운전자 주의분산 연구를 위한 시뮬레이터와 고속도로 주행 실험 비교 검증

Driving Simulator Validation for Cognitive Distraction Research

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Abstract

운전자 주의분산으로 인한 사고가 지속적으로 증가하고 있으며 심각한 사회문제로 인식되고 있다. 이로 인하여, 주행 중 주의분산 연구가 활발히 진행되고 있지만 위험성으로 인하여 실제 도로 주행에서의 연구는 제한적으로 이루어지고 있다. 그 대안으로 시뮬레이터를 이용한 주의분산 연구가 실제 도로상에서의 실험을 대신하여 수행되고 있다. 그러나, 시뮬레이터의 주행 실험이 실제 도로주행과 유사한 결과를 주는지에 대한 올바른 검증이 선행되어야 한다.

본 연구에서는 실제 고속도로에서의 주행과 운전 시뮬레이터 주행 실험 결과를 비교 검증하고자, 15명의 운전자를 대상으로 37km의 시뮬레이터 주행과 36km의 고속도로 주행 실험 결과를 분석하였다. 그 결과, 인지부하 상황에서 모의주행과 실제 고속도로 주행 간의 운전 행동에 유사성이 있음을 확인할 수 있었다.

1. Introduction

In the last decades, there has been a large increase in the use of driving simulators for driving behavior research in a traffic situation. A large amount of research has demonstrated that simulators are effective tools for research on driving speed (Bella, 2008; Godley et al., 2002), driver visual demand (Essa and He, 2006; Son and Park, 2012), and older driver behavior (Son et al., 2010; Son et al., 2013). However, simulators must have appropriate validity to be useful human factors research tools in terms of absolute and relative validity (Godley et al., 2002; Bella, 2008). Absolute validity means the numerical conformity between behavior while driving on roads and while driving through a simulated road, and relative validity refers to the conformity between effects of different variations in the driving situation (Bella, 2008).

The purpose of this paper was to investigate a validity of the DGIST fixed-base driving simulator for driver's cognitive distraction research by comparing driving performance decrements under cognitively loaded driving conditions in a driving simulator and in the real world.

2. Method

1) Participants

Fifteen participants in their twenties were recruited (M=27.7, SD=3.0). They have been driving for at least three years, have driven more than twice a week, and their health condition was self-reported to be adequate to participate in this field operational test.

2) Experimental setup: an instrumented vehicle

The real world driving experiments were conducted in a full size sedan that is instrumented for collecting time-synchronized data. The DGIST instrumented vehicle consists of six video cameras (two for driver and four for road environment monitoring), high speed and low speed CAN logger, driver gaze tracking system, and physiological measurement system (Park & Son, 2010).

3) Experimental setup: a driving simulator

The simulator experiment was conducted in a fixed-based driving simulator, of which car cab was reproduced using the same OEM interior parts of the instrumented vehicle. STISIM Drive™ software collected driving information including distance, speed, steering, throttle, and braking inputs at a nominal sampling rate of 30 Hz.

4) Cognitive distraction

An auditory delayed digit recall task, so called n-back task was selected to create periods of cognitive demand at three different levels (See details in Son et al., 2011).

5) Procedure

The overall procedure consists of two separate experiments, i.e. simulated driving and on-road driving, in two separate days. In the driving simulator experiment, participants received 10 minutes of driving experience and adaptation time in the simulator. The simulation was then stopped and participants were trained in the n-back task while remaining seated in the vehicle. When the simulation was resumed, participants drove in good weather through 37km of straight highway for about 20 minutes, and participants performed a secondary task at a specified segment. In the on-road experiment, following informed consent and completion of a pre-experimental questionnaire about safe driving (safety protocol), participants were trained in the n-back task again to remind them. Then, participants received about 20 minutes of urban road driving experience and adaptation time on the instrumented vehicle. The highway driving experiment began when a subject was confident in safe driving with the instrumented vehicle. In a main experiment session, participants drove in good weather through 36km of highway for about 20 minutes. They also performed a secondary task at a specified highway segment.

4. Results

The data were analyzed with a two-way repeated-measures ANOVA for driving performance measures including mean speed and steering reversal rate. The effect sizes were calculated using the omega squared (ω^2) statistics (Lakens, 2013). Godley et al. (2002) suggested that if ω^2 is small, e.g. $\omega^2 < 0.01$, non-significant results can be confidently proclaimed to reflect non-differences.

1) Absolute validity

For absolute validation, the data were averaged across three cognitive distraction areas in the real world and simulated driving. As shown in Table 1, cognitively distracted driving speeds were slower in the on-road experiment than the simulator experiment. A repeated-measures ANOVA indicated that the main effect for experiment type, i.e. simulator and on-road, was not significant but an effect size was not small ($F(1,14) = 6.889$, $p = .020$, $\omega^2 = 0.101$).

Steering wheel reversal rates (SRR) under cognitively distracted conditions were very similar in the two experiments (see calculation details in Son et al., 2012). The main effect for experiment type was not significant and there was also a very small effect size to corroborate on this non-significant results ($F(1,14) = 1.168$, $p = .298$, $\omega^2 = 0.005$). Thus, absolute validity was established for the steering wheel reversal rate under cognitive distraction, but the cognitively distracted driving speed was not accepted.

Table 1. Absolute validity for 3 levels of cognitive load

Variable		0-back	1-back	2-back
Speed (km/h)	**Sim**	98.6 (2.5)	96.4 (4.9)	97.5 (4.1)
	Road	95.4 (6.9)	94.4 (4.8)	93.1 (7.9)
SRR (Count /min)	**Sim**	114.1 (26.9)	129.6 (32.4)	134.0 (25.6)
	Road	128.0 (20.9)	134.3 (25.7)	139.3 (28.5)

2) Relative validity

For relative validation, the averaged data for the on-road and simulated driving were divided by the 0-back average values across three cognitive distraction areas, respectively. As shown in Table 2, the relative speed decrements under three different levels of cognitive distraction were very similar in both experiments. A repeated-measures ANOVA yielded that the main effect for experiment type was not significant and an effect size was very small ($F(1,14)=.002$, $p=.965$, $\omega^2=0$). Steering wheel reversal rates (SRR) also showed similar result ($F(1.14)=.878$, $p=.365$, $\omega^2=0$). Thus, relative validity for the cognitively distracted driving speed and the steering wheel reversal rate under cognitive distraction was established.

Table 2. Relative validity for 3 levels of cognitive load

Variable		0-back	1-back	2-back
Speed (%)	Sim	100.0 (2.6)	97.8 (4.9)	98.8 (4.2)
	Road	100.0 (7.2)	98.9 (5.1)	97.5 (8.2)
SRR (%)	Sim	100.0 (23.5)	113.6 (28.4)	117.4 (22.4)
	Road	100.0 (16.3)	105.0 (20.1)	108.8 (22.3)

5. Conclusions

The comparison between the on-road and simulated driving performance under three different levels of cognitive distraction offered evidence to conclude that the driving performance changes including relative decrement in mean speed and relative increment in steering wheel reversal rate are a valid measure to use for cognitive distraction research on the DGIST driving simulator. Although it has been known that speed is very useful measure in driving behavior study, the validity of speed only covers research investigating the relative difference between different levels of cognitive distraction. Instead of speed, it was suggested that the steering wheel reversal rate could be a strong measure to assess cognitive distraction in either absolute or relative comparisons.

Therefore, the simulator seems to be a valid tool for cognitive distraction research aiming to observe driver's performance changes under different complexity of cognitive workload.

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