University of Groningen

Driving slow motorised vehicles with visual impairment

Cordes, Christina

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2018

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
Cordes, C. (2018). *Driving slow motorised vehicles with visual impairment: An exploration of driving safety*. University of Groningen.

CHAPTER 6

The Driving Simulator Versus On-road
Assessment: Exploring Validity

Introduction

Driving simulators are valuable tools in research on driver behaviour and traffic safety (cf. Brookhuis & De Waard, 2010). They have a number of advantages over on-road assessments, for example, they allow complete experimental control, they provide a safe traffic environment, they permit standardisation to be established, and they can facilitate an in-depth analysis of diverse driving parameters. Particularly for vulnerable and at-risk drivers, driving simulators offer a valuable opportunity to investigate driving performance both in research and in clinical practice. However, one drawback of driving simulator research is the transferability and predictability of the outcomes to real-life situations, in other words, its validity.

There are many different forms of driving simulators, all of which aim to resemble real on-road driving and do so to varying degrees. How realistic driving simulators are is dependent on numerous factors such as projection size, vestibular input, mock-up, the virtual environment and its projection resolution amongst other things.

Different forms of driving simulator validity can be distinguished (Mullen, Charlton, Devlin, & Bédard, 2011). Face validity simply indicates that an assessment with a clear purpose measures what is intends to measure. Behavioural validity describes the extent to which performance in a driving simulator reflects the same performance in an on-road situation. This validity can be divided into absolute and relative validity. Absolute validity refers to when exactly the same outcomes between two situations occur and is rarely established. In contrast, a driving simulator has relative validity if an effect in the simulator goes in the same direction or is of similar magnitude than in reality. This type of validity is often used in research and a number of studies have established relative behavioural validity for different driving simulator parameters (De Waard & Brookhuis, 1997; Lee, 2003; Lew et al., 2005; Piersma et al., 2016; Veldstra, 2014).

Most research on driving simulator validity is based on groups of healthy participants, which might potentially present problems if this validation is applied to people with impairments. Research has shown that the less competent the driver, the less valid driving simulators are as a research tool (Mullen, Charlton, Devlin, & Bédard, 2011). Special care has to be taken if a driving simulator is used as a screening instrument to establish practical fitness-to-drive in impaired individuals or to decide whether a person should get a driving licence or not. In these cases, high behavioural

validity of the driving simulator is crucial. Lew et al. (2005) studied the predictability of a driving simulator training programme in patients with traumatic brain injury and showed that the simulator was an ecologically valid task to predict driving performance in the long term. An advantage of driving simulators compared to on-road driving assessments is a better test-retest reliability. Even though on-road assessments are seen as the golden standard in assessing practical fitness-to-drive, i.e. have higher face validity, conditions are challenging to control, making it difficult to compare performances between individuals and between trials. In some countries (e.g., Sweden) roads might be too quiet to offer an on-road assessment that reflects the real complexity of the driving task. In such countries, well-established driving simulators might be a robust alternative to an on-road assessment. In addition, on-road assessments are usually evaluated by different driving instructors where high interrater-reliability is not always guaranteed. Due to the shortcomings of on-road assessments, driving simulators may therefore add valuable information.

The advanced microcar and mobility scooter simulator developed for the project Mobility4All used the existing set-up and technology of the UMCG driving simulator (e.g., same mock-up for microcar simulator, lane keeping drives), which has been used for clinical and scientific purposes in recent years (e.g., Brouwer, Busscher, Davidse, Pot, & Van Wolffelaar, 2011; Dotzauer, 2014); Fitness-to-drive assessments on behalf of the Dutch Driving Licence Authority). Thus, many features of the driving simulator used in the present project have been demonstrated to be valid and reliable. However, new virtual environments, different driving conditions (e.g., restricted speeds) and a new mock-up for the mobility scooter driving simulator make further analyses necessary. Since the simulator was used for research purposes, the relative validity of the simulator was investigated in the following. More specifically, performance in the simulator was compared to performance in the mobility scooter on-road test and the individual predictability of the driving simulator in terms of on-road driving performance was explored. In order to be able to use similar parameters, driving performance was operationalised as the number of collisions in the driving simulator compared to the number of critical events in the on-road mobility scooter driving test. A high relative validity of the driving simulator would mean that participants who have more collisions in the driving simulator also have more critical events in the on-road assessment and vice versa.

Analysis

Since on-road tests are seen as the golden standard in driving safety research in the Netherlands, the outcomes of all driving simulator drives combined (average number of collisions across all simulator drives) were compared to the mobility scooter on-road drive. The correlation between the number of collisions in the driving simulator and the critical events in the mobility scooter on-road test was established, and simulator performance of participants who failed the mobility scooter on-road test was explored in detail. Since simulator sickness contributed to a high rate of drop-out amongst participants, a separate paragraph is devoted to this matter. Visually induced simulator sickness is a common side effect of driving simulators and is similar to motion sickness. Symptoms include dizziness, headaches, drowsiness or nausea, for example and several theories have been put forward to explain the cause of simulator sickness (Stoner, Fisher, & Mollenhauer Jr., 2011). Simulator sickness itself may pose a threat to the validity of the driving simulator task by affecting the individual's driving performance.

Results

Simulator sickness

A major problem that occurred during the driving simulator assessment was the number of people that could not complete the full driving simulator task due to them developing simulator sickness symptoms. More than half of the participants (54.9%) dropped out at some point during the simulator drives (total duration of the simulator drives approximately 50 min). Since it is known that simulator sickness can also influence driving performance and thereby the validity of the driving simulator, the Misery Scale (Bos et al., 2013) was used to assess simulator sickness symptoms and to stop the experiment when a threshold was exceeded (see **Chapter 5**). Although this approach protected both the participants and the validity of the data, it also contributed to the low number of participants that completed all tasks in the driving simulator. There was no significant difference between the drop-out rates between visually impaired participants (57.4%) and normal-sighted controls (51.4%). However, compared to drop-out rates in a similar driving setting (about 40% in older participants and 20% in younger participants; Dotzauer, 2014), the drop-out rate due to simulator sickness was unexpectedly high (Table 6.1). As can be seen, participants with peripheral visual field defects suffered

Table 6.1. Number and percentage of participants per group who experience driving simulator sickness			Very low acuity	Low acuity	Peripheral field defects	Combination	Control
Simulator sickness	yes	Count	5	9	9	8	19
		%	55.6	56.3	64.3	53.3	51.4
	no	Count	4	7	5	7	18
		%	44.4	43.7	35.7	46.7	48.6
$\chi(4) = 0.715$, n.s.							

particularly badly from simulator sickness. However, no significant differences in drop-out rate due to simulator sickness could be found between the different groups.

Apart from the consequences of simulator sickness described above, the high drop-out rate made it challenging to establish a relationship between the driving simulation tasks and the mobility scooter on-road test. Nevertheless, an attempt is made to link the two experiments in the following.

Association between the driving simulation tasks and the mobility scooter on-road test

A moderate positive correlation between the number of collisions in the driving simulator and the recorded critical events in the mobility scooter on-road test was found ($r = 0.347$, $p < 0.05$). Generally, it can be said that driving performance in the driving simulator was similar to the on-road test in terms of number of collisions and critical events. In both the on-road test and the driving simulator task, visually impaired participants showed a higher number of collisions (number of critical events) compared to normal-sighted controls (Table 6.2).

Table 6.2. Percentage collisions/critical events of visually impaired and normal-sighted controls in the simulator/on-road test	Number of collisions/ critical events	Visually impaired (%)	Controls (%)	All participants (%)
Simulator	0	27.6	68.0	46.3
	1	27.6	32.0	29.6
	≥2	44.8	0.0	24.1
On-road	0	24.1	72.0	46.3
	1	34.5	20.0	27.8
	≥2	41.4	8.0	25.9

Predictability of the driving simulator

The failure rate of the mobility scooter on-road test was generally low (n = 5) and the participants who failed all had some form of visual impairment (see **Chapter 4**). Only two out of those five participants completed all simulator drives, two only completed the microcar simulator drives, and one participant did not complete any of the simulator tasks. Table 6.3 shows that with one exception, all participants who failed the on-road drive had more than two collisions in the driving simulator. Those who failed the on-road test (median number of collisions = 1.25) did not have significantly more collisions in the driving simulator compared to those who passed the on-road test (median number of collisions = 0.17; U = 56.0, p = 0.125). However, due to the small sample size, results need to be interpreted with caution.

Table 6.3. Comparisons of the performances of individuals who failed the on-road test and their performances in the driving simulator									
		On-road	Number of collisions driving sim						
Participant	Group	Critical events	MC1[a]	MC2	MSp1[b]	MSp2	MSs1[c]	MSs2	Average per drive
M4A_012	Combined visual impairment	1	X	X	X	X	X	X	X
M4A_032	Peripheral field defect	3	0	0	X	X	X	X	0
M4A_058	Peripheral field defect	2	3	1	1	1	2	3	1.8
M4A_065	Combined visual impairment	2	1	2	0	0	1	0	1.5

[a] MC = Microcar; [b] MSp = Mobility scooter pavement; [c] MSs = Mobility scooter street; x = did not complete drive

Discussion and conclusion

To be able to transfer the outcomes of driving simulator tasks to real life situations, it is important that the validity of the driving simulator is established. In this chapter, the association between the driving simulator tasks and the mobility scooter on-road drive was explored. The results show that the performance between driving simulator tasks and on-road tests are moderately associated. Visually impaired participants performed worse than normal-sighted controls both in the simulator

and in the on-road drive. However, participants who failed the on-road test did not necessarily perform worse in the driving simulator tasks. Whereas the driving simulator is not able to predict driving safety in real-life situations well, participants show a similar driving performance in both settings.

Factors contributing to the association not being stronger between the two tasks could be the large drop-out rate (54.9%) in the driving simulator task or the relatively low rate of failures in the on-road drive (6%). Due to the large amount of missing data it was difficult to explore the relationship between the two tasks. In addition, although it was made sure that participants with simulator sickness symptoms stopped the tasks before symptoms got too severe, we cannot guarantee that the discomfort some participants experienced affected their performance in the driving simulator. One surprising observation was the high drop-out rate in participants with visual field defects. The mismatch between optic flow and vestibular input is often described as a relevant cause of simulator sickness. Since people with visual field defects are exposed to less optic flow due to their restricted visual field, we expected that simulator sickness would be reduced in these people compared to participants with other visual impairment. However, in the present study the opposite effect was found: Participants with visual field defects were more affected by simulator sickness than other visually impaired participants. An explanation for this occurrence could be found in the Postural Instability Theory (Riccio & Stoffregen, 1991) which proposes that simulator sickness occurs when a person attempts to maintain stability in a new environment in which the body has not yet learned strategies to preserve postural stability. Due to their impairment, participants with visual field defects might have moved their head more than other participants to get an overview of the simulator environments, which might have led to less postural stability and therefore more severe simulator sickness symptoms. More research is necessary to tackle the high rate of dropouts in the simulator due to simulator sickness. Although no significant difference was found between the dropout rates of visually impaired and normal-sighted participants, it is remarkable that the incidence of simulator sickness symptoms is unusually high in this patient group. Reasons for this high rate of simulator sickness could be the composition of the virtual environments (urban surrounding creating more optic flow), the task (manoeuvring around obstacles involving a substantial amount of steering and braking), and the individual characteristics of the participants (e.g., older age).

A limitation of this study is that the parameters of the driving simulator tasks and the on-road test were similar but not identical. Whereas the number of collisions was used as a measure for driving safety in the simulator, the number of critical events was used for the on-road test. A reason for this approach was that the number of collisions in the on-road test was negligible, because the test leader intervened to protect the safety of the participants. Critical events were defined as situations in which the test leader stopped the mobility scooter using a remote control, and as situations that were rated as potentially unsafe (see **Chapter 4**).

Another factor that could have weakened the association between the simulator and on-road tasks was the behaviour of the traffic agents in the virtual environment. In the driving simulator, traffic agents were programmed to be "on a collision course" with the participants (i.e. traffic agents adapt their speed according to the driver), thereby creating an slighty unusual environment aimed at increasing chances for collision, whereas in the on-road situation other traffic participants naturally looked to avoid dangerous situations.

This study was the first to investigate driving performance in slow motorised vehicles in a simulated environment, aiming at a high degree of ecological validity. Even though on-road tests might have a higher face validity, they have limitations as well (e.g., less safety, unpredictability of traffic and hence lower reliability). Simulators may be used to assess performance in situations that cannot easily be created in an on-road environment. Furthermore, the simulator tasks in the present study added valuable information to the driving performance of visually impaired individuals (see **Chapter 3** and **4**) and should therefore be seen as a complimentary task to the mobility scooter driving test. Future research should focus on studying approaches to reduce simulator sickness and on further investigating the validity and usability of simulator tasks for establishing practical fitness to drive.