability transfers to improved driving ability of older drivers and found interesting effects (Ball et al., 2002; Ball et al., 2010; Ball et al., 2007; Ball et al., 2013; Cassavaugh and Kramer, 2009; Edwards et al., 2009a,b; Rebok et al., 2014; Roenker et al., 2003). In a recent meta-analysis it is indicated that cognitive training interventions hold promise for maintaining everyday mobility (Ross et al., 2013), however there is some debate about the transfer effects of cognitive training to daily life activities like driving (Mayhew et al., 2014; Reijnders et al., 2013).

One important cognitive ability is executive control (EC), which is the ability to plan, guide and monitor complex goal-directed actions (Karbach and Kray, 2009). According to Miyake et al. (2000), EC consists of separate control components such as switching, updating and inhibition. According to the inhibitory deficit hypothesis (Hasher and Zacks, 1988; Lustig et al., 2007), older people have particular problems with inhibition, which is the ability to deliberately suppress automatic responses when necessary (Bunge and Crone, 2009; Miyake et al., 2000).

Surprisingly, although there are lots of studies investigating several types of cognitive training in order to improve cognitive abilities of older people, to our knowledge, no study has investigated the effect of a cognitive inhibition training on cognitive abilities. With regard to driving, the relation between inhibition and driving ability of older drivers is also not studied extensively. De Raedt and Ponjaert-Kristoffersen (2000) found that inhibition is related to an on-road summarized driving measure consisting of speed control, lateral position and reactions to signals, however, this was not found by Adrian et al. (2011). Daigneault et al. (2002) found that inhibition is related to on-road crash involvement.

Since these studies indicated that inhibition is important for driving ability of older people and inhibition seems to decrease with advancing age, it is surprising that the effect of a training of inhibition on driving ability of older people is not investigated yet. Until now, training inhibition is limited to health areas like problematic drinking, eating and gambling behavior. After following an inhibition training, young adults had a lower intake of alcohol and high calorie food, and preferred lower bets when gambling (Houben, 2011; Houben et al., 2011; Houben and Jansen, 2011; Jones and Field, 2013; Stevens et al., 2015).

The aim of the present study was twofold. The first aim was to investigate the relation between inhibition and specific driving measures (e.g., gap acceptance) in older drivers, since previous research has concentrated on an on-road summarized driving measure or crash involvement (Adrian et al., 2011; Daigneault et al., 2002; De Raedt and Ponjaert-Kristoffersen, 2000). This study investigates specific driving measures, like left turn gap acceptance decision, since recent research has shown that it depends on the specific driving measure under investigation which cognitive abilities are important (Aksan et al., 2015; Anstey and Wood, 2011; Cuenen et al., 2015; Mullen et al., 2008).

The second aim was to investigate whether an inhibition training can lead to an improvement of cognitive ability and driving ability in older drivers. As mentioned above, this has not been investigated yet. It is crucial to know the effect of interventions to keep drivers older safe drivers for as long as possible, since older drivers are the fastest growing segment of the driving population and research has indicated that driving cessation leads to a decline in out-of-home activities, leading to social isolation and even depression (Marottoli et al., 1997; Ragland et al., 2005).

3.2 Method

3.2.1 Participants

Participants needed to fulfill the following inclusion criteria: have an age of 65 years or older, being still an active driver, not having had a stroke or sequel in the last six months, have experience with a Personal Computer (PC), not being color-blind and having a Mini-Mental State Examination (MMSE) score of 25 or above. The MMSE is a brief test that investigates a person’s cognitive status. It consists of items assessing orientation to time and place, registration and recall, attention, language and constructional ability (Folstein et al., 1975). Possible scores range from 0 to 30, with higher scores reflecting better cognitive status. Recruitment occurred in the community via (local) media; via oral presentations for senior associations, and with flyers distributed in senior flats, hospitals and 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, fifty-nine participants volunteered. However, seventeen participants dropped out due to simulator sickness (n=13) and personal circumstances (i.e., hospitalization, n=4). Hence, forty-two participants remained in the sample. Participants were randomly assigned to an active control condition (n=20) or an experimental condition (n=22).

3.2.2. Materials and measures

3.2.2.1. Driving ability

Driving ability was measured in a driving simulator since a simulator provides the opportunity to investigate dangerous situations in a standardized, safe and controlled environment (Lee et al., 2003) and allows the investigation of specific driving measures. Recently, positive evidence for simulator validity has been provided (Fisher et al., 2011). The study was conducted on a fixed-based medium-fidelity driving simulator (STISIM M400; Systems Technology Incorporated) with a force-feedback steering wheel, brake pedal and accelerator. The visual virtual environment was presented on a large 180˚ field of view seamless curved screen, 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 was collected at frame rate. Two practice rides preceded the main ride to get acquainted with the driving simulator. In the first practice 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 practice ride (5.5 km) was similar to the main ride to acquaint drivers with several traffic situations. The main ride solely consisted of inner-city (50 km/hour) segments, and to decrease the risk of simulator sickness did not contain any curves. The main ride included several situations that are known to be difficult for the older driver, i.e., right of way decisions (Hakamies-Blomqvist, 1993), responses to signs (Bao and Boyle, 2008; Jongen et al., 2012) and gap acceptance for turning left (Jongen et al., 2012; Yan et al., 2007). With regard to right of way decisions, participants were required to give right of way to the car driver from the right minor road. Cross traffic from right occurred when the driver approached the intersection. With regard to responses to signs, participants were required to make a complete stop at an intersection with a stop sign (i.e., mean driving speed = 0 km/h). Cross traffic from left or right occurred when the driver approached the intersection. With regard to gap acceptance for turning left: when the driver approached the intersection, the instruction to turn left was played. On the major road in the opposite lane, a stream of oncoming cars was driving with a speed equaling the speed limit, forcing the driver to make a stop. The first part of the stream consisted of very small gaps (less than 3s) and was followed by the second part of the stream that, similar to Yan et al. (2007), consisted of gaps uniformly increasing in duration from 3s to 16s. Participants were asked to indicate their decision to turn left when they judged it was safe to do so by pressing a button. This procedure was followed to minimize the chance of simulator sickness that was very high in a previous study where participants actually made the left turn maneuver (Jongen et al., 2012). The intersections all consisted of a four-way intersection consisting of a straight piece of road and a minor road to the left and to the right.

A total of six specific driving measures were derived for analyses. 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 adopt slower speeds to compensate for age-related increases in response time (Fisher et al., 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 and Ramaekers, 1995; Vuurman et al., 2007; Wester et al., 2008) and provides a sensitive measure of driver impairment (De Waard, 1996; Ramaekers, 2003). Mean driving speed (km/h) and SDLP (m), were measured across separate road segments (i.e., 4.8 km) without any events (Trick et al., 2010). The other four driving measures were selected since they represent situations that are mentioned most often in the literature to be difficult for the older driver (Bao and Boyle, 2008; Horswill et al., 2009; Yan et al., 2007). Two measures of 'giving way' were selected to assess whether drivers would comply with Belgian traffic regulations that drivers must give right of way or make a full stop at a stop sign: Giving right of way (yes or no) and Complete stop at a stop sign (yes or no; Bao and Boyle, 2008; Jongen et al., 2012). Left turn gap acceptance decision (s) is the time headway between two vehicles on the major road into which a left-turn driver chooses to turn (Jongen et al., 2012; Yan et al., 2007). Finally, the number of crashes throughout the whole ride was measured.

3.2.2.2. Cognitive ability

Inhibition and attention were investigated as measures of cognitive ability. Inhibition was measured with the auditory stop signal task (SST), see Figure 1 for a visualization of the task. This task was adapted from Jongen et al. (2011) and Ross et al. (2014) (see also: Logan and Cowan, 1984; and Verbruggen and Logan, 2008). This task included two practice sessions (40 trials each) and one experimental session (88 trials). In all sessions, participants were required to press a button (left or right) as quickly as possible in response to a stimulus ('X' or 'O') presented centrally on screen (go trials). In each trial, after 1000ms, a fixation cross was presented for 500ms. After this, a stimulus was presented for 1000ms. The first practice session served to determine the individual's mean Reaction Time (RT), which was used as a reference for the second practice session and the experimental session. These latter sessions consisted of the same task as the first practice session, but in addition, a stop signal (i.e., an auditory stimulus of 1000Hz, 70dB, 100ms) was presented on a randomly selected 25% of the trials. Upon presentation of this stop signal, the participant needed to refrain from responding to the stimulus on that trial (stop trials). Importantly, the Stop Signal Delay (SSD; i.e., the time interval between the stimulus and the stop signal) was initially set 50ms below the individual's mean RT. Subsequently the interval varied dynamically, according to a staircase algorithm, to converge on a SSD at which the probability of stopping on stop trials was 50%. SSD was increased by 50ms if the response was withheld and decreased by 50ms when it was not. The Stop Signal Reaction Time (SSRT), the time participants need to inhibit their predominant response after hearing the stop signal, is an often used measure of inhibition. This measure can be derived by subtracting the mean SSD from the mean RT. A longer SSRT therefore indicates decreased inhibition. During the first practice session, participants received no feedback, while during the second practice session, participants received 4 types of feedback: (1)'correct' when responding correct to a go or stop signal, (2) 'false' when pressing the wrong button, (3) 'respond faster' when responding too late, (4) 'you did not have to respond' when responding to a stop signal. During the experimental session, participants received only 2 types of feedback: (1) 'respond faster' when responding too late and (2) 'you did not have to respond' when responding to a stop signal. The experimental session was divided into four blocks, hence, participants had the opportunity to pause.

Attention was measured with the Useful Field of View (UFOV). This test consists of three subtests assessing participants' visual processing speed (UFOV1), divided attention (UFOV2) and selective attention (UFOV3; Ball et al., 1993). UFOV-total (i.e., the sum of scores on the three subtests) was used as a measure of attention capacity. This test was PC-based, with stimuli presented on a 19-inch monitor and responses made using a computer mouse. This version of the UFOV has been shown to be both reliable and valid (Edwards et al., 2005). Scores are expressed in milliseconds, representing the exposure duration required for an observer to perform at an accuracy level of 75%. For each subtest, possible scores range from 16.7ms to 500ms. Lower scores, correspond with improved attention.

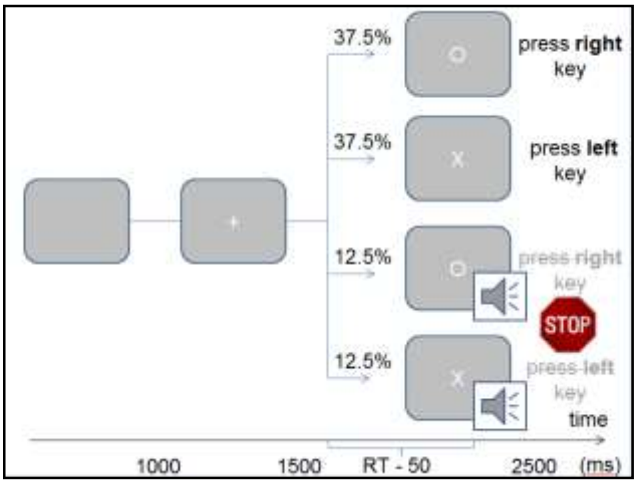

Figure 1: Diagram illustrating the applied auditory stop signal paradigm. On the diagram RT - 50 ms value is indicated for the delay of the auditory stimulus (SSD). However, this only illustrates the initial setting; as described in the text this interval varied during the task based on the stopping performance.

3.2.2.3. Inhibition training

A visual SST was used to train inhibition, see Figure 2 for a visualization of the training. 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 given two days to complete each session. If they did not complete a session in time, it was marked as missed, and participants moved on to the next session. In total, participants were allowed to miss a maximum of 5 sessions. Hence, the total number of session varied between 20 and 25. A one-day session consisted of 12 blocks, and each block consisted of 32 trials. In 75% of the trials, participants were required to press a button (left or right) as quickly as possible in response to a go stimulus (blue, green, purple or black colored arrow pointing left or right) presented centrally on screen (go trials). In each trial, after 1000ms, a fixation cross was presented for 500ms. After this, a stimulus was presented for 1000ms. In 25% of the trials, a go stimulus was replaced by a stop signal (i.e., red colored arrow pointing left or right). Upon presentation of this stop signal, the participant needed to refrain from responding to the stimulus on that trial (stop trials).

The first block of each session served to determine the individual's mean RT, which was used as a reference for the subsequent blocks. Importantly, to serve as a training task, the task became more difficult if participants showed an improvement in inhibition. The level of difficulty was determined by the Stop Signal Delay (SSD; i.e., the time interval between the stimulus and the stop signal), with higher levels of difficulty corresponding to a higher SSD.

The SSD was initially set (i.e., level 0) at 0ms after stimulus onset. In level 1, the SSD was 50ms after stimulus onset. In level 2, it was 250ms before the mean RT. In level 3, it was 200ms before mean RT. In level 4, it was 150ms before mean RT. From level 5 onwards, the SSD decreased with 25ms before mean RT, ending at level 9 with a SSD 25ms before mean RT.

After each block, it was determined whether the level would increase, decrease, or remain the same. Participants could reach a higher level when in a block they had maximum 3 misses (i.e., no response on go trial) or false responses (i.e., press wrong button on go trials) on go trials and maximum 1 unsuccessful inhibition (i.e., response on stop trial) on stop trials. In case participants did not fulfill these criteria in one block, they remained on the same level. When they did not fulfill these criteria in the next block, their level decreased by one. Participants received 3 types of feedback: (1) 'respond faster' (120ms after average RT) when responding too late, (2) 'false' when pressing the wrong button, and (3) 'you did not have to respond' when responding to a stop signal.

Participants in the active control condition could reach a maximum level of 2, while participants in the experimental condition, could reach a maximum level of 9. In addition, participants in the active control condition, started each session at level 0, while participants in the experimental condition, started each session at the level of the previous session.

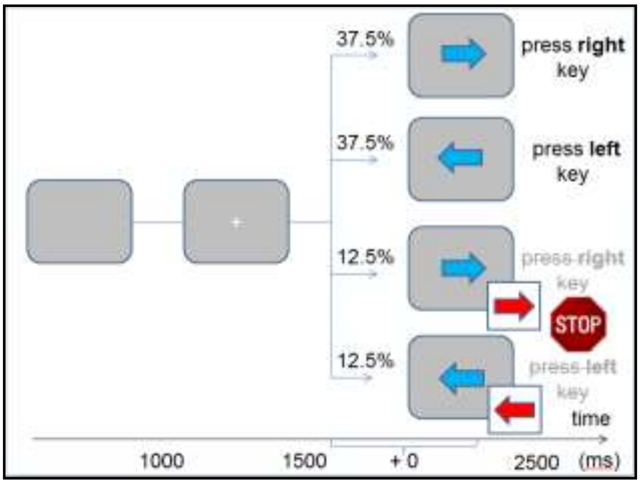

Figure 2: Diagram illustrating the applied visual stop signal paradigm. On the diagram + 0 ms value is indicated for the SSD. However, this only illustrates the initial setting (level 0); as described in the text this interval varied during the training based on the stopping performance. In addition, this figure only illustrates the blue colored go stimulus; as described in the text, the go stimulus had several colors.

3.2.3. Procedure

Participants first had to give their consent. After successful completion of the pre-test, participants were randomly assigned to either the experimental condition (n=22) or the active control condition (n=20). During the pre-test, participants in both conditions conducted the cognitive tasks (i.e., UFOV, SST) and driving task. A demo of the inhibition training was given, to ensure that participants understood the training. After the pre-test, participants completed the inhibition training, according to their condition, for maximum 25 days. During the post-test, participants of both conditions again conducted the cognitive tasks and driving task. At the completion of the study, participants received a €25 gift certificate as remuneration for their participation. Order of the cognitive tasks was counterbalanced between participants during the pre- and post-test.

3.2.4. 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). In addition, for the auditory SST task exclusion criteria were derived from Congdon et al. (2012). Participants were excluded if they had a percentage of correct trials less than 60%, a percentage of false trials more than 10%, a percentage of successful inhibition less than 25% or more than 75% and an SSRT lower than 50 ms.

Univariate analyses of variance (ANOVA) were conducted to check whether there were significant differences between the two conditions at pre-test on demographic measures, cognitive measures and driving measures.

To verify if there is a relation between cognitive and driving ability in order to answer the first aim of the present study, bivariate Pearson correlation analyses were conducted between inhibition (i.e., SSRT on the auditory SST) on the pre-test and performance on the attention and driving measures during pre-test.

To investigate the effect of the training on cognitive and driving ability in order to answer the second aim of the present study, repeated measures ANOVA were conducted for each of the dependent measures. For cognitive ability, SSRT and UFOV-total served as separate dependent variables. For driving ability, the specific driving measures served as separate dependent variables. In the ANOVA, Measurement (i.e., pre-test, post-test) served as within-subjects variable and Condition (i.e., active control condition, experimental condition) served as between-subjects variable.

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.

3.3. Results

3.3.1. The relation between inhibition and cognitive and driving ability

Pearson correlations between auditory SSRT and attention, and between auditory SSRT and driving ability on pre-test are presented in Table 1. For attention, there was a significant correlation, indicating that an increased inhibition corresponds with an improved attention. For the driving measures, there was a marginally significant correlation with SDLP (p=.09) and crashes (p=.05), indicating that an increased inhibition corresponds with improved lateral control and less crashes.

Table 1: Bivariate Pearson correlation between inhibition and cognitive and driving ability at pre-test.

Attention/driving measure	SSRT
UFOVtotal	.38*
Mean driving speed	-.20
SDLP	.28
Gap acceptance	.23
Complete stop	.23
Giving right of way	-.12
Crashes	.31

*<.05, **<.01

3.3.2. Differences at pre-test

See Table 2 for the descriptive statistics of the demographic, cognitive and driving measures in the active control condition and the experimental condition, for the pre-test and post-test. At pre-test, participants in the two conditions did not significantly differ on the demographic, cognitive or driving measures.

Table 2: Means and standard deviations for the dependent cognitive and driving measures.

Measure	Pre-test		Post-test	
	Active control condition	**Experimental condition**	**Active control condition**	**Experimental condition**
Demographic measures	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	74.85 (5.62)	73.14 (6.60)	n.a.	n.a.
MMSE (number)	28.95 (1.15)	28.68 (0.95)	n.a.	n.a.
Cognitive measures	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
SST (ms)	209.21 (55.24)	193.70 (41.14)	172.83 (44.20)	177.93 (53.51)
UFOV-total (ms)	260.74 (124.39)	289.24 (163.18)	190.16 (103.60)	222.52 (169.92)
Driving measures	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Mean driving speed (km/h)	39.92 (4.10)	41.22 (7.34)	40.85 (5.04)	41.20 (5.36)
SDLP (m)	.17 (.04)	.16 (.04)	.17 (.04)	.16 (.03)
Gap acceptance (s)	6.56 (1.64)	6.82 (1.50)	6.14 (1.43)	6.00 (1.16)
Complete stops at stop signs (0= no/1 = yes)	0.45 (0.39)	0.59 (0.43)	0.48 (0.47)	0.59 (0.40)
Giving right of way (0 = no/1 = yes)	0.75 (0.30)	0.77 (0.26)	0.80 (0.25)	0.80 (0.30)
Crashes (number)	0.49 (0.72)	023 (0.43)	0.27 (0.64)	0.27 (0.46)

3.3.3. Manipulation check

Participants in the experimental condition completed an average of 23.05 training sessions (SD=2.32), and participants in the active control condition completed an average of 23.63 training sessions

(SD=1.64). In the active control condition, participant could not reach a level higher than 2. Consequently, the observed performance of those participants remained at a level lower than 2 over the course of the training period. In contrast, in the experimental condition, participants could reach a maximum level of 9. Consequently, the observed performance of those participants reached a higher level than 2. Figure 3 provides a visualization of performance during the training period. Although the performance of participants in the experimental condition increased during the training period, improvements were small.

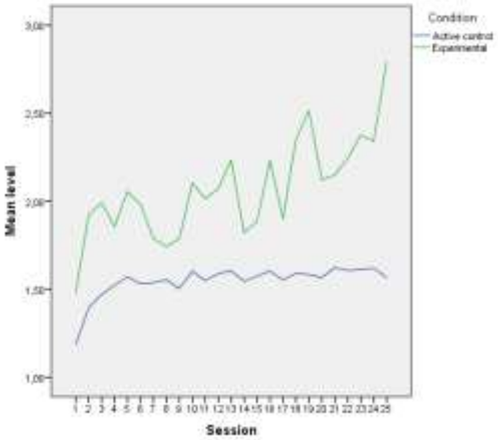

Figure 3: Mean level of participants at the end of each session per condition.

3.3.4. Training effects

See Table 3 for the results of the repeated measures ANOVA for the cognitive and driving measures. Regarding cognitive ability, there was a significant main effect of Measurement for the inhibition task and attention task, indicating that in comparison to the pre-test participants of both conditions had an improved inhibition and attention during the post-test. For the inhibition task, Cohen's d was 0.54, indicating a medium effect size. For the attention task, Cohen's d was 0.48, indicating a small effect size.

Regarding driving ability, there was a significant main effect of Measurement for gap acceptance, indicating that during the post-test participants of both conditions accepted smaller gaps than during pre-test. Cohen's d was 0.41, indicating a small effect size.

Table 3: Corrected F and probability values per dependent cognitive and driving measure.

Cognitive measure	***F***	***P***
SST		
Measurement	11.67	.002**
Measurement x condition	1.82	.19
Condition	0.12	.73
UFOV-total		
Measurement	12.78	.001**
Measurement x condition	0.01	.92
Condition	0.54	.47
Driving measure	F	P
Mean driving speed		

Measurement	0.21	.65
Measurement x condition	0.22	.64
Condition	0.34	.57
SDLP		
Measurement	0.03	.87
Measurement x condition	0.73	.40
Condition	0.88	.36
Gap acceptance		
Measurement	7.18	.01**
Measurement x condition	0.77	.39
Condition	0.02	.89
Complete stop at stop signs		
Measurement	0.03	.86
Measurement x condition	0.03	.86
Condition	1.32	.26
Giving right of way		
Measurement	0.39	.54
Measurement x condition	0.06	.82
Condition	0.02	.89
Crashes		
Measurement	0.52	.48
Measurement x condition	1.23	.28
Condition	1.01	.32

3.4. Discussion

This study aimed to investigate in older drivers (1) the relation between inhibition and cognitive ability, and the relation between inbhition and driving ability, and (2) whether a computerized home-based inhibition training can improve cognitive ability and driving ability. The findings will be discussed, separately for the two aims.

3.4.1. The relation between inhibition and cognitive ability and driving ability

The relation between inhibition and cognitive ability and the relation between inhibition and driving ability was investigated during pre-test. An increased inhibition corresponded with an increased attention. This transfer can be explained by a dual-process model of selective attention which includes both the selection of relevant information and the inhibition of irrelevant information (Posner and Snyder, 1975). Previous research also indicated that a decrease in inhibition is related to a decrease in selective attention (McDowd and Filion, 1992).

With regard to driving ability, an increased inhibition corresponded marginally significant with a decreased SDLP and crashes. These results add to the existing literature by showing for the first time that higher inhibition is related, not only to a summarized measure of driving ability (Daigneault et al., 2000), but also to some specific measures of older drivers' driving ability (i.e., SDLP and crashes). Moreover, it replicates previous recent research with younger drivers (Jongen et al., 2011; Jongen et al., 2012; Ross et al., 2014).

3.4.2. The effect of an inhibition training on cognitive ability and driving ability

The effect of an inhibition training was investigated on a comparable inhibition task and an untrained attention task and driving task. With regard to cognitive abilities, results indicated that all participants had an improved inhibition and attention at post-test compared to pre-test. Since inhibition was the cognitive function being trained, it is not surprising that inhibition improved after following the training. Also the improvement of attention is maybe what we could have expected since results of the first aim indicated that an improved inhibition corresponds with an improved attention. These results add to the existing literature by showing for the first time for older people that a training of inhibition can improve inhibition and that this improvement transfers to an improved attention.

With regard to the driving task, results indicated that all participants accepted smaller gaps to turn left at post-test compared to pre-test. Possibly, at post-test people choosed smaller gaps, since they needed to compensate less for their decline in cognitive abilities, because their cognitive abilities were improved at post-test. Research has indicated that older drivers choose large gaps when turning left in order to compensate for the decline in cognitive abilities (Alexander et al., 2002; Fisher et al., 2011; McKnight, 1988). Although results of the first aim indicated that an improved inhibition corresponds marginally significant with an improved lateral control and less crashes, there was no effect of the training on these driving measures.

Surprisingly, although we expected only improvements of cognitive ability and driving ability in the experimental condition, similar improvements occurred in the active control condition. This is not surprising if we look at the mean level that was reached during the training by both conditions. Although the mean level was significantly higher for the experimental condition, the difference was small. Therefore, in our opinion, it is possible that a training with a limited difficulty level (i.e., level 2) is sufficient to achieve cognitive improvement in older adults being 65 years or older. However, a no-training control condition is necessary to discriminate between a genuine training effect and test-retest effect.

Interestingly, in a previous study we investigated the effect of a working memory (WM) training on WM and driving ability of older drivers. In that study participants were assigned to an experimental condition who received an adaptive WM training (WM span up to 15) or an active control condition who received a non-adaptive WM training (WM span of 3). We found that participants improved on WM and four measures of driving ability (i.e., speed control, gap acceptance, lateral control and crashes). As in this study, we found improvements for both the experimental as the active control condition. So although the present inhibition training did not succeed in improving the majority of the investigated driving measures, an inhibition training with a low difficulty level seems sufficient to improve aspects of cognitive ability of older people (i.e., inhibition and attention). In sum, it seems that, the inhibition training at least improves cognitive abilities like inhibition and attention, but does not transfer to many aspects of driving ability (with the exception of gap acceptance). This is in line with the criticism that cognitive training can improve cognitive abilities, but that transfer effects to daily life activities such as driving are often missing (Mayhew et al., 2014; Reijnders et al., 2013).

3.4.3. Implications

Based on the present results, inhibition seems to be related to a measure of lateral control and crashes. Therefore, it is important that people who have problems with lateral control and/or had several recent crashes follow interventions for increasing inhibition.

It seems that inhibition in older people can be improved by training of that specific cognitive function. Since according to the inhibitory deficit hypothesis especially inhibition seems to decrease with age, this is an important finding. Moreover, this improvement in inhibition seems to transfer to an untrained task of attention. Hence, it seems possible to counteract or postpone the decline of some aspects of cognitive ability with an inhibition training.

Unfortunately, it seems that the training did not improve driving ability on the majority of the specific investigated driving measures. Possibly, the training has effect on other driving measures where it can be expected that inhibition matters more like detection of and reaction to road hazards, since previous research with younger drivers found a relation between inhibition and these driving measures (Jongen et al., 2012; Ross et al., 2014). It can also be expected that inhibition is more related to risky driving behaviors like speeding and yellow light running. However, these are uncommon events in older drivers (Eby et al., 2009; West, 2010).

Surprisingly, although inhibition was related to SDLP and crashes, the training did not improve these driving measures. The lack of training effects can be due to the particular training used in the present study or that these driving measures cannot easily be improved by a cognitive training. The training used was a modified version of a context-general stop signal task. Future research should investigate the effect of other types of inhibition training. For example, instead of using a stop signal task, a modified version of the go/no-go task could be used. Previous research found transfer effects to health behavior with this type of training (Houben et al., 2011; Houben and Jansen, 2011). Moreover, in this study a context-general inhibition training was used. Guerrieri et al. (2012) also used a context-general inhibition training and like us, found no transfer to daily life activities (i.e., eating behavior). Previous research used a context-specific inhibition training and did found transfer effects to daily life activities (i.e., drinking and eating behavior; Houben, 2011; Houben et al., 2011; Houben and Jansen, 2011; Jones and Field, 2013). According to the law of identical elements and the practice-specificity approach of learning abilities, the best training conditions are those allowing the learning of the same underlying processes that will be used in the transfer task (Schmidt and Lee, 2005; Thorndike and Woodworth, 1901). Therefore, if the benefits are to transfer to driving ability, they must be acquired in a driving-specific context. Hence a training more directly targeting driving ability will have more effect. Recent studies also indicated that a context-specific training might be more successful in improving driving ability (Gaspar et al., 2012; Mayhew et al., 2014). For instance, recent research has investigated the effect of a simulator-based training and found promising effects immediately after training (Casutt et al., 2014; Lavallière et al., 2009; Romoser and Fisher, 2009), as well as several years later (Romoser, 2012).

3.4.4. Limitations and future research

Several limitations need to be addressed. First, the present study only investigated immediate training effects. Future research should investigate the durability of these effects and whether booster sessions are needed to improve or maintain effect over an extended period of time. Recently, it was indicated that initial training effects of a speed-of-processing were maintained over 5 years amplified by booster sessions (Ball et al., 2013). Also related to the impact of training dosage, the training investigated here consisted of 25 sessions. However, previous research has found promising effects of an inhibition training consisting of solely 1 session (Houben, 2011; Houben et al., 2011; Houben and Jansen, 2011).

Secondly, the training investigated here was conducted via the internet at home. Although this has several advantages, it diminishes experimenter control compared with the control possible in laboratory-based research using a standard testing environment and standardized testing procedures.

Finally, the possibility of a self-selection bias has to be kept in mind. Especially those drivers that think of themselves as good drivers will volunteer to participate in a study investigating driving ability. Future research should investigate the effect of the training on other groups. For instance, people with cognitive disturbances like dementia, since they have larger decreases in inhibition compared to healthy people (Amieva et al., 2004) or young people who typically are more involved in risky driving like speeding (Eby et al., 2009). Interestingly, recent research has indicated that young drivers are more vulnerable for speeding in the presence of peers when they have a decreased level of inhibition (Jongen et al., 2013).

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4. The effect of a driving simulator based training on specific measures of driving ability of older drivers: the role of feedback.

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Summary

This study aimed to investigate in older drivers whether a driving simulator based training would enhance driving ability. 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 active control (N=15) or an experimental condition (N=15). Participants in the control condition received general information about traffic and conducted a quiz, while participants in the experimental condition received feedback on their driving ability. During the pre-test and post-test, driving ability was assessed. Results indicate that the training lead to an improvement of some measures of driving ability. These findings will be discussed.

4.1. Introduction

The number of older drivers is increasing. Previous research indicates that older drivers have problems with some driving situations, e.g., giving right of way at intersections (Eby et al., 2009). 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. Training could serve this purpose. Several studies have investigated the effect of a cognitive training on driving ability of older people since cognitive abilities are important for driving ability and even people with an advanced age, have considerable plasticity in their cognitive functioning (Kramer and Willis, 2002). These 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) and even driving ability (Ball et al., 2010; Ball et al., 2013; Cassavaugh and Kramer, 2009; Edwards et al., 2009a,b; Roenker et al., 2003). However, the number of studies showing transfer effects from cognitive training to driving ability is limited. As a consequence, there is debate about the (transfer) effects of a cognitive training (Melby-Lervåg and Hulme, 2013; Shipstead et al., 2012). Several studies found improvement on the trained tasks after following a cognitive training, but not on untrained tasks (Gaspar et al., 2012; Lange and Süb, 2015; Mayhew et al., 2014; Zinke et al., 2012). 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 and Lee, 2005; Thorndike and Woodworth, 1901). Therefore, if the benefits are to transfer to driving ability, they must be acquired in a driving-specific context. Hence a training more directly targeting driving ability will have more effect. Recent studies also indicated that a context-specific training might be more successful in improving driving ability (Gaspar et al., 2012; Mayhew et al., 2014). For instance, recent research has investigated the effect of a simulator-based training for older drivers and found promising effects on driving ability immediately after training (Akinwuntan et al., 2005; Casutt et al., 2014; Lavallière et al., 2009; Romoser and Fisher, 2009), as well as several years later (Devos et al., 2010; Romoser, 2012).

The aim of the present study was to investigate whether a driving simulator training leads to an improvement of driving ability in older drivers. More specifically, we wanted to investigate the value of customized feedback. Based on previous research as mentioned above, we hypothesized that the driving simulator training would improve driving performance on specific measures like speed, lateral control and giving way. Since both conditions actively trained in the simulator, we expected improvements in both conditions, however, we expected larger improvements in the experimental condition since they received customized feedback prior to the simulator sessions.

4.2. Method

4.2.1. 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. In total, forty participants volunteered. However, ten participants dropped out due to simulator sickness or personal circumstances (i.e., hospitalization). Participants had a mean age of 69.93 years and on average had an MMSE score of 28.80. Participants were randomly assigned to an active control (N=15) or an experimental condition (N=15).

4.2.2. Driving simulator scenario

The experiment was conducted on a mobile 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 4800 x 900 pixels resolution and 60Hz refresh rate). STISIM version 3 was used as software. Two practice rides preceded the main ride to get acquainted with the driving simulator. 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 a lane change to pass a road obstacle was introduced to acquaint drivers with the experience of driving in a simulator (i.e., steering, signal use, looking behavior).The main ride (11 km) included several situations that are known to be difficult for the older driver, for example right of way decisions (i.e., making a complete stop at a stop sign and giving right of way). In this scenario, situations that were trained during the training session were included. Both exactly the same as comparable situations were included in order to investigate both the near and far transfer effect of the training. The situations were presented in the scenario in a randomized fashion. The ride consisted of inner-city (50 km/hour) segments and outer-city segments (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).

A total of five 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) and giving right of way (yes or no).

4.2.3. Driving simulator training

During the training session, participants of the experimental condition viewed a playback movie of their own drive that they made during the pre-test. During this movie, they received both reinforcing and corrective feedback from the researcher tailored to the participant's (un)safe driving behavior during specific situations. In addition, they saw a playback movie of the same drive including commentaries from a driver instructor. These were comments on how to react best in the specific driving situations. In contrast, participants of the active control condition viewed a presentation consisting of general information about traffic. Afterwards, they filled in a quiz about traffic. At the end, they viewed a presentation with the correct answer on the questions of the quiz together with a brief explanation. Finally, participants of both conditions drove in the driving simulator, hence participants of both conditions had equal experience in the driving simulator. All participants drove 4 scenarios of 2.5 km each. One scenario focused on training intersections (i.e., turning left, giving right of way, and making a complete stop at a stop sign), while another scenario focused on training reactions to hazards (i.e., obstacle, and sudden event). Each scenario had two levels of difficulty (i.e., a low difficulty level without other road users and a high difficulty level with other road users). The training was conducted in the lab.

4.2.4. 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 variance (ANOVAs) were conducted for each of the dependent measures. In the ANOVA for driving ability, the driving measure served as the dependent variable, Measurement (i.e., pre-test, post-test) and Transfer (i.e., near transfer, far transfer) served as within-subjects variable and Condition (active control condition, experimental condition) served as between-subjects variable. In the ANOVA of two driving measures (i.e., mean driving speed and SDLP) speed limit (i.e., 50km/h, 70 km/h, and 90km/h) served as an additional within-subjects variable. For one driving measure (i.e., crashes) the within-subjects variable Transfer 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.

4.3. Results

There was a significant main effect of Measurement for SDLP ($F(1,28)=9.12$, $p=.005$) and crashes ($F(1,28)=24.49$, $p<.001$), indicating that participants had an improved lateral control and had less crashes after the training. Cohen's d was 0.74 for SDLP, indicating a medium effect size, and 1.09 for crashes, indicating a large effect size. In addition, there was a significant interaction between Measurement and Condition and Transfer for mean driving speed ($F(1,14)=6.03$, $p=.03$), indicating that participants in the active control condition drove faster after the training at segments measuring far transfer. Cohen's d was 0.14, indicating a small effect size. In addition, there was a significant interaction between Measurement and Condition and Transfer for giving right of way ($F(1,14)=12.25$, $p=.004$), indicating that participants in the experimental condition gave more right of way after the training at segments measuring far transfer. Cohen's d was 1.29, indicating a large effect size.

4.4. Conclusion

This study aimed to investigate whether a driving simulator training leads to an improvement of driving ability in older drivers. The results showed that there was an improvement of SDLP and crashes after the training in both conditions. In addition, the results showed that there was an improvement of mean driving speed in the control condition and of giving right of way in the experimental condition after the training on segments measuring far transfer. Surprisingly, the customized feedback only had an effect on giving right of way. Driving actively in a simulator seems to be sufficient to have an effect on lateral position and crashes. However, it is possible that these improvements are due to a learning effect (performing the task for the second time) instead of a training effect. Therefore, it is necessary to collect additional data of a no-training control condition. In case improvements are due to the training, the training might serve as a method to remediate deficits of some aspects of driving ability in the elderly. Future research is then necessary to investigate the duration of these training effects.

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