Investigating the influence of working memory capacity on driving behavior when combined with cognitive load: an LCT study of young novice drivers.

Veerle Ross[1], Ellen M. M. Jongen[1], Weixin Wang[1] ,Tom Brijs[1], Kris Brijs[1,2], Robert A. C. Ruiter[3] & Geert Wets[1]

[1]Transportation Research Institute – Hasselt University, Belgium [2]XIOS University College, Belgium [3]Maastricht University

BACKGROUND

- **Distraction** refers to any activity that takes the driver's attention away from the driving task. At least 25% of the car crashes in the United States can be related to some form of driver distraction (Young & Regan, 2007) and distracted driving is a worldwide problem (Young & Lenné, 2010). Hands-free technology (e.g., hands-free cell phones) should decrease the impact of secondary tasks on driving (Harbluk et al., 2007). Interference by distraction can however occur directly at the sensory input level (e.g., visual) but also at the cognitive level (Victor et al., 2009). Hands-free technology still induces **cognitive load** and it has been shown that engaging in such activities disrupts driving performance (Nunes & Recarte, 2002). People only have limited capacity to process ongoing activities. Therefore, they can only process a limited amount of information before performance impairment occurs which then leads to an increased crash risk (Rosenbloom, 2006).
- **Working memory capacity (WMC) is related to a person's ability to select goal-relevant information** (Buckner, 2004). The goal-directedness minimizes the influence of distracting stimuli in favor of attendance to task-relevant stimuli (de Fockert et al., 2001). When WM resources are depleted by a secondary task, task-irrelevant information interferes more readily with the primary task and performance deteriorates (Lavie et al., 2004). It can be expected, and has been shown before, that people with higher WM capacity are less susceptible to interference by distraction (Engle, 2010).
- **Visuospatial WM capacity (VSWM)** is responsible for processing and storing visual and spatial information, **verbal WM capacity (VWM)** is responsible for processing and storing auditory and verbal information (Baddely, 2003). Both types of information are processed during driving, thereby requiring both VSWM and VWM.
- In the present study, driving will be combined with a secondary task meant to induce cognitive distraction. More specifically, an **auditory-verbal response N-back** task will be used, which induces verbal cognitive load (Mehler et al., 2011).
- **Young novice drivers** are more susceptible to distraction since they lack spare WM capacity to devote to secondary tasks (e.g., driving requires more effort due to lack of experience; Young & Regan, 2007). Despite their limitations, they are more willing to accept new technologies (e.g., hand-free phone; Neyens & Boyle, 2007) and perceive less risk in using such technologies (Stutts et al., 2005).
- The **lane change task (LCT)** is an efficient and low-cost tool often used to investigate effects of distraction (induced by visuospatial and/or cognitive load) while driving (Harbluk et al., 2007).
- **Although WM capacity was already related to LCT performance, only a limited selection of driving parameters were studied. Furthermore, the interaction between VSWM/VWM and the influence of cognitive load on LCT performance has not been studied before. This interaction is of interest here as it will reflect whether participants with higher WM capacity are less susceptible to increases of cognitive load.**

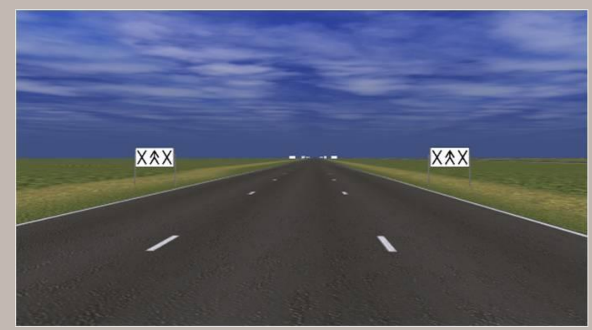
AIM & HYPOTHESES

Aim: To investigate, for young novice drivers (n= 51; mean age 19.42), the influence of WMC on LCT performance when combined with cognitive load. **Hypotheses**: 1) Cognitive load will impair driving performance; 2) Increased WMC will be related to superior driving performance; 3) Driving performance of participants with high WMC will be less degraded when cognitive load is increased. Due to the secondary task's auditory-verbal nature, higher VWM is expected to become more important when cognitive load is increased.

LANE CHANGE TASK (LCT)

•LCT Sim v1.2, developed by Daimler AG

•Three-km road tracks with 18 lane change signs



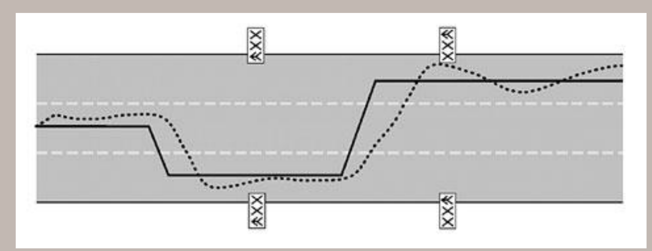
•Six tracks:

- •1-2: training
- •3: baseline
- •4-6: combined with the auditory-verbal N-back with increasing complexity (counterbalanced among participants)

•Instruction:

- •Change lanes immediately when you recognize the information on the sign. The change should be in a deliberate manner; as quickly and as efficiently as possible and should be completed before reaching the sign.
- •For track 4-6: balance your effort between both tasks, both are equally important.

•Dependent measures: mean deviation (MDEV), lane change initiation (LCI) and percentage correct lane changes (PCL)



DISTRACTION

Auditory-verbal response N-back WM task (Mehler et al., 2011).

•Resembles distracting tasks such as cell phone conversations → demands temporary storage and manipulation of information

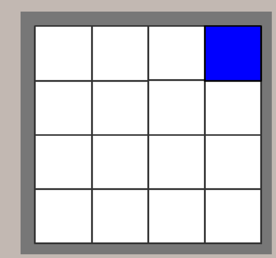
•Numerical values 0-9

•3 complexity levels

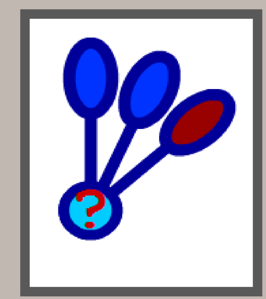
- •0-back: repeat out loud the last number that you heard
- •1-back: repeat out loud the number before the last number that you heard
- •2-back: repeat out loud the number that you heard two numbers ago

WMC TASKS

•Visuospatial WM capacity: **Visuospatial Span (VS)**



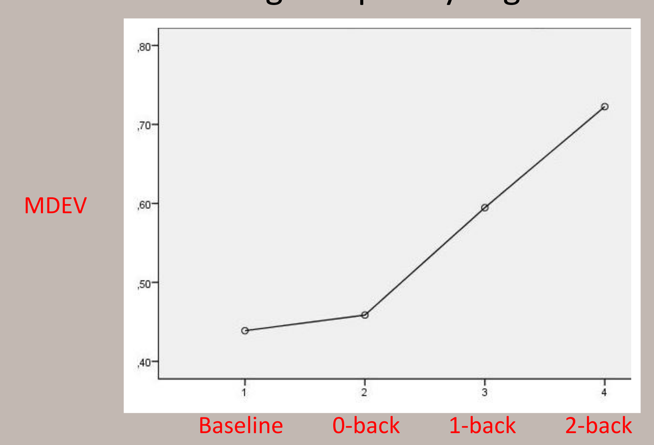
•Verbal WM capacity: **Letter Span (LS)**



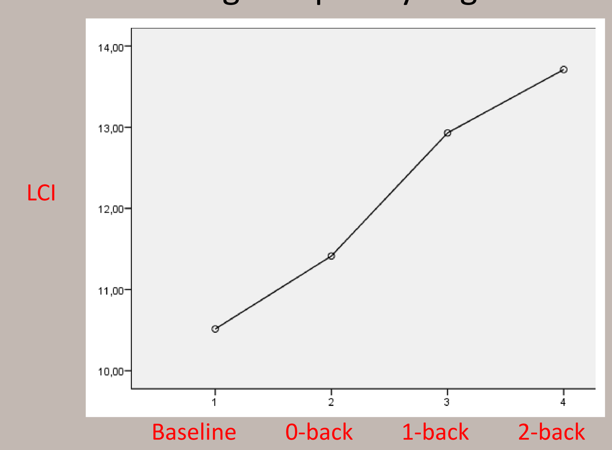
RESULTS

1) Cognitive load impairs driving performance

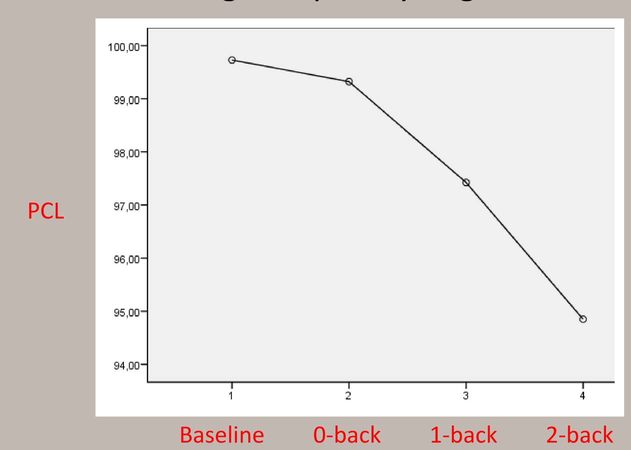
MDEV: more deviance from normative model with increasing complexity cognitive load



LCI: lane changes are initiated more slowly with increasing complexity cognitive load



PCL: more erroneous lane changes are made with increasing complexity cognitive load

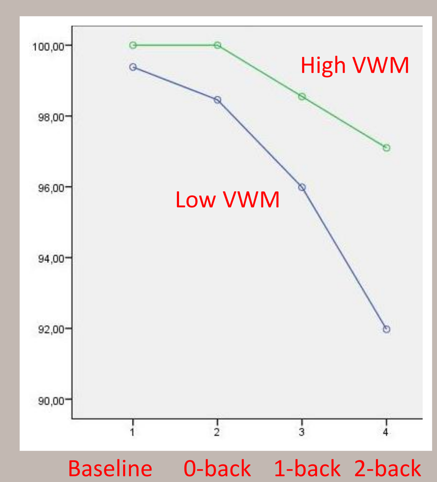


2) Increased WMC is related to superior driving performance

•VSWM:
- •Negative relation: **MDEV**
- •Positively relation: **PCL**

•VWM
- •Negative relation: **MDEV**
- •Negative relation: **LCI**

3) PCL performance was affected less in those with increased VWM



•Negative impact of cognitive load on both groups

•Difference between groups is significant at the 1- and 2-back level

DATA ANALYSIS

• **Exploratory** analyses to identify outliers per cognitive load level, and per dependent measure.

•**Repeated measures ANOVA** on the secondary task to test if the distraction was effective.

•**Repeated measures ANCOVA** to asses: 1) if cognitive load had detrimental effects on LCT driving behavior (main effect cognitive load); 2) if WMC was positively related to LCT driving behavior (main effect WMC); 3) if the effect of cognitive load on driving behavior was dependent on WMC (interaction effect cognitive load * WMC). Separate models were analyzed per dependent measure. Outliers were removed from the relevant analyses

DISCUSSION

•Replication of previous research:

- •**Cognitive load degraded LCT performance** :
  - • With increasing load , participants deviated more from the normative model (**MDEV**), reacted slower to signs (**LCI**) and made more erroneous lane changes (**PCL**) (Harbluk et al., 2007; Engström & Markkula, 2007).
- •Participants with **higher WMC showed less overall deviation from the normative path** (Mäntylä et al., 2009).

•Extension of previous research:

- •The results support multiple recourse theories (Wickens, 2008) since **VSWM /VWM influenced driving performance independently.**
- •It was shown for the first time that **participants with higher WMC initiated lane changes faster (LCI) and made more correct lane changes (PCL).**
- •Most importantly, this study for the first time showed that **participants with a higher VWM were less influenced by increasing load complexity**, as reflected by a **smaller decrease of correct lane changes (PCL)** in people with high (versus low) VWM when load increased. Due to increasing verbal load, VWM could alleviate detrimental effects on driving performance. Which also provides support for multiple resources theories (Wickens, 2008).
  - • Coincides with theories and findings that the availability of more WMC leaves room for greater abilities to employ attention in order to avoid distraction (de Fockert et al., 2001).

IMPLICATIONS

•**Training WMC could lead to overall better driving performance**. Importantly, it might even, at least for some driving parameters, lead to **superior coping with distraction**.

•**WMC could be used to screen young novice drivers** for the necessity of training. For instance in combination with a driver learning program as graduated driver licensing (GDL).

•Nonetheless, the degrading effect of distraction by cognitive load in this study, for both low and high WMC participants, clearly indicates the **need to try to eliminate distraction while driving as much as possible**.

LIMITATIONS

Is the LCT transferable to real-life driving? It only requires lane changes over a constant time period; not other driving tasks are required. The instruction to change lanes in a deliberate manner may not resemble daily driving conditions. However, the LCT has been proven a valid way for measuring distraction effects (Engström & Markkula, 2007) and lane keeping and detection measures resemble necessary functions for real-life driving.

Contact information: Veerle Ross, Hasselt University, Transportation Research Institute (IMOB), Wetenschapspark 5 bus 6, 3590 Diepenbeek, Belgium – Tel. +32 11 26 91 08 – email: veerle.ross@uhasselt.be