National Technical University of Athens
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Traffic and safety behaviour of drivers with neurological diseases affecting cognitive functions

PART 2/2

A Doctoral Thesis presentation by

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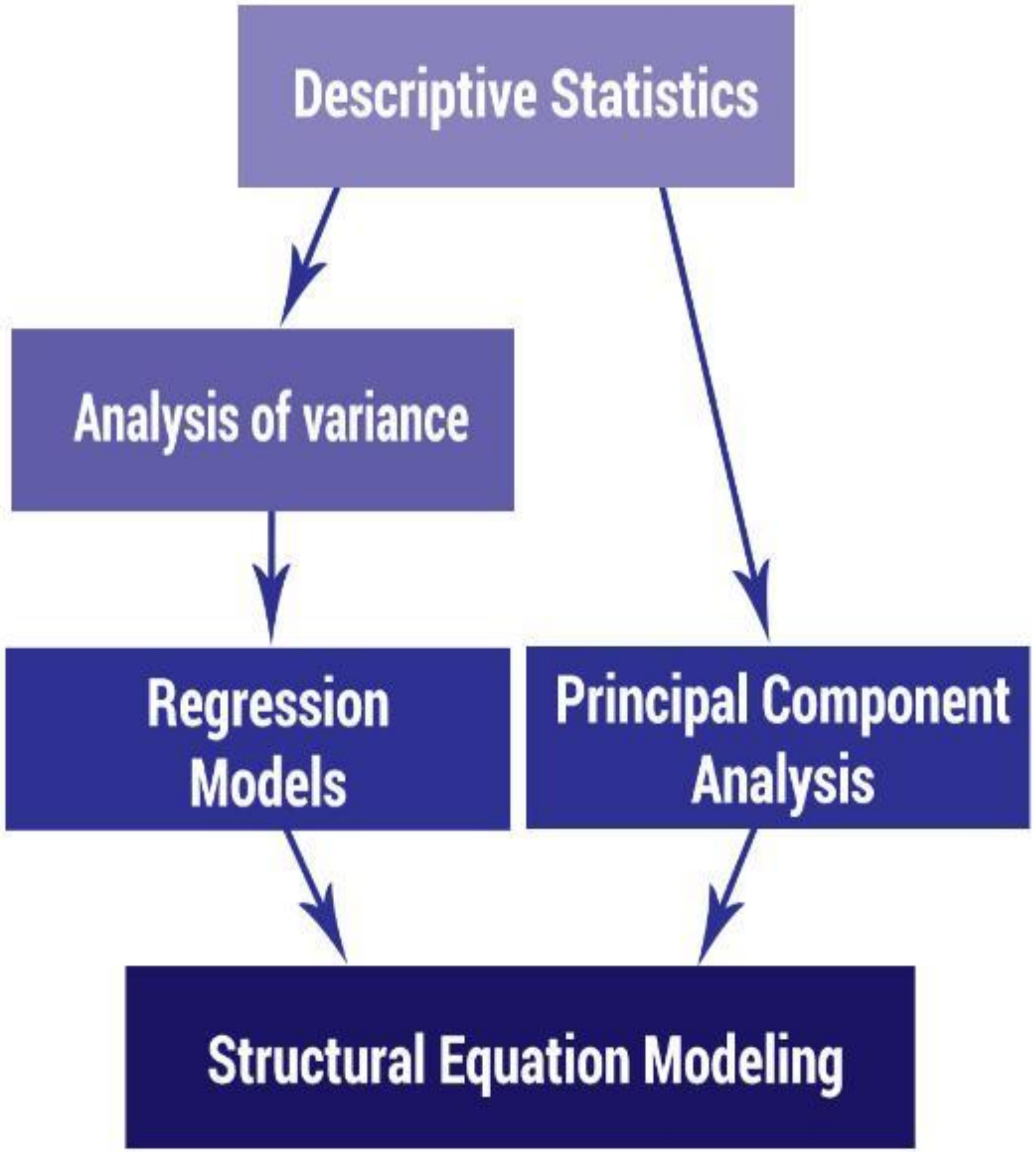
Statistical Analysis

- In chapter 5 an **innovating statistical analysis methodology** has been developed and presented in order to investigate all the critical parameters that affect reaction time, accident probability, driving performance and driving errors.

- The developed methodology consists of five individual analyses:
  - **Descriptive analysis**
  - **Analysis of variance**
  - **Regression analysis**
  - **Principal Component Analysis**
  - **Structural Equation Model analysis**

- All different statistical analyses provide remarkable findings for this PhD dissertation research.

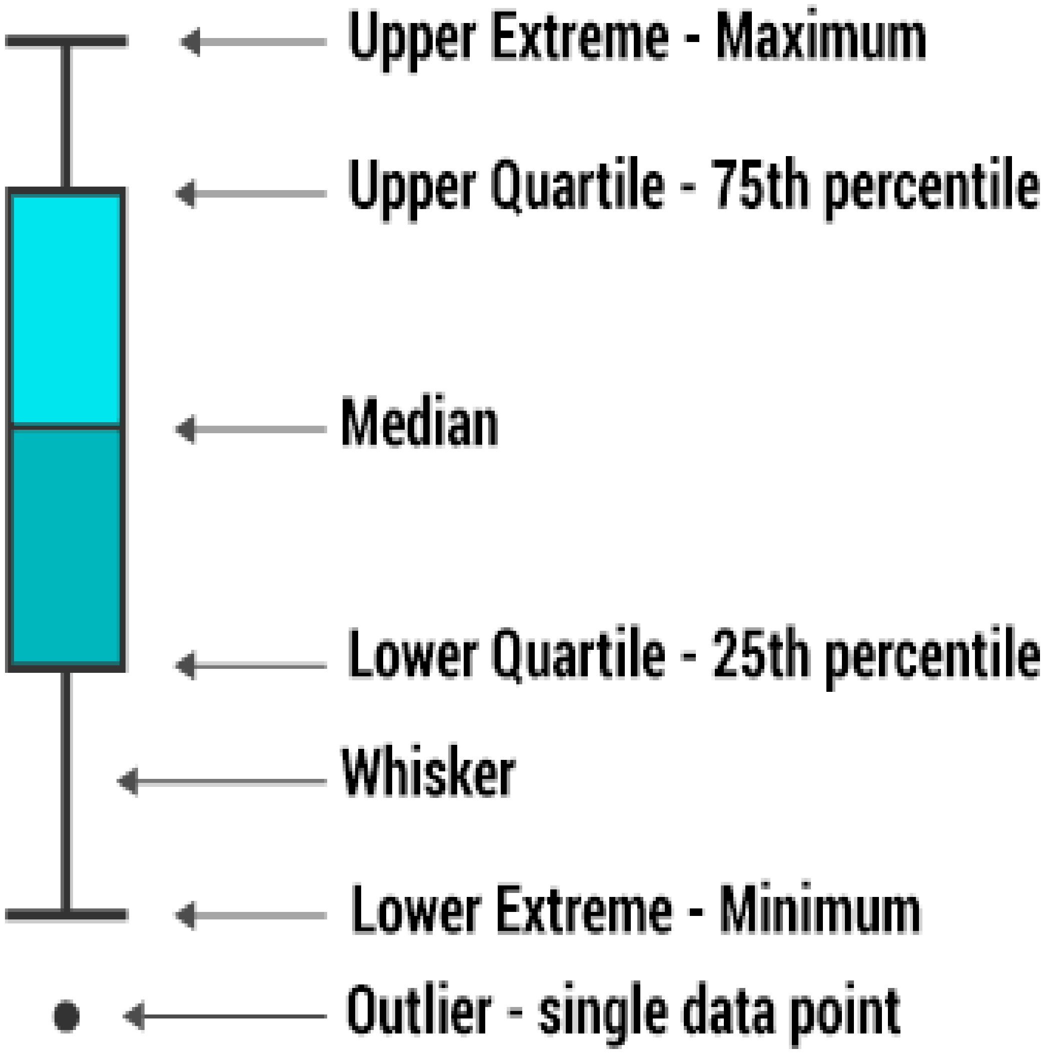


Step 1 - Descriptive statistics

- **In the first statistical step**, the descriptive analysis of all the experiment variables took place, which allows for a first understanding of the large number of parameters examined.

- **126 boxplots were developed** correlating mean speed, time headway, lateral position, steering angle variability, reaction time at unexpected incidents, accident probability, and driving errors, with traffic volume, driving area, regarding age and cerebral disease of the participants.

- A **correlation table** is investigating any of a broad class of statistical relationships between driving simulator variables



Step 1 - Descriptive statistics (Mean Speed)

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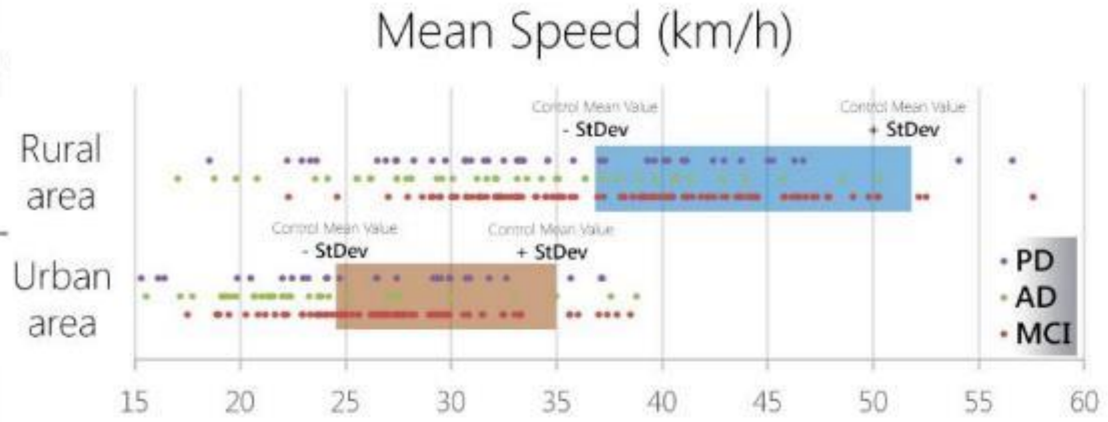
Mean Speed		below lower limit	inside the 'typical area'	higher than upper limit
Rural Area	PD	57%	36%	7%
	AD	67%	33%	0%
	MCI	43%	54%	3%
Urban Area	PD	43%	46%	11%
	AD	69%	25%	6%
	MCI	27%	64%	9%



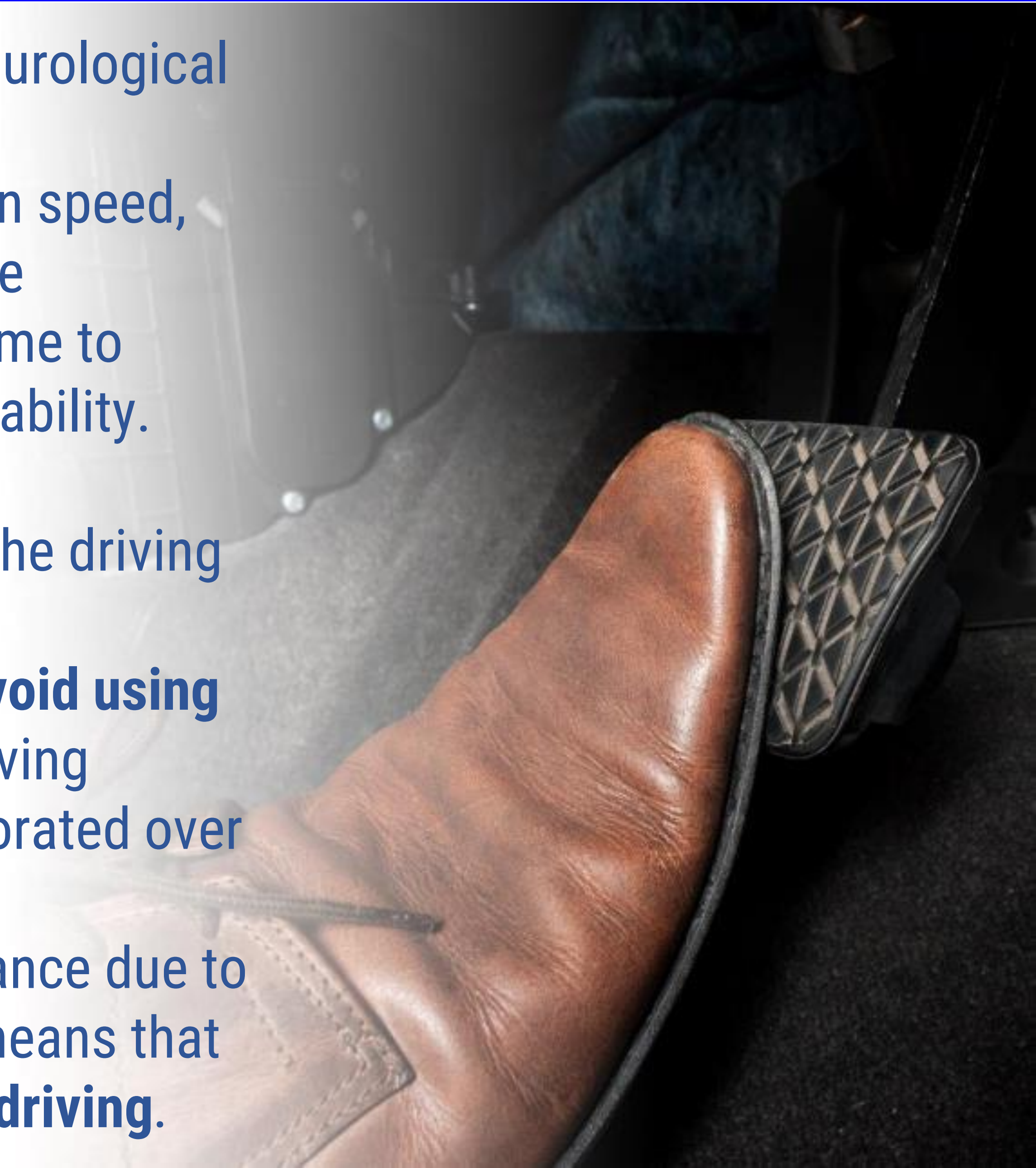
Step 1 - Synthesis of Descriptive statistics

- All three cerebral pathologies examined lead to **lower driving speeds** in all examined conditions (AD group has the lowest mean speeds among the other participants)
- **AD group in urban area** with low traffic volume when using the mobile phone have higher variability in steering angle
- AD and PD groups have the **worst reaction times** (40% worse than controls)
- The **mobile phone use has a significant effect** on reaction time for AD and PD groups
- AD and PD drivers have the highest accident probability, and especially when conversing on the mobile phone **their accident probability is climbing to 50%**.
- High traffic volume **leads to more mistakes** for all participants, as it is a more complex environment.

Step 2 - ANOVA findings

- The first ANOVA indicated that the presence of a neurological disease affecting cognitive functions was found to **significantly affect** in both road environments: mean speed, mean speed variability, time headway, steering angle variability, time to lane crossing, time to collision, time to collision variability, reaction time and accident probability.

- The second ANOVA regarding questionnaire about the driving habits and the driving behaviour indicated that:
  - **Patients self-reported, that they are likely to avoid using their vehicle** because they are afraid of their driving abilities which they admit that have been deteriorated over the years.
  - This awareness of deteriorated driving performance due to brain pathologies is of notable significance; it means that this group of drivers tries to **self-regulate their driving**.



Step 3 - Regression analyses 1/2

- **In the third statistical step**, within the framework of the explanatory analysis, the development of **Regression Models** took place regarding key performance parameters
- **28 General Linear Models (GLMs)** were extracted regarding the **effect of MCI, AD and PD** on: mean speed, time headway, lateral position, steering angle variability, reaction time at unexpected incidents, accident probability, and driving errors

Parameter Estimates of the GLM
Dependent variable: Mean Speed (km/h)
Model: (Intercept), Disease, No distraction Condition

	Low Traffic					High Traffic					
Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	
(Intercept)	44,8	1,2	1508,3	1	0,000	42,1	1,0	1942,3	1	0,000	Rural Area
MCI	-5,3	1,7	9,2	1	,002	-5,0	1,5	11,8	1	,001	
AD	-10,8	2,0	28,2	1	,000	-8,4	1,7	25,8	1	,000	
PD	-9,3	2,1	19,6	1	,000	-8,3	1,8	20,2	1	,000	
Controls	0[a]					0[a]					
(Scale)	63,808[b]	7,9				47,559[b]	5,8				
Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	
(Intercept)	30,1	0,9	1047,4	1	0,000	27,8	0,7	1417,1	1	0,000	Urban Area
MCI	-2,0	1,4	2,0	1	,160	-2,3	1,1	4,5	1	,034	
AD	-4,3	1,6	7,0	1	,008	-4,2	1,3	10,4	1	,001	
PD	-3,8	1,9	4,1	1	,042	-3,1	1,4	4,7	1	,030	
Controls	0[a]					0[a]					
(Scale)	33,815[b]	4,7				19,695[b]	2,8				

a. Set to zero because this parameter is redundant.
b. Maximum likelihood estimate.

Parameter Estimates of the GLM
Dependent variable: Reaction Time (millisec)
Model: (Intercept), Disease, No distraction Condition

	Low Traffic					High Traffic					
Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	
(Intercept)	1625,9	86,3	354,7	1	0,000	1752,7	98,4	316,9	1	0,000	Rural Area
MCI	379,7	130,1	8,5	1	,004	439,9	150,4	8,6	1	,003	
AD	829,7	150,6	30,4	1	,000	748,6	170,5	19,3	1	,000	
PD	584,0	158,0	13,7	1	,000	552,6	194,1	8,1	1	,004	
Controls	0[a]					0[a]					
(Scale)	350248,06[b]	43953,0				503994,57[b]	61344,3				
Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	
(Intercept)	1385,8	69,9	392,7	1	0,000	1323,6	55,1	577,1	1	0,000	Urban Area
MCI	51,1	102,1	0,3	1	,617	175,9	82,0	4,6	1	,032	
AD	476,8	118,9	16,1	1	,000	361,3	99,6	13,2	1	,000	
PD	232,5	133,0	3,1	1	,080	265,1	107,9	6,0	1	,014	
Controls	0[a]					0[a]					
(Scale)	166258,12[b]	24123,3				103214,49[b]	15472,5				

a. Set to zero because this parameter is redundant.
b. Maximum likelihood estimate.

Parameter Estimates of the GLM
Dependent variable: Accident Probability
Model: (Intercept), Disease, No distraction Condition

	Low Traffic					High Traffic					
Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	
(Intercept)	0,13	0,0	11,2	1	0,001	0,04	0,0	1,4	1	0,238	Rural Area
MCI	-0,01	0,1	0,0	1	,916	0,09	0,0	3,2	1	,072	
AD	0,15	0,1	5,4	1	,020	0,19	0,1	11,6	1	,001	
PD	-0,03	0,1	0,2	1	,691	0,04	0,1	0,4	1	,521	
Controls	0[a]					0[a]					
(Scale)	,068[b]	0,0				,055[b]	0,0				
Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.	
(Intercept)	0,07	0,0	2,8	1	0,095	0,10	0,0	4,7	1	0,030	Urban Area
MCI	0,16	0,1	6,2	1	,013	0,15	0,1	4,4	1	,037	
AD	0,23	0,1	9,6	1	,002	0,20	0,1	5,3	1	,021	
PD	0,12	0,1	2,0	1	,156	0,19	0,1	4,2	1	,042	
Controls	0[a]					0[a]					
(Scale)	,066[b]	0,0				,076[b]	0,0				

a. Set to zero because this parameter is redundant.
b. Maximum likelihood estimate.

Step 3 - Regression analyses 2/2

» **42 General Linear Models regarding the effect of distraction** on mean speed, time headway, lateral position, steering angle variability, reaction time at unexpected incidents, accident probability, and driving errors of patients with MCI, AD and PD and controls.

Parameter Estimates of the GLM
Dependent variable: Reaction Time (millisec)
Model: (Intercept), Distractor

MCI group

Rural Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	2096	71,3	863,6	1	0,000
Conversation	-91	100,8	0,8	1	,365
Mobile phone	343	135,5	6,4	1	,011
No distraction	0[a]				
(Scale)	411902,492[b]	41930,6			

Urban Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	1505	48,6	960,8	1	0,000
Conversation	199	70,2	8,0	1	,005
Mobile phone	-56	104,7	0,3	1	,595
No distraction	0[a]				
(Scale)	146249,419[b]	17735,3			

a. Set to zero because this parameter is redundant.
b. Maximum likelihood estimate.

Parameter Estimates of the GLM
Dependent variable: Reaction Time (millisec)
Model: (Intercept), Distractor

AD group

Rural Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	2489	126,5	387,5	1	0,000
Conversation	-33	181,9	0,0	1	,857
Mobile phone	1246	403,9	9,5	1	,002
No distraction	0[a]				
(Scale)	735576,750	107294,9			

Urban Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	1782	81,9	473,3	1	0,000
Conversation	65	135,5	0,2	1	,629
Mobile phone	164	208,8	0,6	1	,431
No distraction	0[a]				
(Scale)	221345,075	41102,7			

a. Set to zero because this parameter is redundant.
b. Maximum likelihood estimate.

Parameter Estimates of the GLM
Dependent variable: Reaction Time (millisec)
Model: (Intercept), Distractor

PD group

Rural Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	2217	156,1	201,6	1	0,000
Conversation	37	225,0	0,0	1	,869
Mobile phone	792	312,2	6,4	1	,011
No distraction	0[a]				
(Scale)	023341,347	148482,0			

Urban Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	1579	87,0	329,1	1	0,000
Conversation	487	129,9	14,1	1	,000
Mobile phone	-14	204,1	0,0	1	,946
No distraction	0[a]				
(Scale)	204419,592	38981,3			

a. Set to zero because this parameter is redundant.
b. Maximum likelihood estimate.

Parameter Estimates of the GLM
Dependent variable: Reaction Time (millisec)
Model: (Intercept), Distractor

Control group

Rural Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	1660	51,4	1042,2	1	0,000
Conversation	-60	73,7	0,7	1	,415
Mobile phone	93	87,3	1,1	1	,287
No distraction	0[a]				
(Scale)	293335,870[b]	25015,8			

Urban Area

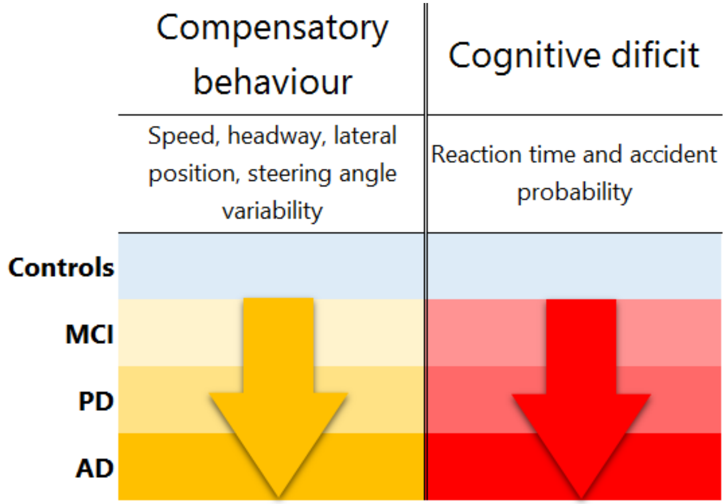
Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	1344	53,0	643,6	1	0,000
Conversation	76	76,7	1,0	1	,319
Mobile phone	115	93,4	1,5	1	,219
No distraction	0[a]				
(Scale)	224620,578[b]	22985,2			

a. Set to zero because this parameter is redundant.
b. Maximum likelihood estimate.

Step 3 - Synthesis of Regression analyses 1/2

MCI, AD and PD drivers compared to healthy controls

	Rural	Urban	Comment
Mean speed	↓	↓	Lower speed for all groups of patients in all examined contitions
Time headway	↑		Larger headways for AD and PD group in rural area
Lateral position		→	More closely to the right border for the MCI group in urban road
Steering angle variability	↓		Lower variability in steering angle for the PD group in rural area in high traffic
Reaction time	↑	↑	Larger reaction times for all groups of patients in all examined contitions
Accident probability	↑	↑	Higher accident probability for the AD group in all examined conditions and for the MCI and PD groups in urban area
Driving errors			No significant differences



- The disease leads to more pronounced **driving impairments** in several longitudinal or lateral control measures
- Patients have a **more conservative and cautious** driving pattern
- The compensatory behaviour of the first mechanism is **not sufficient to counterbalance** the driving deficits due to cognitive impairments

Step 3 - Synthesis of Regression analyses 2/2

MCI, AD and PD drivers compared to their undistracted driving

	Conversation with passenger	Mobile phone use	Comment
Mean speed	■	↓	Lower speed for MCI group in rural road when using mobile phone
Time headway	■	↑	Larger headway for MCI group in rural road when using mobile phone
Lateral position	■	←	More closely to the left border of the road for the AD group in rural road when using mobile phone
Steering angle variability	■	■	No significant impact of distraction in any group
Reaction time	↑	↑	Larger reaction time for all groups in all conditions when using mobile phone and for the MCI and PD groups when conversing with passenger in urban road
Accident probability	↑	↑	Higher accident probability for all groups in all conditions when using mobile phone and for the MCI and PD groups when conversing with passenger in urban road

» The driving profile of individuals with neurological diseases affecting cognitive functions **changed radically** under the more demanding driving condition that included the use of a hand-held mobile phone

» In the driving condition with the mobile phone, the drivers with MCI, AD and PD applied again the compensatory strategy of reducing their speed but in this case the outcome was not successful, as **indicated by the pronounced increase of their reaction time and accident risk**.

Step 4 - Principal Component Analysis

The size and interdisciplinary nature of the database lead us to implement 4 Principal Component Analyses (PCA) regarding:

- **driving performance variables**
- **driving errors variables**
- **neurological variables**
- **neuropsychological variables**

in order to investigate which observed variables are most highly correlated with the common factors and how many common factors are needed to give an adequate description of the data.

Driving Performance Variables (simulator)

Rotated Component Matrix[a]

	Factor 1	Factor 2	Factor 3
StdLateralPosition	**,923**		
TTLAverage	**,905**		
StdWheelAverage	**,900**		
WheelAverage	,845		
LateralPositionAverage	,835		
HWayAverage	-,738		
StdHWayAverage	-,708		
StdTTLAverage	,666		
StdTTCAverage	,631		
TTCAverage	,623		
BrakeAverage	,553		
StdBrakeAverage	,553		
AverageSpeed		**,776**	
TheadAverage		-,697	
RalphaAverage		,677	
StdRalphaAverage		,669	
StdevAverageSpeed		,637	
GearAverage			**,753**
StdGearAverage			,751
StdRpmAverage			,664
RpmAverage			,573

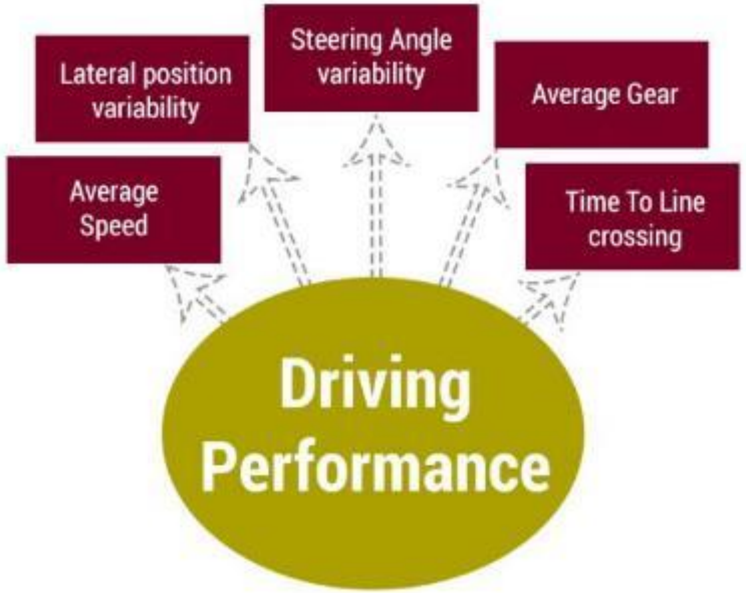
Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

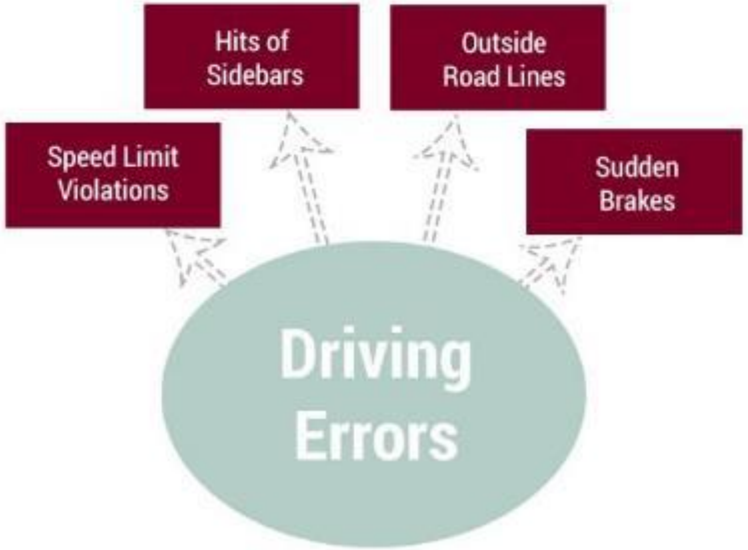
a. Rotation converged in 6 iterations.

Total Variance Explained

Rotation Sums of Squared Loadings			
Component	1	2	3
Total	8,5	5,7	2,2
% of Variance	38,5	25,7	10,1
Cumulative %	38,5	64,2	74,3

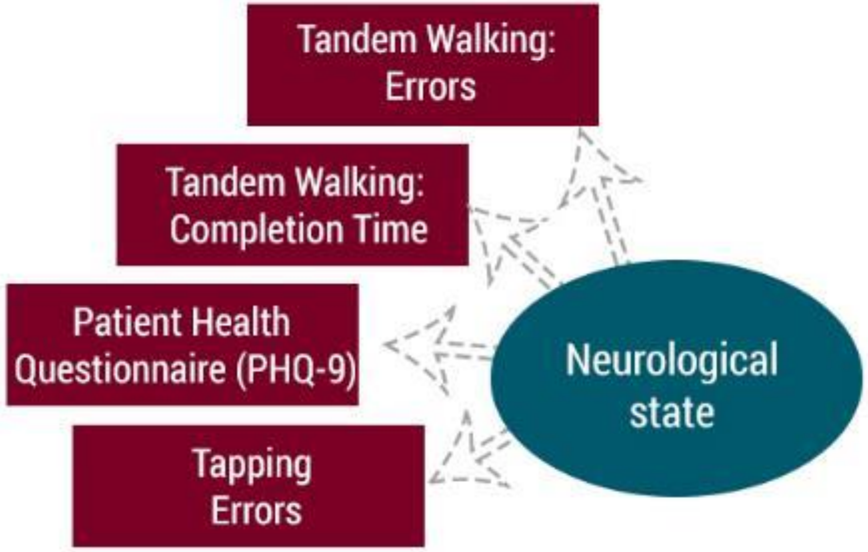
Step 4.5 - Development of Latent variables

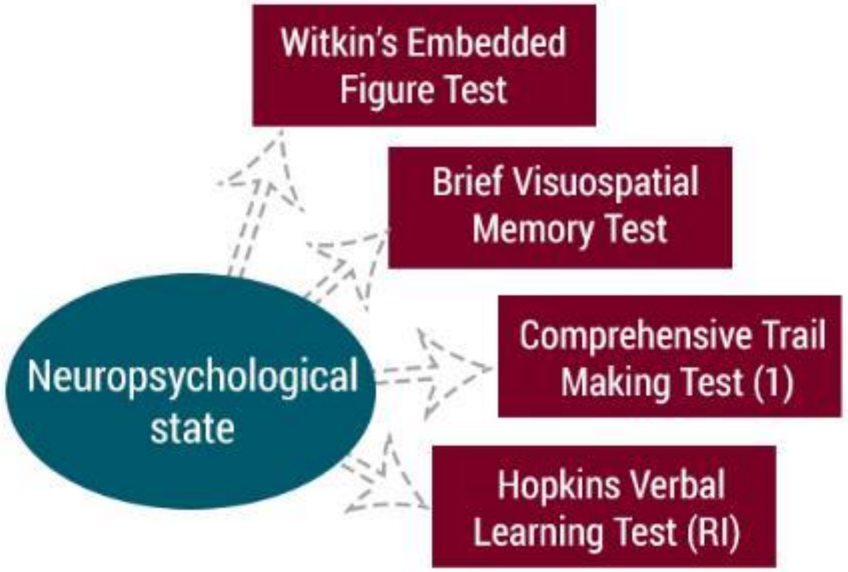




Use of the most highly correlated observed variables of each principal component which describe adequately the data, in order to develop four non-observed, latent variables:

"driving performance"
"driving errors"
"neurological state"
"neuropsychological state"

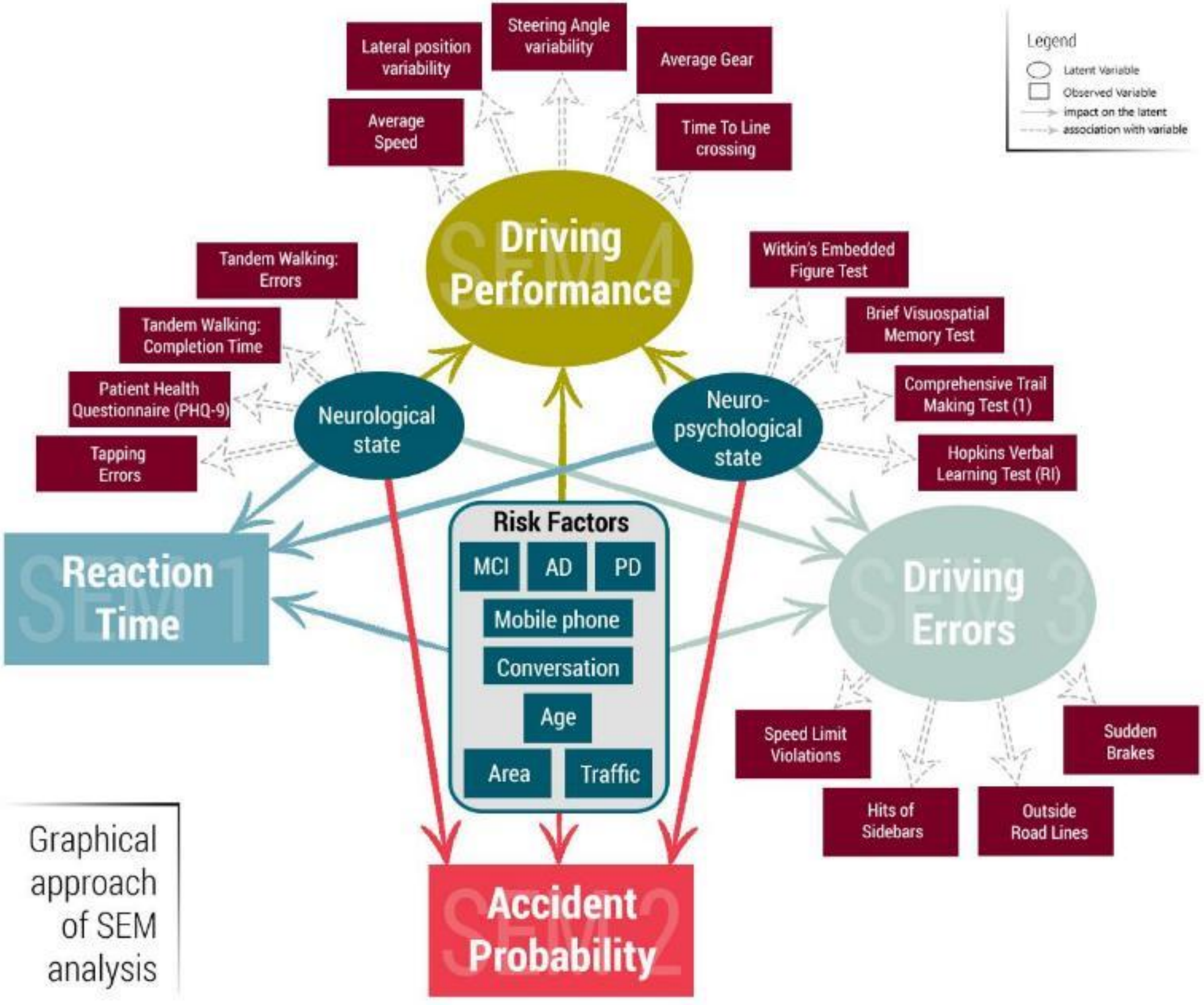




Step 5 - Structural Equation Models (SEMs)

- **In the fifth and final statistical step**, the core statistical analysis of the present PhD thesis took place, including the implementation of 4 Structural Equation Models (SEMs) for the first time in the scientific field of driving behaviour of drivers with neurological diseases affecting cognitive functions.
- Structural Equation Modeling is a very **general, powerful multivariate analysis technique** that includes several analysis methods and involves the evaluation of two models:
  - **Measurement Model**
    - The part of the model that relates indicators to latent factors
    - The measurement model is the factor analytic part of SEM
  - **Path model**
    - This is the part of the model that relates variable or factors to one another (prediction)
    - If no factors are in the model then only path model exists
- **Goodness-of-fit measures**
    - Standardized Root Average Square Residual (SRMR)
    - Root Average Square Error of Approximation (RMSEA)
    - Comparative Fit Index (CFI)
    - Tucker Lewis Index (TLI)

Step 5 - SEM analysis



Graphical approach of SEM analysis

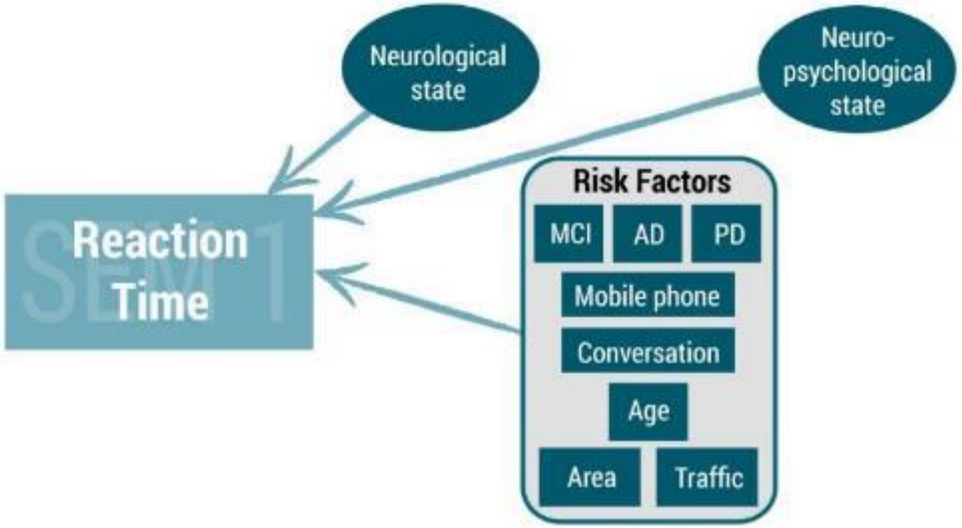
4 latent variables: "driving performance", "driving errors", "neurological state" and "neuropsychological state", developed by 17 observed variables

8 key observed variables (risk factors): MCI, AD, PD, urban area, low traffic conditions, advanced age, mobile phone use, and conversation with passenger

4 SEMs: regarding the impact of the 8 key risk factors and of 2 latent variables "neurological state" and "neuropsychological state" on the observed variables "reaction time" and "accident probability" and the latent ones "driving errors" and "driving performance"

Step 5 - SEM regarding *REACTION TIME*

- A critical finding that **supports the validity** of the overall SEM is that the contribution of the observed variables on the construction of the latent variables was in all cases statistically significant
- All predictors (except for low traffic conditions) had a **significant contribution** on the prediction of the reaction time
- The obtained goodness-of-fit measures are **generally close to the respective limits**



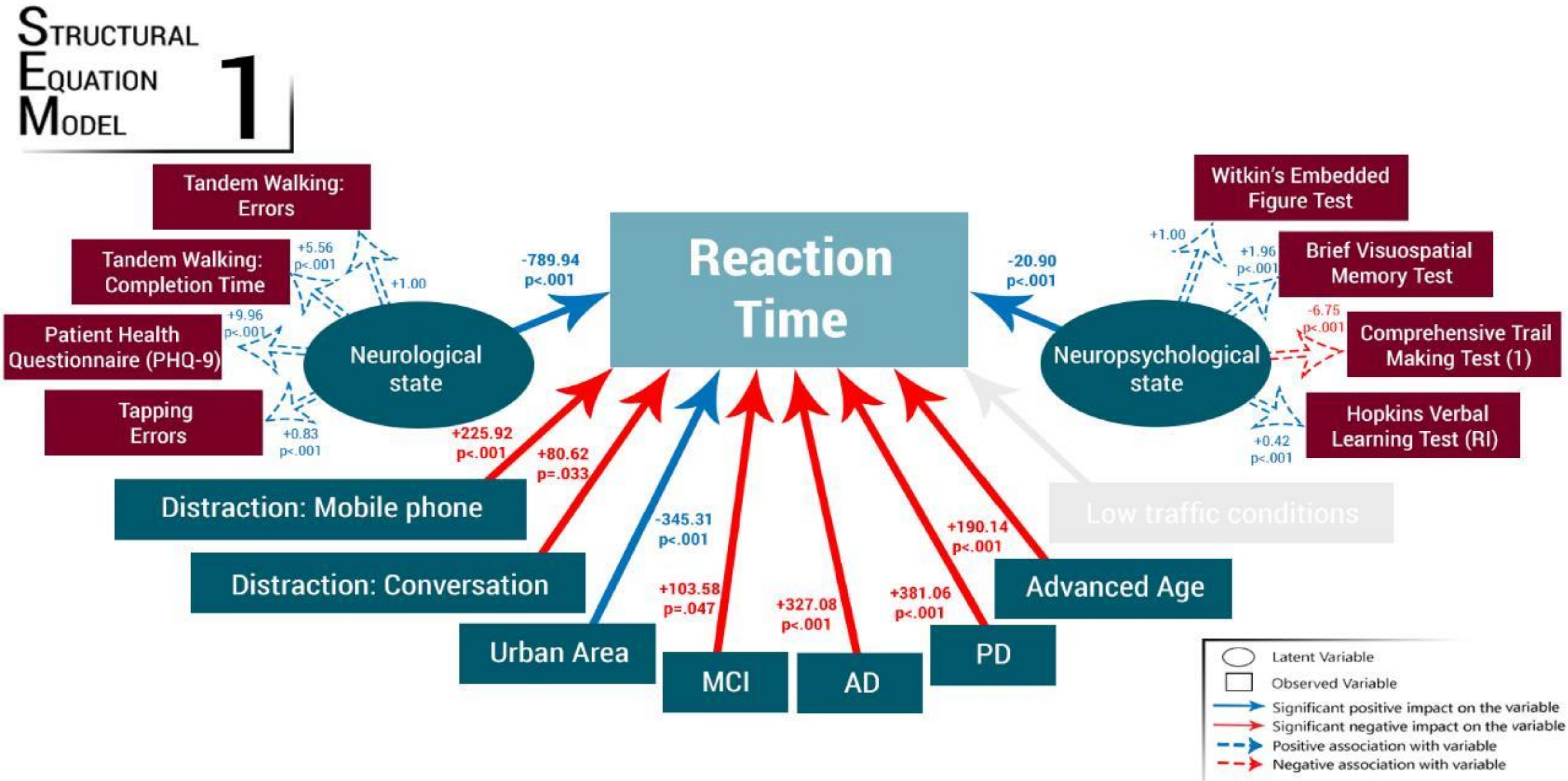
Latent variables	Est.	Std.err	Z-value	P(>|z|)
Neuropsychological State *(latent 1)*				
Witkin's Embedded Figure Test	1.000			
Brief Visuospatial Memory Test	1.962	0.048	40.927	**<.001**
Comprehensive Trail Making Test (1)	-6.752	0.405	-16.685	**<.001**
Hopkins Verbal Learning Test (RI)	0.415	0.020	20.818	**<.001**
Neurological State *(latent 2)*				
Tandem Walking: Errors	1.000			
Tandem Walking: Completion Time	5.557	0.873	6.364	**<.001**
Patient Health Questionnaire (PHQ-9)	9.956	2.416	4.120	**<.001**
Foot taping errors	0.829	0.170	4.885	**<.001**

Regressions	Est.	Std.err	Z-value	P(>|z|)
Reaction Time				
Disease - MCI	103.575	52.205	1.984	**.047**
Disease - AD	327.075	87.927	3.492	**<.001**
Disease - PD	381.056	88.544	4.304	**<.001**
Urban Area	-345.309	33.260	-10.382	**<.001**
Advanced Age	190.137	43.877	4.333	**<.001**
Distraction - Conversation	80.614	37.769	2.134	**.033**
Distraction - Mobile Phone	225.921	54.088	4.177	**<.001**
Neuropsychological State *(latent)*	-20.899	6.464	-3.233	**<.001**
Neurological State *(latent)*	-789.943	226.670	-3.485	**<.001**

Summary statistics	ML
Minimum Function Test Statistic	1928.87
Degrees of freedom	81

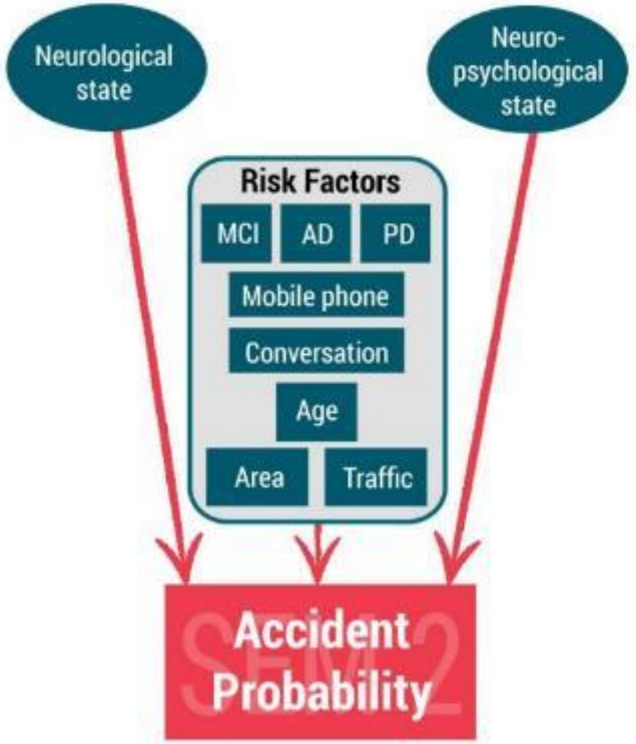
Goodness of fit	
SRMR	0.138
RMSEA	0.132
CFI	0.722
TLI	0.702

Step 5 - SEM regarding *REACTION TIME*



Step 5 - SEM regarding *ACCIDENT PROBABILITY*

- » The contribution of the observed variables on the construction of neuropsychological state was statistically significant
- » 5 predictors had a **significant contribution** on the prediction of accident probability
- » The obtained goodness-of-fit measures are **generally close to the respective limits**



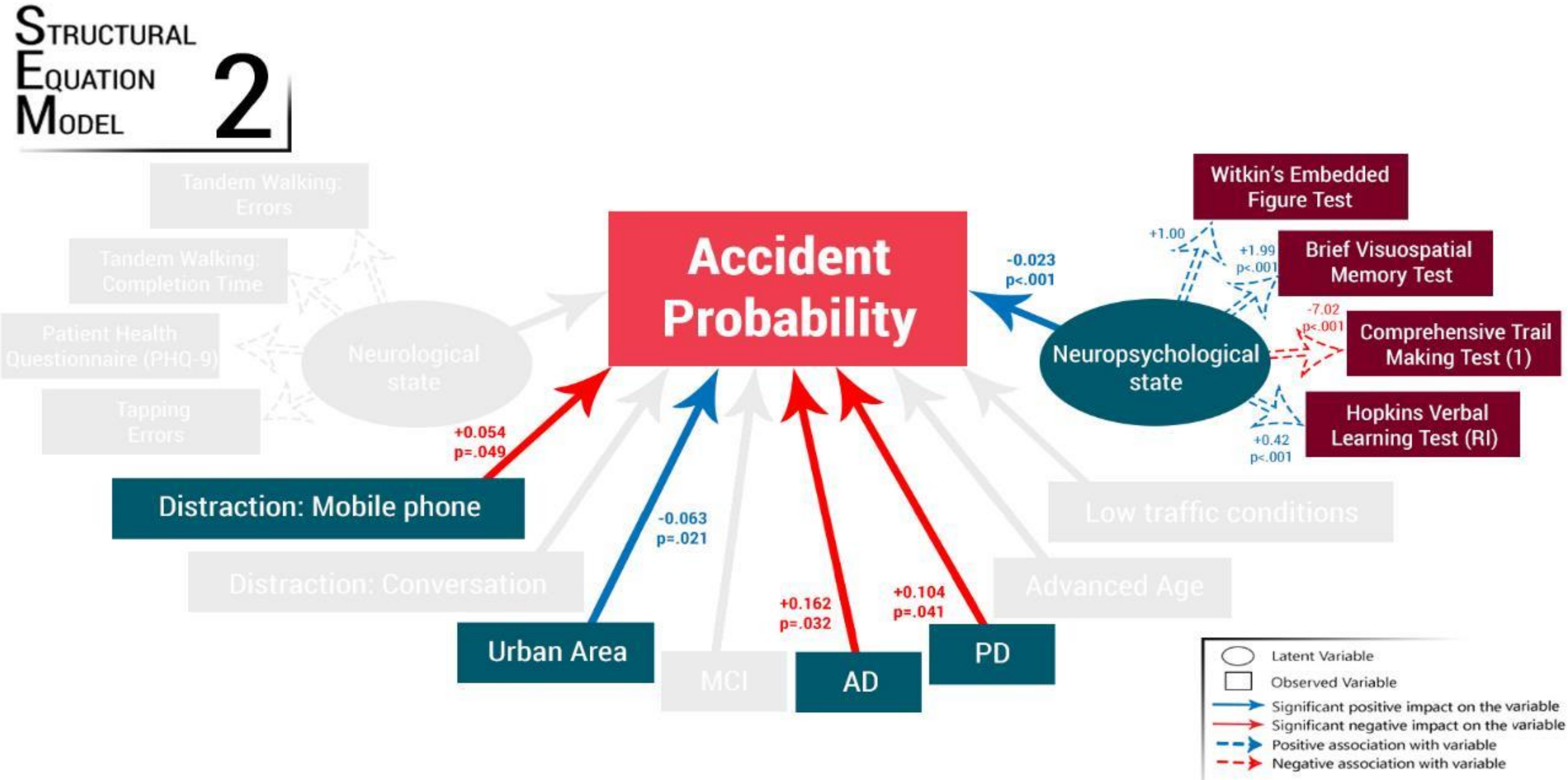
Latent variables	Est.	Std.err	Z-value	P(>|z|)
Neuropsychological State *(latent 1)*				
Witkin's Embedded Figure Test	1.000			
Brief Visuospatial Memory Test	1.989	0.047	42.238	**<.001**
Comprehensive Trail Making Test (1)	-7.022	0.375	-18.740	**<.001**
Hopkins Verbal Learning Test (RI)	0.421	0.018	23.199	**<.001**

Regressions	Est.	Std.err	Z-value	P(>|z|)
Accident Probability				
Disease - AD	0.162	0.062	2.146	**.032**
Disease - PD	0.104	0.060	2.017	**.041**
Urban Area	-0.063	0.027	-2.306	**.021**
Distraction - Mobile Phone	0.054	0.036	1.909	**.049**
Neuropsychological State *(latent)*	-0.023	0.004	-5.612	**<.001**

Summary statistics	ML
Minimum Function Test Statistic	711.78
Degrees of freedom	21

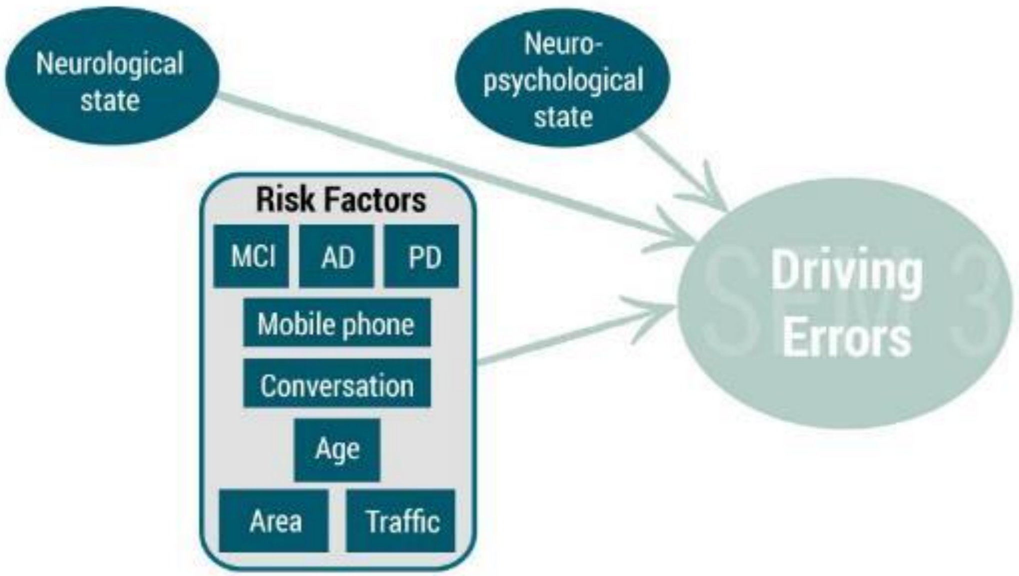
Goodness of fit	
SRMR	0.125
RMSEA	0.135
CFI	0.699
TLI	0.659

Step 5 - SEM regarding *ACCIDENT PROBABILITY*



Step 5 - SEM regarding *DRIVING ERRORS*

- A critical finding that **supports the validity** of the overall SEM is that the contribution of the observed variables on the construction of the latent variables was in all case statistically significant
- **4 predictors had a significant contribution** on the prediction of the latent variable "driving errors"
- The obtained goodness-of-fit measures are **generally close to the respective limits**



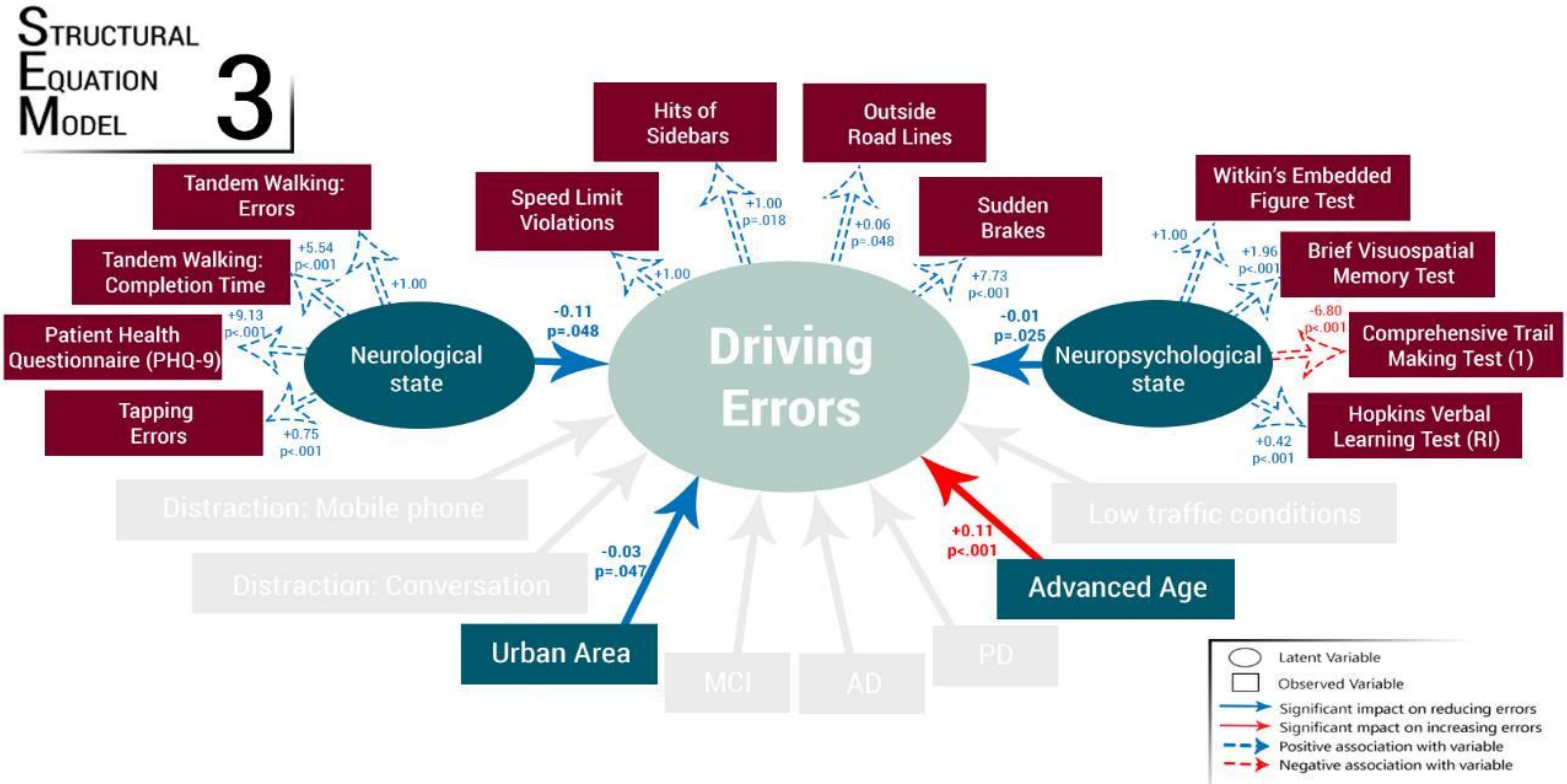
Latent variables	Est.	Std.err	Z-value	P(>|z|)
Driving Errors *(latent 1)*				
Speed Limit Violations	1.000			
Hits of Sidebars	1.000	0.421	2.374	**.018**
Outside Road Lines	0.059	0.034	1.961	**.048**
Sudden Brakes	7.731	2.339	3.306	**<.001**
Neuropsychological State *(latent 2)*				
Witkin's Embedded Figure Test	1.000			
Brief Visuospatial Memory Test	1.955	0.046	42.238	**<.001**
Comprehensive Trail Making Test (1)	-6.799	0.391	-17.385	**<.001**
Hopkins Verbal Learning Test (RI)	0.416	0.019	21.553	**<.001**
Neurological State *(latent 3)*				
Tandem Walking: Errors	1.000			
Tandem Walking: Completion Time	5.537	0.875	6.326	**<.001**
Patient Health Questionnaire (PHQ-9)	9.128	2.127	4.292	**<.001**
Foot taping errors	0.748	0.144	5.191	**<.001**

Regressions	Est.	Std.err	Z-value	P(>|z|)
Driving Errors				
Urban Area	-0.027	0.015	-1.960	**.047**
Advanced Age	0.106	0.033	3.230	**<.001**
Neuropsychological State *(latent)*	-0,005	0.002	-2.236	**.025**
Neurological State *(latent)*	-0.113	0.064	-1.992	**.048**

Summary statistics	ML
Minimum Function Test Statistic	1445.72
Degrees of freedom	73

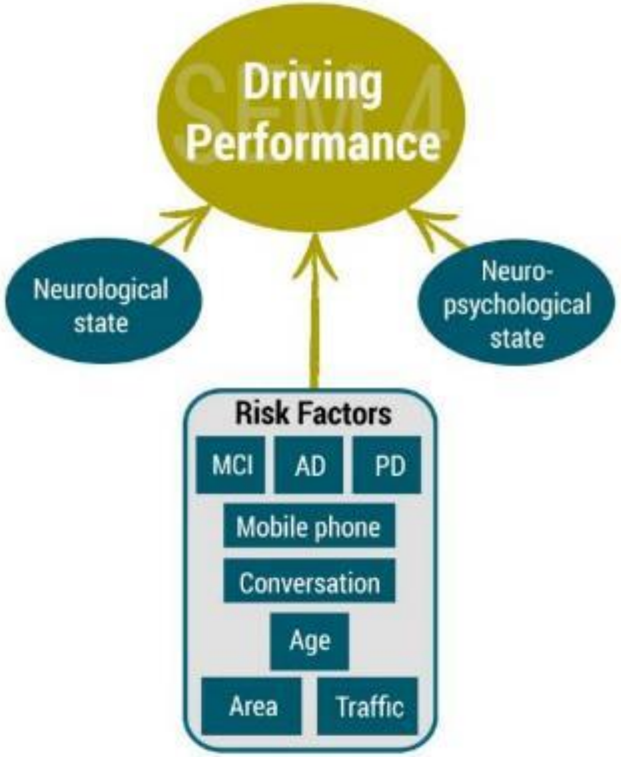
Goodness of fit	
SRMR	0.118
RMSEA	0.125
CFI	0.720
TLI	0.669

Step 5 - SEM regarding *DRIVING ERRORS*



Step 5 - SEM regarding *DRIVING PERFORMANCE*

- A critical finding that **supports the validity** of the overall SEM is that the contribution of the observed variables on the construction of the latent variables was in all case statistically significant
- **All predictors (except for conversing with passenger) had a significant contribution** on the prediction of the latent variable "driving performance"
- The obtained goodness-of-fit measures are **generally close to the respective limits**



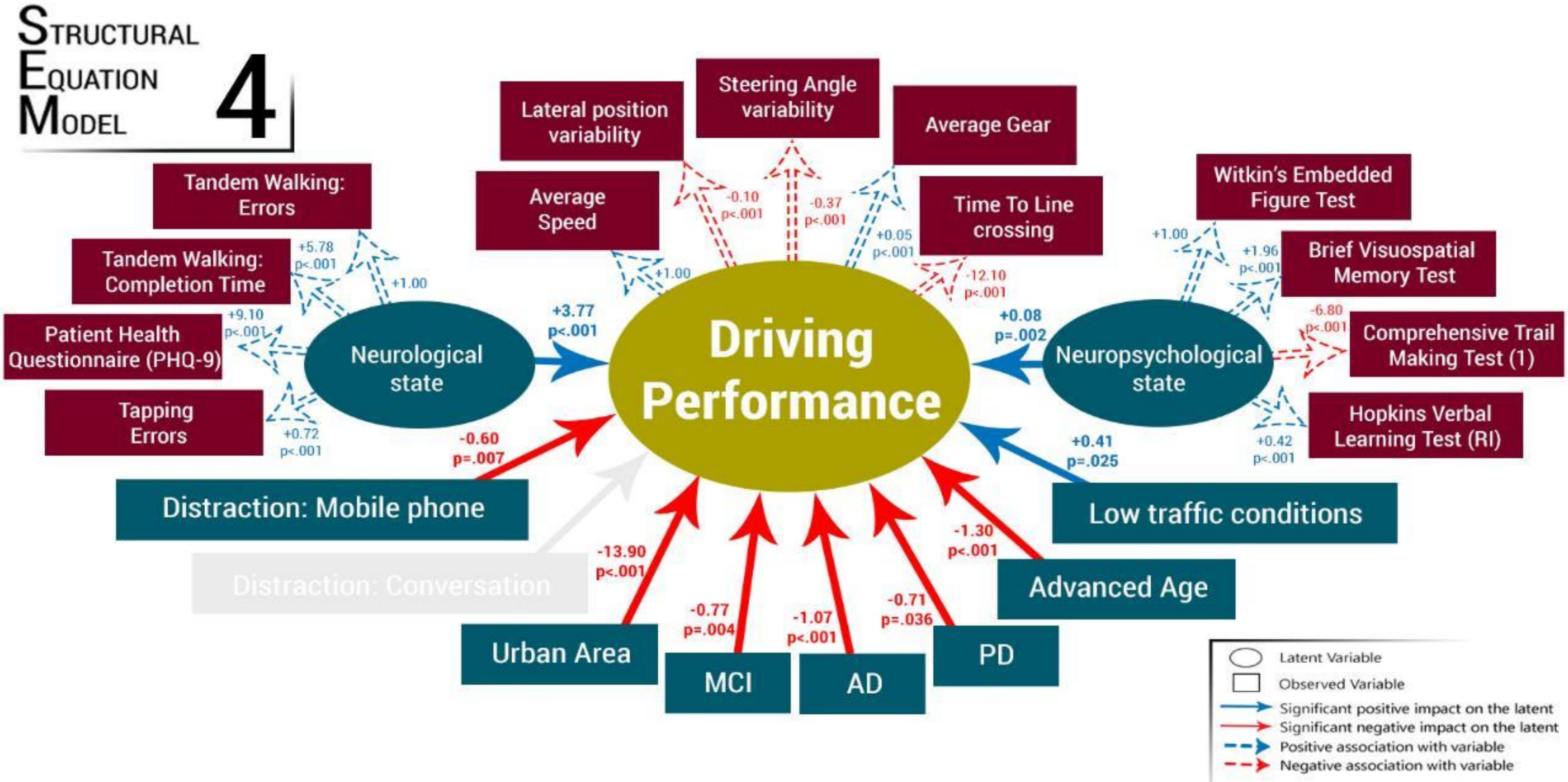
Latent variables	Est.	Std.err	Z-value	P(>|z|)
Driving Performance *(latent 1)*				
Average Speed	1.000			
Lateral Position Variability	-0.098	0.003	-29.483	**<.001**
Steering Angle Variability	-0.373	0.028	-13.303	**<.001**
Time to Line Crossing	-12.102	0.483	-25.039	**<.001**
Average Gear	0.049	0.002	29.762	**<.001**
Neuropsychological State *(latent 2)*				
Witkin's Embedded Figure Test	1.000			
Brief Visuospatial Memory Test	1.962	0.047	41.964	**<.001**
Comprehensive Trail Making Test (1)	-6.803	0.390	-17.430	**<.001**
Hopkins Verbal Learning Test (RI)	0.416	0.019	21.553	**<.001**
Neurological State *(latent 3)*				
Tandem Walking: Errors	1.000			
Tandem Walking: Completion Time	5.777	0.937	6.166	**<.001**
Patient Health Questionnaire (PHQ-9)	9.101	2.077	4.382	**<.001**
Foot taping errors	0.721	0.134	5.363	**<.001**

Regressions	Est.	Std.err	Z-value	P(>|z|)
Driving Performance				
Disease - MCI	-0.772	0.267	-2.889	**.004**
Disease - AD	-1.066	0.329	-3.237	**<.001**
Disease - PD	-0.705	0.336	-2.100	**.036**
Urban Area	-13.902	0.390	-35.638	**<.001**
Low Traffic Conditions	0.414	0.185	2.245	**.025**
Advanced Age	-1.296	0.235	-5.521	**<.001**
Distraction - Mobile Phone	-0.604	0.223	-2.701	**.007**
Neuropsychological State *(latent)*	0.082	0.026	3.174	**.002**
Neurological State *(latent)*	3.765	0.871	4.320	**<.001**

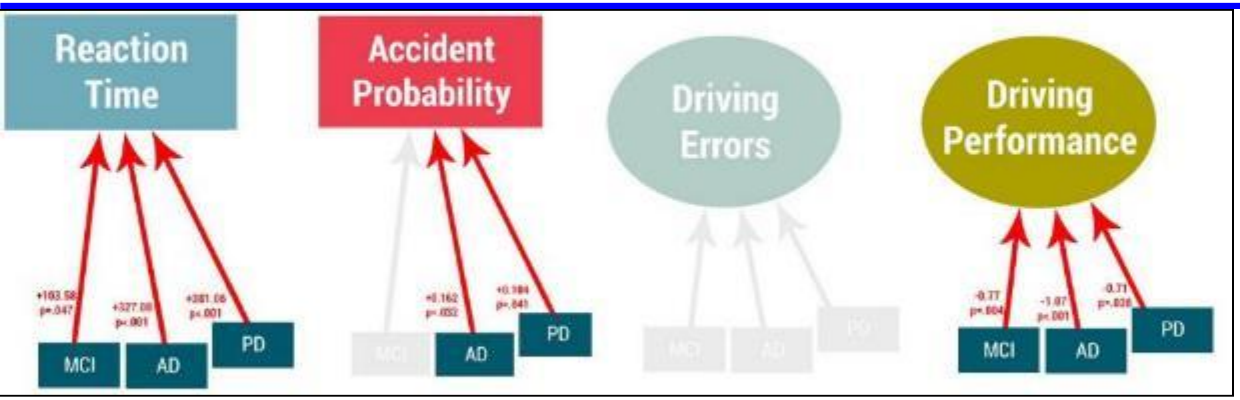
Summary statistics	ML
Minimum Function Test Statistic	3517.01
Degrees of freedom	146

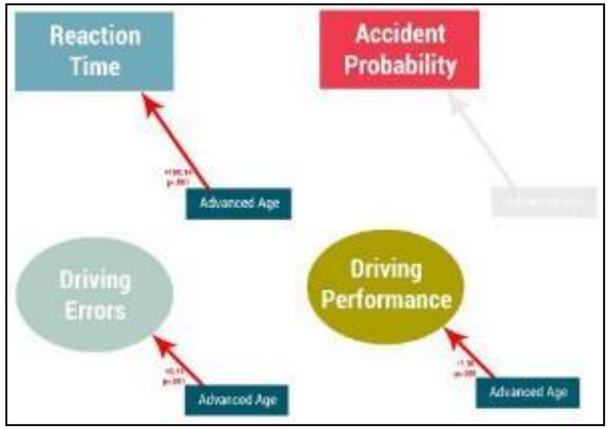
Goodness of fit	
SRMR	0.122
RMSEA	0.124
CFI	0.755
TLI	0.700

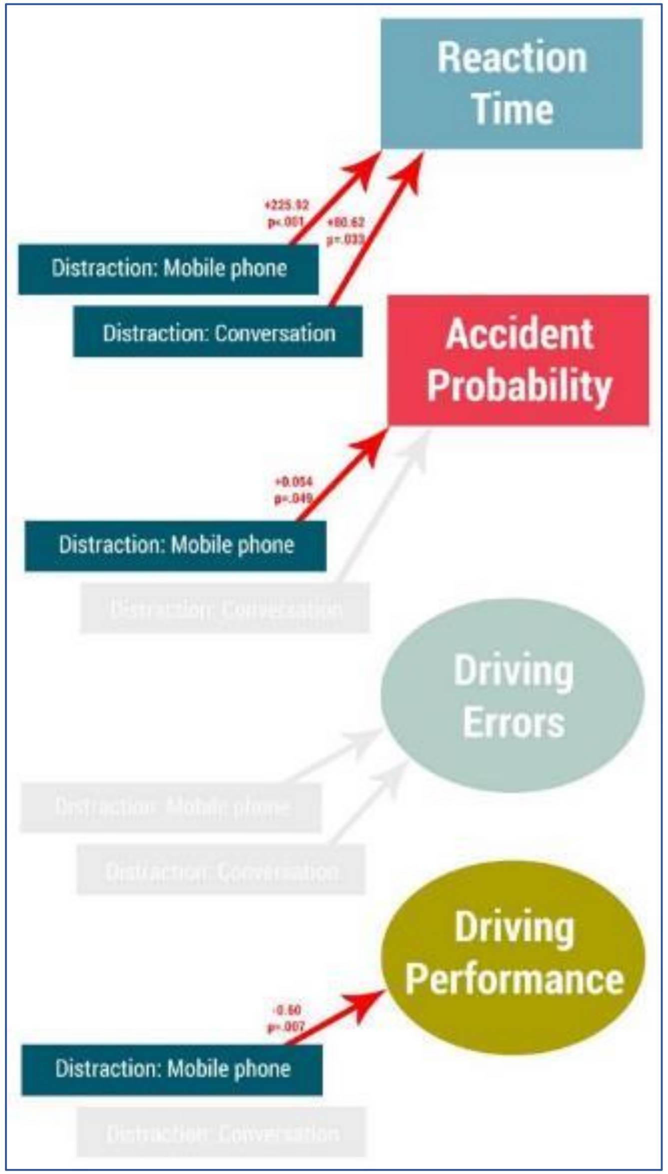
Step 5 - SEM regarding *DRIVING PERFORMANCE*

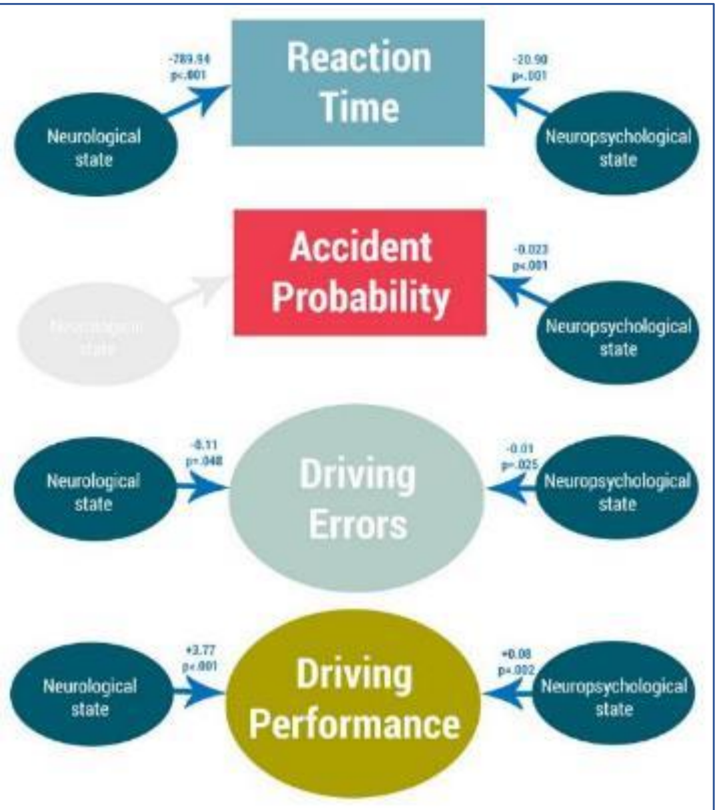


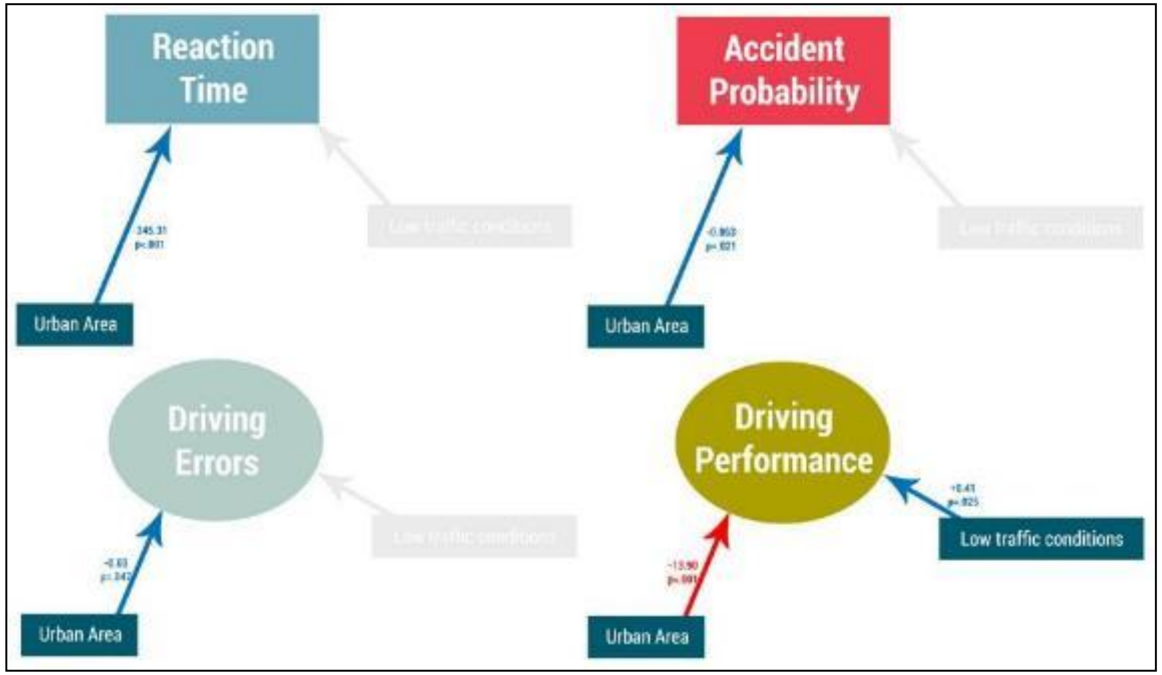
Step 5 - SEM Synthesis











5 PhD Dissertation Innovations

Methodological

1. **Implementation** of a large inter-disciplinary experiment involving medical, psychological and driving assessment

2. **Application** of an original integrated inter-disciplinary latent analysis methodology

Key research findings

3. **Quantification** of the impact of neurological diseases affecting cognitive functions, on drivers' traffic and safety behaviour

4. **Comparative** performance analysis of drivers with different neurological diseases affecting cognitive functions

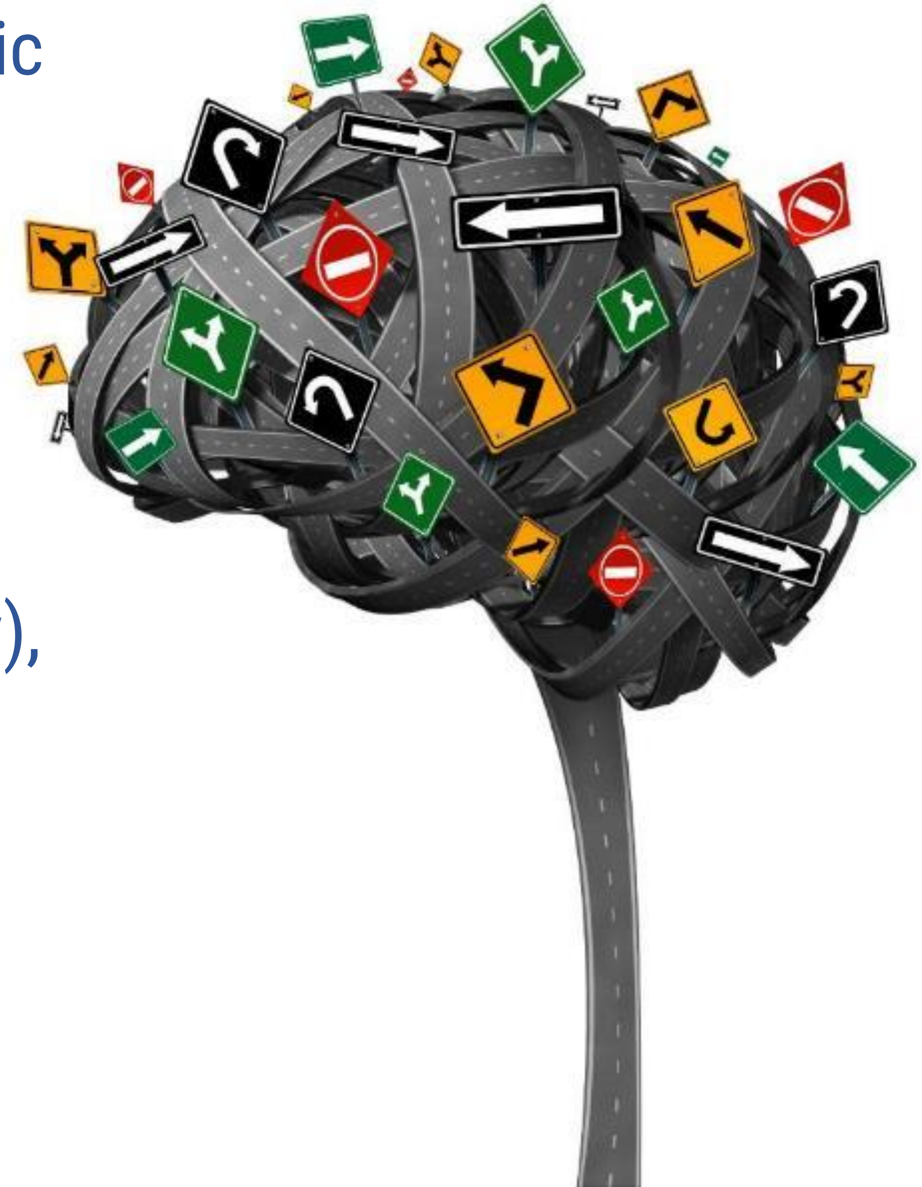
5. **Identification** of the impact of distraction on the performance of drivers with cerebral diseases

PhD Innovation 1/5

» The design and implementation of a large scale **inter-disciplinary experiment** which includes two scientific branches, a traffic engineering, and a medical (a neurological and a neuropsychological), is a central component of the present PhD thesis.

» Given the integration of **these different scientific disciplines involved in impaired driving research** (traffic engineering, neurology and neuropsychology), this PhD dissertation covers a research field with an obvious - but not previously exploited - multidisciplinary nature.

» **6 GB** of data after **1.400 hours** of assessments of **225 participants,** concludes to a master file



PhD Innovation 2/5

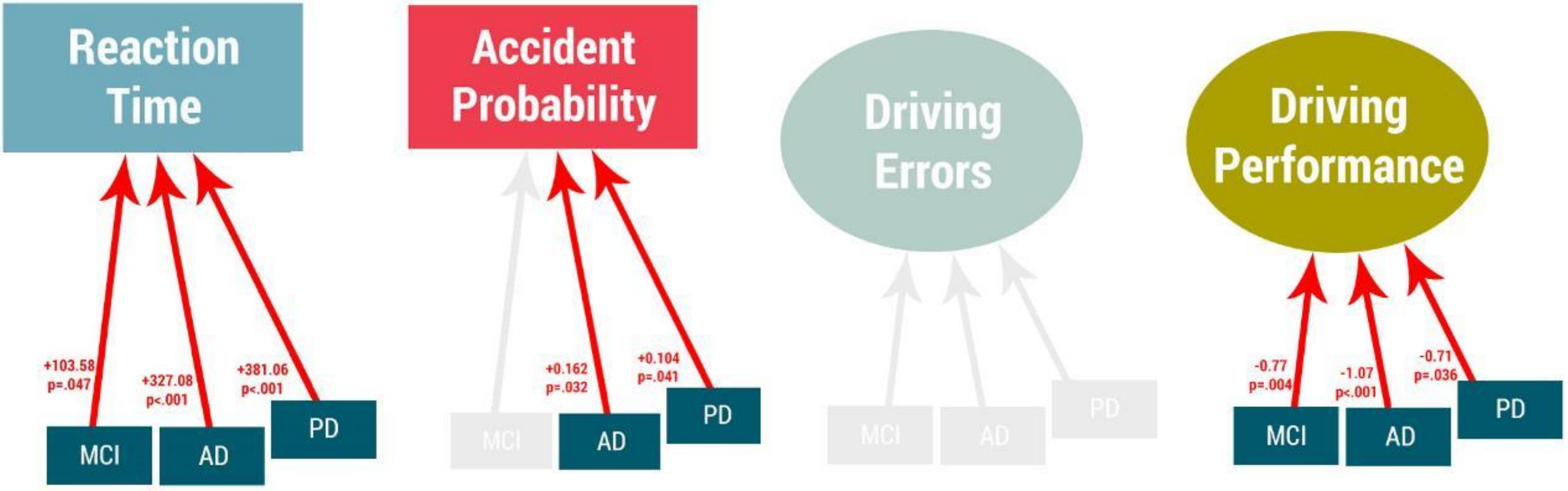
- The second innovation of this PhD dissertation is also methodological, suggesting the implementation of four latent variables covering all three fields of this inter-disciplinary PhD thesis: **"driving performance" and "driving errors"** extracted from the driving simulator experiment, **"motor skills"** extracted from the neurological database and **"cognitive fitness"** extracted from the neuropsychological database, in order to construct four Structural Equation Models (SEMs).
- **Interdisciplinary interaction between latent variables**

PhD Innovation 3/5

- The **quantification of the impact of** neurological diseases affecting cognitive functions **on drivers' traffic and safety behaviour** is an innovation which is the core of this PhD dissertation, regarding the key research findings.
- Patients are aware of their deterioration of their driving skills, they try to **compensate their driving behaviour** (low speeds, large headways, low variability in the steering angle) but they **have significantly worse reaction times and higher accident probability** than the healthy drivers.

PhD Innovation 3/5

- **The quantified analysis of the multivariate SEMs** about driving behaviour characteristics of the drivers, indicated that:
  - the presence of MCI, AD and PD **has detrimental impact on reaction time, accident probability and driving performance,** whereas their impact on driving errors isn't significant.



PhD Innovation 4/5

- The fourth innovation of this PhD dissertation is derived also from the key research findings and **concerns the comparative performance analysis** of drivers with different neurological diseases affecting cognitive functions
- The impact of **PD and AD is much more detrimental on reaction time**, comparing to the impact of MCI
- **MCI didn't have any significant impact on accident probability**, whereas **AD increased the accident probability by 16% and PD by 10%**.
- Summarizing, the innovative 4 comparative performance analyses of drivers with different neurological diseases affecting cognitive functions, indicated **AD as the riskiest group of drivers** (had the greatest impact on accident probability and driving performance and almost the greatest on reaction time), followed by PD, whereas the group of MCI is considered safer compared to the other two examined brain pathologies.

PhD Innovation 5/5

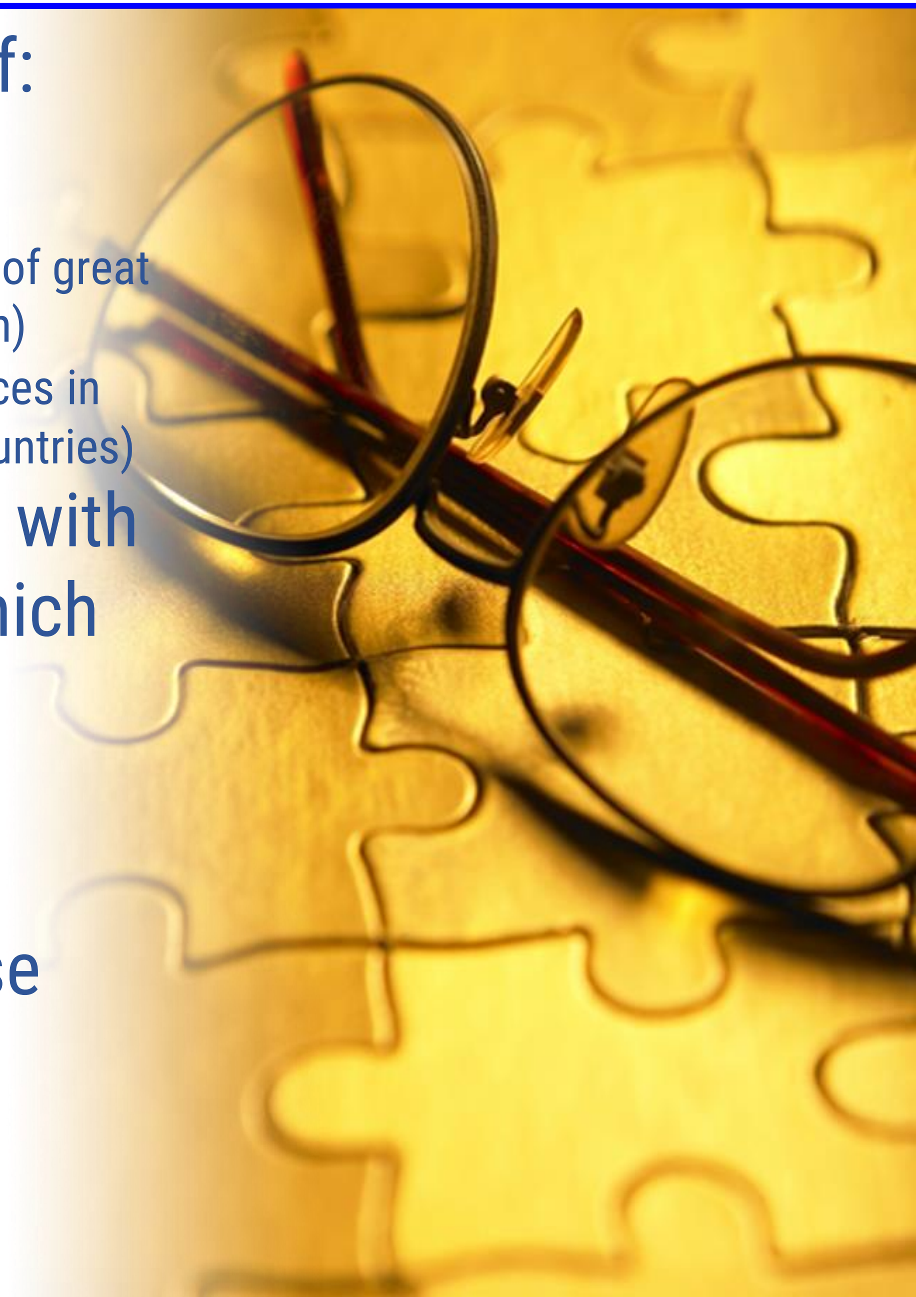
- The fifth innovation of this PhD dissertation concerns the **effect of distraction on the performance of drivers with MCI, AD and PD**, by exploring driving while conversing with a co-passenger and driving while conversing through a handheld mobile phone.

- Exploring and quantifying the impact of distraction on drivers with MCI, AD and PD **has not been addressed so far** among the international scientific community.

- It appeared that the distraction conditions didn't have such a significant impact on several driving performance measures in the group of controls, in contrast with the findings extracted from **the patients' groups regression analyses in which the impact of distraction and especially the mobile phone use was detrimental**.

Future challenges 1/2

- **Sample schemes should be strengthened** in terms of:
  - **size** (more participants with MCI, AD and PD)
  - **the type of the neurological diseases affecting cognitive functions** (participants with REM Behaviour Disorder, Frontotemporal Dementia etc. are of great interest regarding their driving behaviour and could be inserted in the research)
  - **location and origin** (MCI, AD and PD drivers in Greece may present differences in driving behaviour with drivers of the same brain pathologies living in other countries)
- **Periodically assess** the driving behaviour of patients with cerebral diseases over time, in order to identify to which extent, **the progression of the disease deteriorates several driving performance measures**
- **More latent variables** could be developed and investigated, depending on the experimental database and the specific research questions
- SEMs can be developed on **on-road and naturalistic experiments** or field survey studies



Future challenges 2/2

- It is important to take into consideration that every driver with a neurological disease affecting cognitive functions **should be treated individually**, through a modern interdisciplinary driving evaluation

- The results of this PhD thesis can potentially contribute to a **significant reduction in road accidents** and related casualties, which are especially prevalent in Greece, if the data and the results extracted, will be **exploited by the authorities in order to implement appropriate road safety policy** directions regarding the vulnerable group of drivers with neurological diseases affecting cognitive functions