RSS2019 ROAD SAFETY & SIMULATION INTERNATIONAL CONFERENCE

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Transformations in Transportation

The University of Iowa

The National Advanced Driving Simulator

Can structural equation models assess overall driving performance in driving simulator experiments?

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Outline

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  - Sample characteristics
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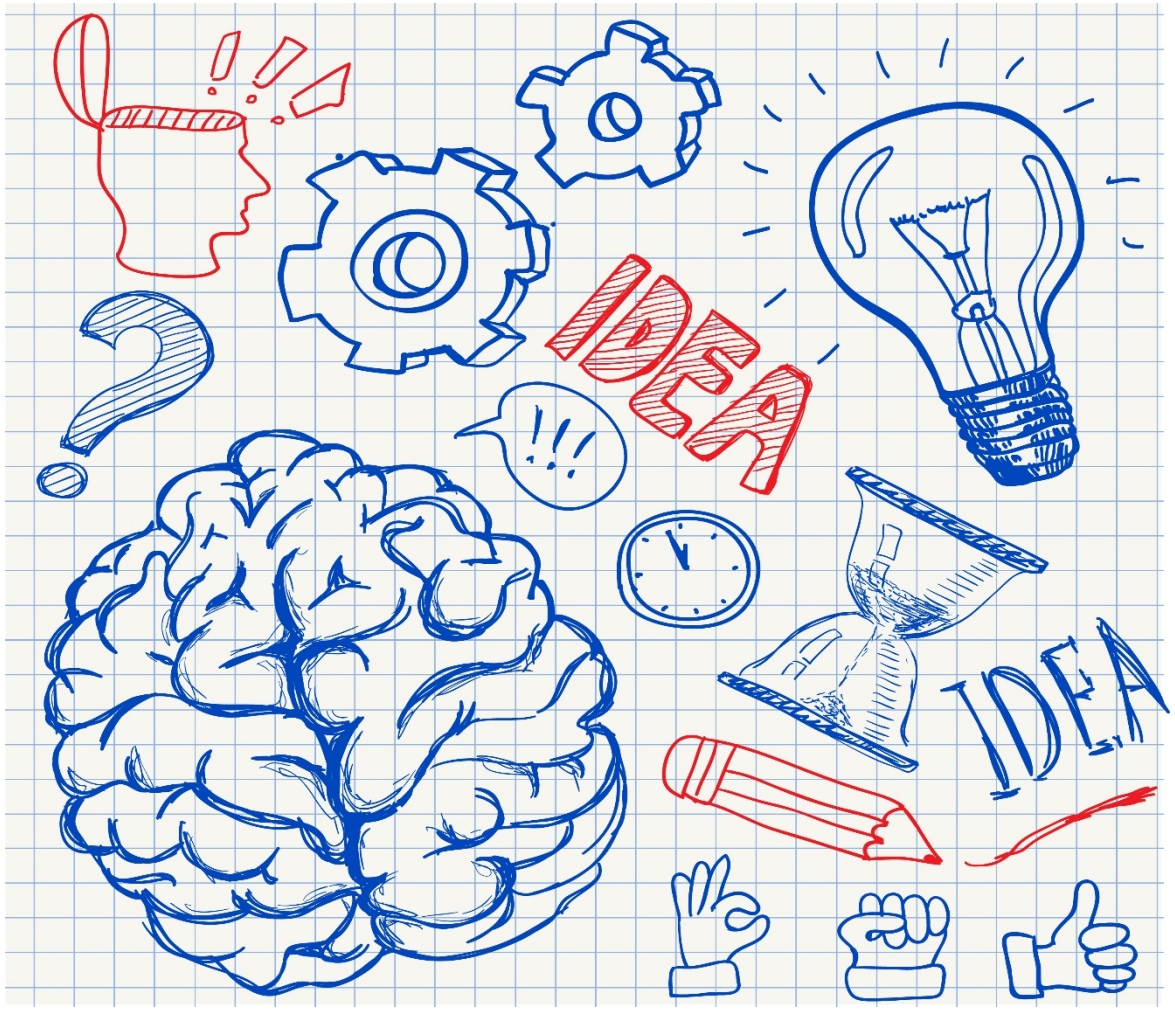


Introduction

- **Human factors** are the basic causes in 65-95% of road accidents (Salmon et al., 2011).
- Human factors involve a large number of specific factors that may be considered as **accident causes**, including (Yannis et al., 2013):
  - **Driver injudicious action** (speeding, traffic violations etc.)
  - **Driver error or reaction** (loss of control, failure to keep safe distances, sudden braking etc.)
  - **Behaviour or inexperience** (aggressive driving, nervousness, uncertainty etc.)
  - **Driver distraction** (cell phone use, conversation with passenger etc.)
  - **Driver impairment** (alcohol, fatigue etc.)

Latent model analysis overview

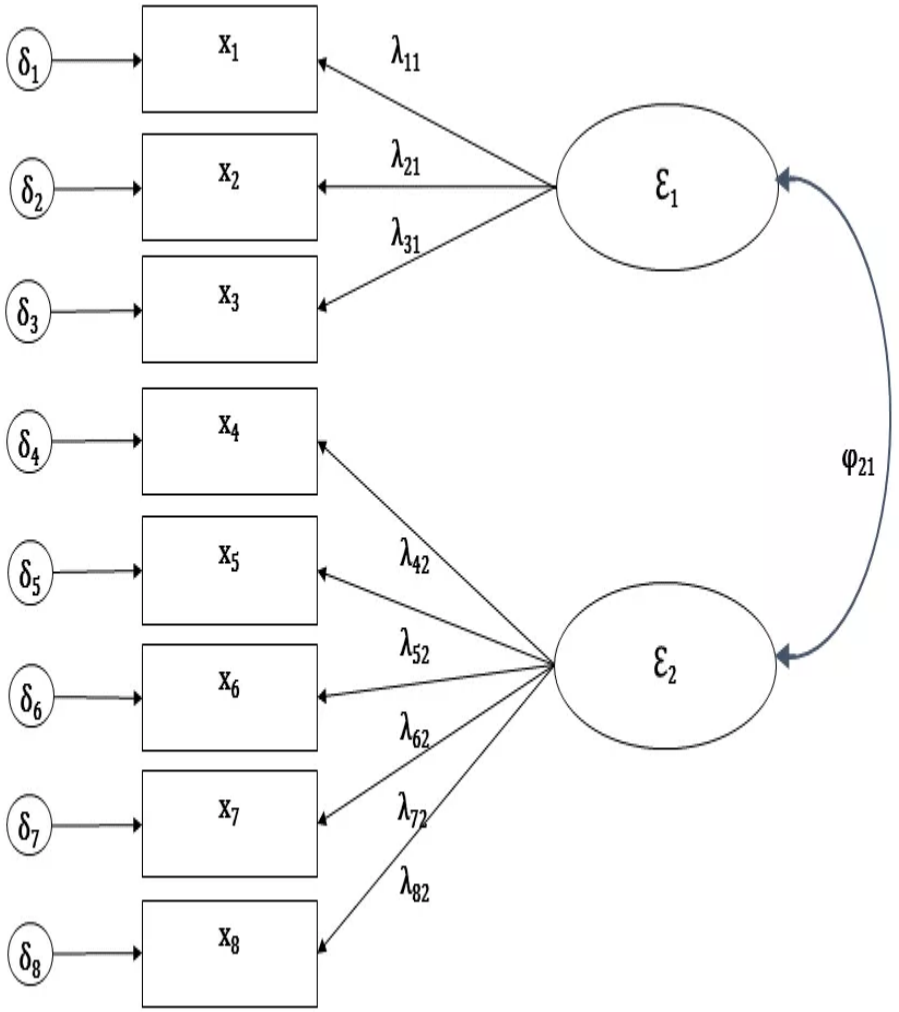
Structural Equation Modeling is a very general, powerful multivariate analysis technique that includes several analysis methods

SEM involves the evaluation of **two models**:

- **Measurement** Model
  - The part of the model that relates indicators to latent factors, the factor analytic part of SEM
- **Path** model
  - This is the part of the model that relates variable or factors to one another (prediction)

Goodness-of-fit measures

- SRMR < 0.08, RMSEA < 0.08
- CFI > 0.90, TLI > 0.90



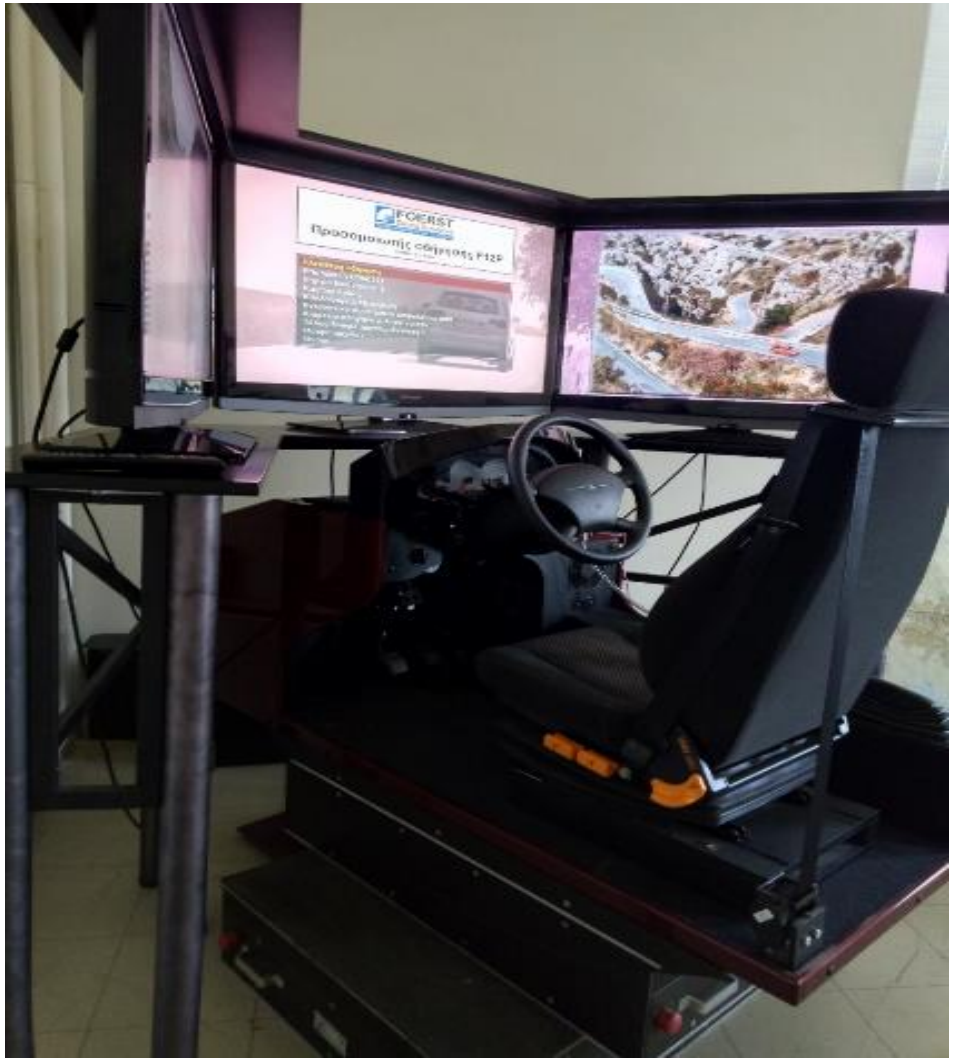
Objectives

To investigate whether **Latent model analysis** through a Structural Equation Model can be implemented on driving simulator data

To investigate and quantify the effect of several risk factors including distraction sources, driver characteristics, road and traffic environment on the **overall driving performance** and not in specific driving performance measures

Driving Simulator Characteristics

- **Quarter-cab** driving simulator
- **3 LCD wide screens** 40" (full HD), total angle view 170 degrees, driving position and support base
- **Dimensions** at a full development: **230x180 cm** with a base width of 78 cm
- **Adjustable driver seat**, steering wheel 27cm diameter, pedals (throttle, brake, clutch), dashboard and two external and one central mirror
- **Controls available to the driver**: 5 gears plus reverse gear, flash, wipers, lights, horn, brake and starter



Driving simulator experiment (1/2)

Road environment
- Rural: 2.1 km long, single carriageway
- Urban: 1.7 km long, dual carriageway

Traffic scenarios
- QL: Low traffic - 300 vehicles/hour
- QH: High traffic - 600 vehicles/hour

Unexpected incidents at each trial
- Child crossing the road
- Sudden appearance of an animal

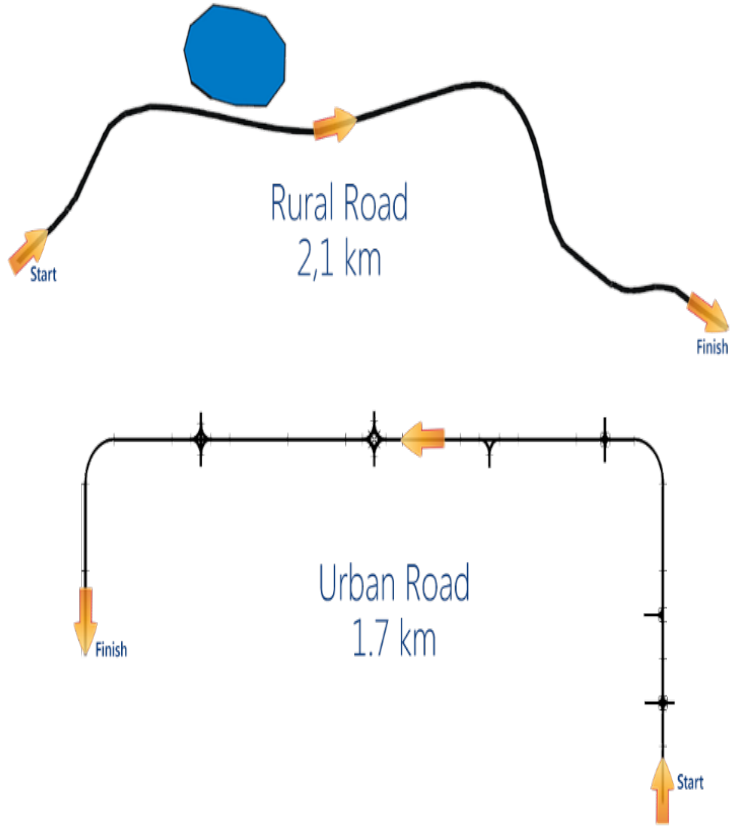
Distraction conditions
- No distraction
- Cell phone use
- Conversation with the passenger

Driving simulator experiment (2/2)

Randomization
Randomization was implemented in the order of area type, traffic scenarios as well as distraction scenarios to **remove bias**

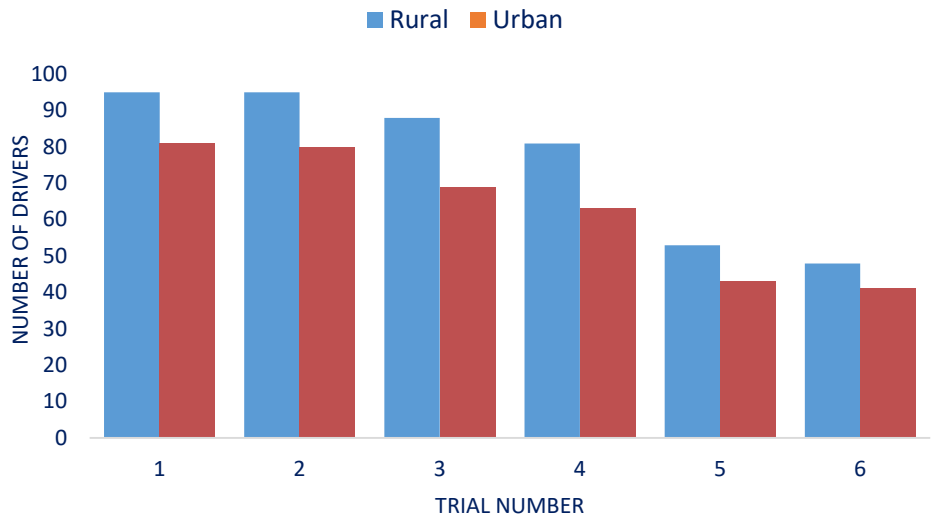
Familiarization
- During the familiarization with the simulator, the participant practiced in:
- **handling the simulator** (starting, gears, wheel handling etc.)
- keeping the lateral position of the vehicle
- keeping stable speed, appropriate for the road environment
- Braking and immobilization of the vehicle

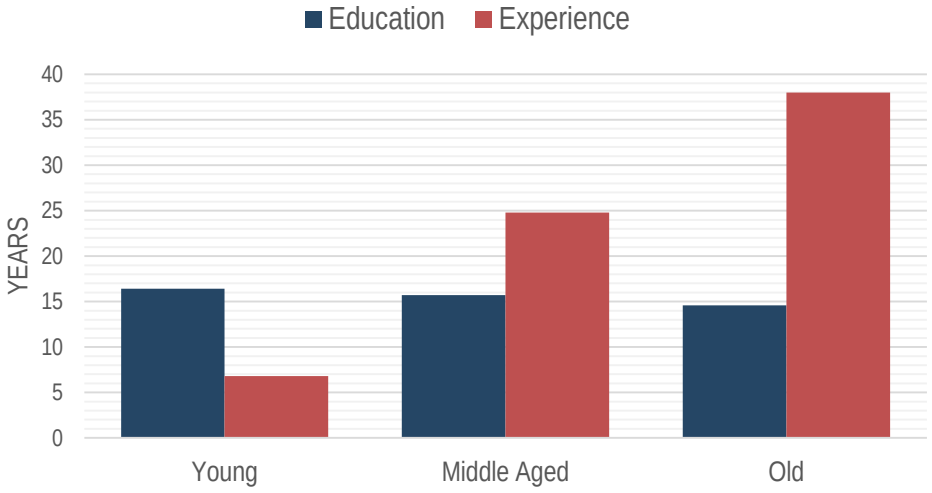
During this **practice drive**, two unexpected incidents took place.

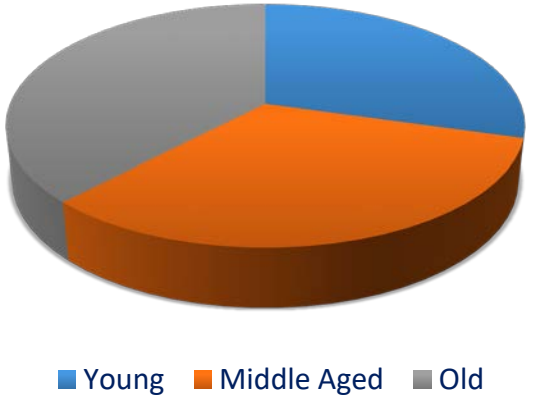


Sample characteristics

- 28 young drivers (18-34)
- 31 middle aged drivers (35-54)
- 36 older drivers (55+)







Driving Simulator Parameters

	Variable	Explanation
1	Time	current real-time in milliseconds since start of the drive.
2	x-pos	x-position of the vehicle in m.
3	y-pos	y-position of the vehicle in m.
4	z-pos	z-position of the vehicle in m.
5	road	road number of the vehicle in [int].
6	richt	direction of the vehicle on the road in [BOOL] (0/1).
7	rdist	distance of the vehicle from the beginning of the drive in m.
8	rspur	track of the vehicle from the middle of the road in m.
9	ralpha	direction of the vehicle compared to the road direction in degrees.
10	Dist	driven course in meters since begin of the drive.
11	Speed	actual speed in km/h.
12	Brk	brake pedal position in percent.
13	Acc	gas pedal position in percent.
14	Clutch	clutch pedal position in percent.
15	Gear	chosen gear (0 = idle, 6 = reverse).
16	RPM	motor revolvation in 1/min.
17	HWay	headway, distance to the ahead driving vehicle in m.
18	DLeft	Distance to the left road board in meter.
19	DRight	Distance to the right road board in meter.
20	Wheel	Steering wheel position in degrees.
21	THead	time to headway, i. e. to collision with the ahead driving vehicle, in seconds.
22	TTL	time to line crossing, time until the road border line is exceeded, in seconds.
23	TTC	time to collision (all obstacles), in seconds.
24	AccLat	acceleration lateral, in m/s^2
25	AccLon	acceleration longitudinal, in m/s^2
26	EvVis	event-visible-flag/event-indication, 0 = no event, 1 = event.
27	EvDist	event-distance in m.
28	ErrINo	number of the most important driving failure since the last data set
29	ErrIVal	state date belonging to the failure, content varies according to type of failure.
30	Err2No	number of the next driving failure (maybe empty).

Analysis method

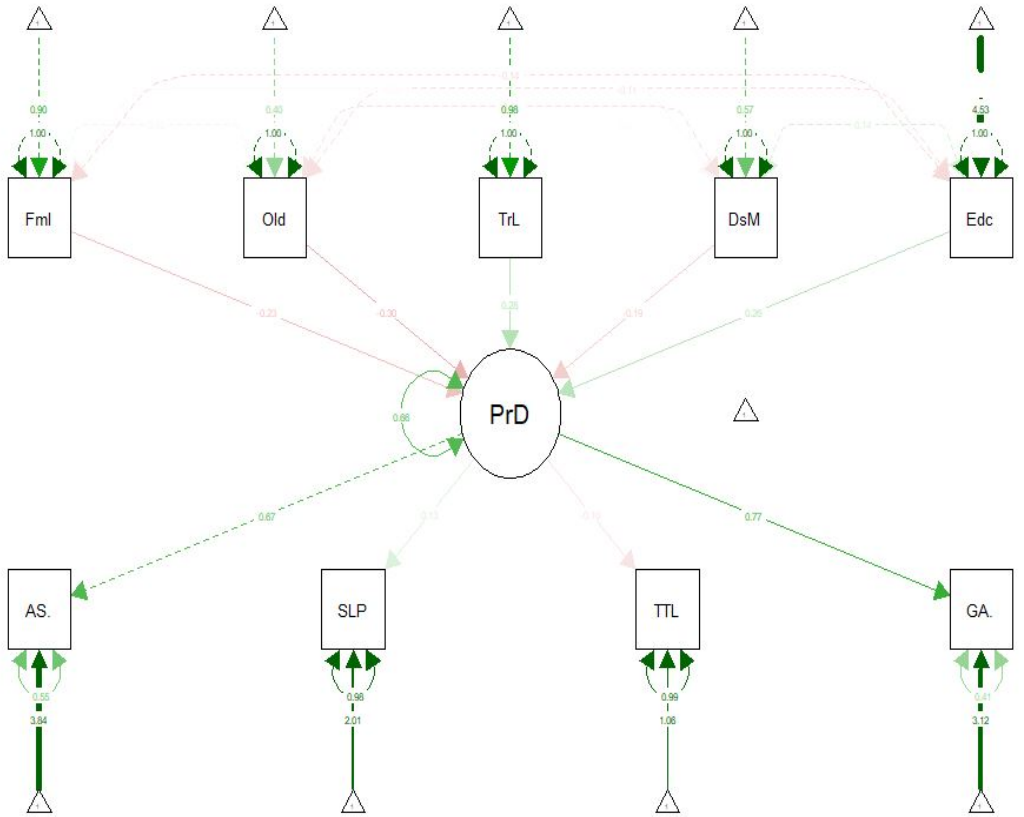
- The experiment data storage was performed automatically at the end of each experiment. The simulator recorded data at intervals of **33 milliseconds**

- The average value of all **driving performance measures** was estimated in total and for a time period of 15 seconds before and 15 seconds after the event

- Two **Structural Equation Models** (SEM) are developed where the dependent variable of the model is
  - **Overall driving performance**
  - **Difference** of overall driving performance before and after the event

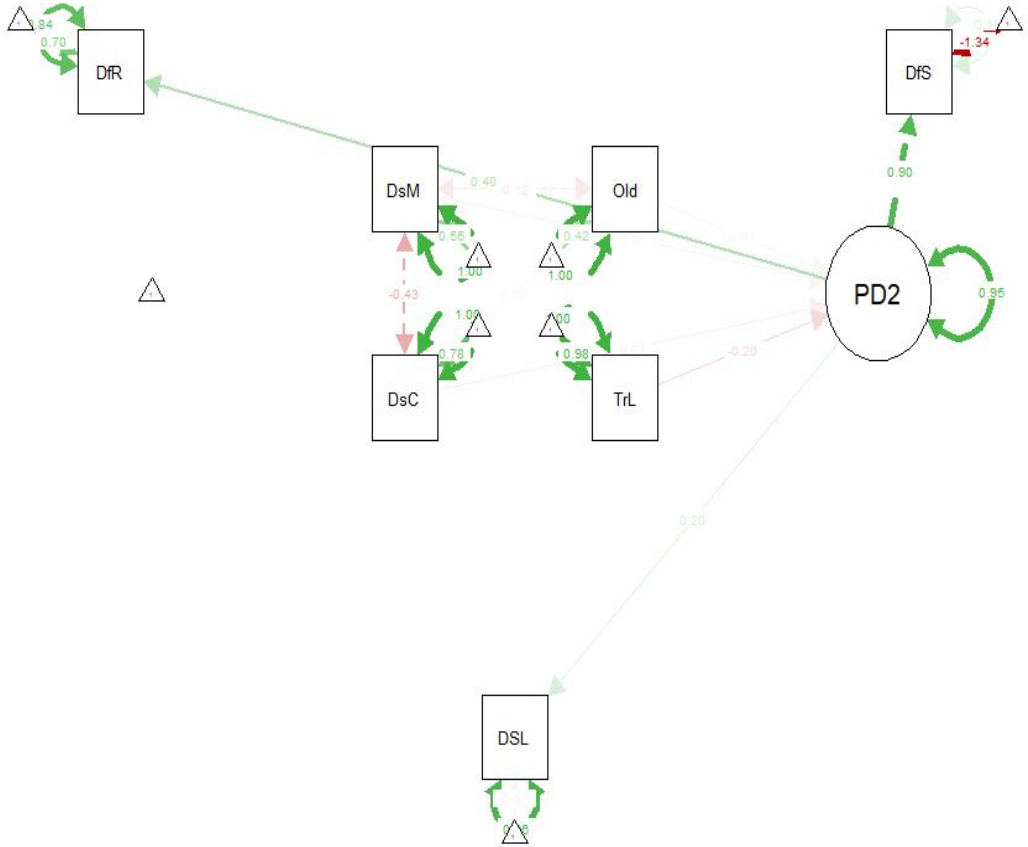
Driving Performance SEM

	Est.	Std.err	t value.	P(>|z|)
Latent Variable				
Driving Performance				
Average Speed	1.000	-	-	-
Stdev Lateral Position	0.128	0.042	3.047	0.002
Average Gear	0.061	0.005	12.870	0.000
Time to Line Crossing	-0.320	0.135	-2.374	0.018
Regressions				
Driving Performance				
Gender - Female	-3.645	0.688	-5.457	0.000
Age - Old	-6.766	1.070	-6.323	0.000
Traffic - Low	4.389	0.661	6.644	0.000
Distraction – Mobile	-3.390	0.788	-4.300	0.000
Education	-0.610	0.110	-5.755	0.000
Summary statistics				
Minimum Function Test	271.08			
Degrees of freedom	17			
Goodness-of-fit measure				
SRMR	0.070			



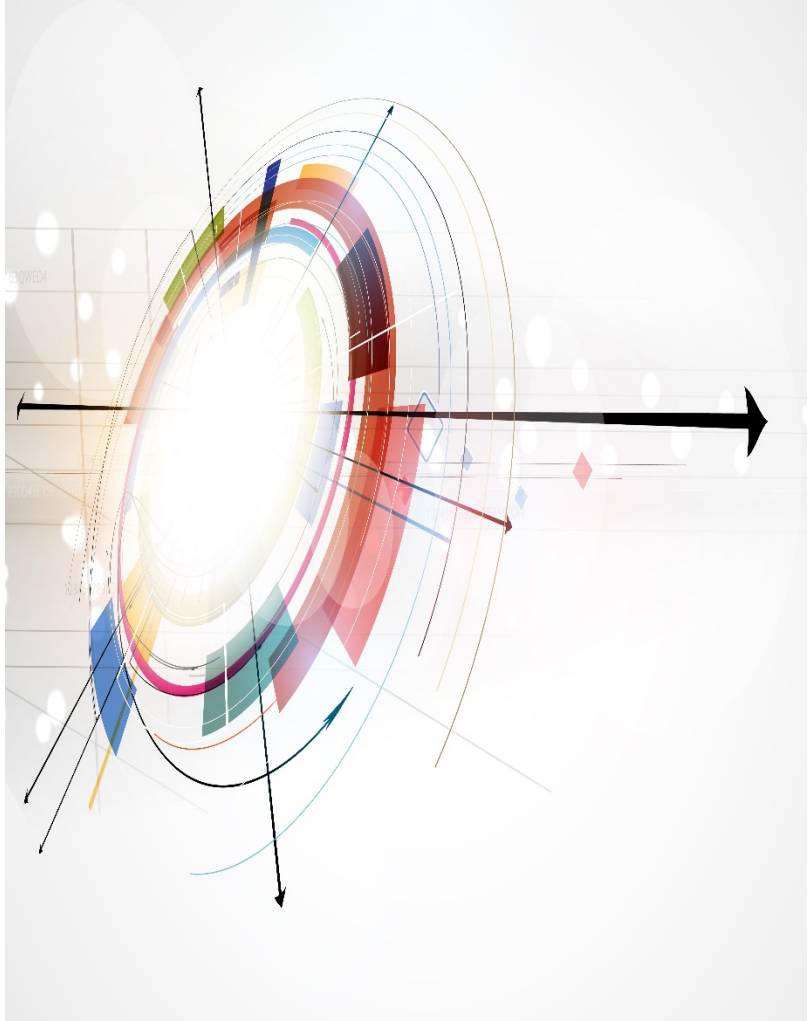
Difference of Driving Performance SEM

	Est.	Std.err	t value.	P(>|z|)
Latent Variable				
Dif Driving Performance				
Dif Average Speed	1.000	-	-	-
Dif Stdev Lateral Position	0.003	0.001	3.016	0.003
Dif Motor Revolvation	29.225	7.542	3.875	0.000
Regressions				
Dif Driving Performance				
Distraction – Cell phone	-1.075	0.768	-1.399	0.162
Distraction – Passenger	-1.303	0.624	-2.090	0.037
Traffic - Low	-3.156	0.554	-5.700	0.000
Age - Old	1.425	0.767	1.858	0.063
Summary statistics				
Minimum Function Test	26.22			
Degrees of freedom	8			
Goodness-of-fit measure				
SRMR	0.027			



Conclusions

- Results allow an important scientific step forward from piecemeal analyses to a sound **combined analysis** of the interrelationship between several risk factors and driving performance
- The selection of the specific **measures** that define overall performance should be guided by a rule of representativeness between the selected variables
- **Driver-related characteristics** play the most crucial role in overall driving performance
- Development of Structural Equation Model on different **experimental methods** (Naturalistic experiments, field test etc.) should be considered



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