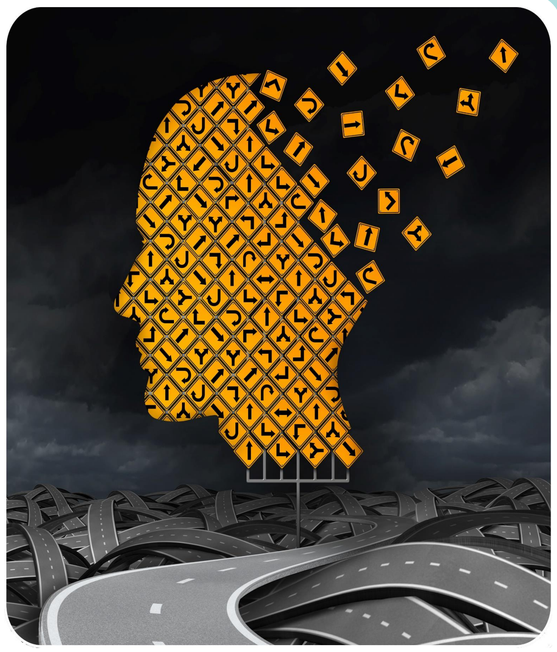
WHICH ARE THE CRITICAL MEASURES TO ASSESS THE DRIVING PERFORMANCE OF DRIVERS WITH BRAIN PATHOLOGIES?

D. Pavlou[a], I. Beratis[b], E. Papadimitriou[a], C. Antoniou[a], G. Yannis[a], S.G. Papageorgiou[b]

[a]Department of Transportation Planning and Enginnering, NTUA, 5 Heroon Polytechniou str., GR-15773, Athens, Greece

[b] 2nd Department of Neurology, "Attikon" University General Hospital, NKUA, 75 Mikras Asias str., GR-11527, Athens, Greece

Overview



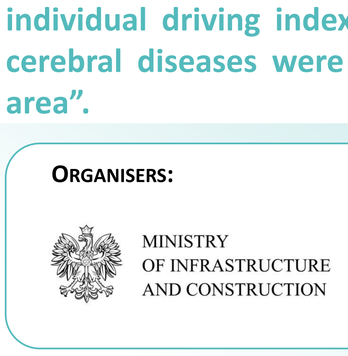
- The objective is to **identify the driving performance measures in which drivers with brain pathologies significantly deviate** from the general population.
- A driving simulator experiment: **109 drivers with cognitive impairments** (MCI, AD and PD) vs **31 healthy drivers** of similar demographics, compared at the following parameters: **mean speed, time headway, lateral position, reaction time at incidents**
- **Hypothesis:** the presence of a brain pathology has a negative effect on the driving performance measures.
- All driving indexes were compared to the range of **"typical" values** of the respective distribution of healthy drivers. Thus, we expected that **the group of patients significantly deviate** from the range of "typical values" of the control group, in most cases.

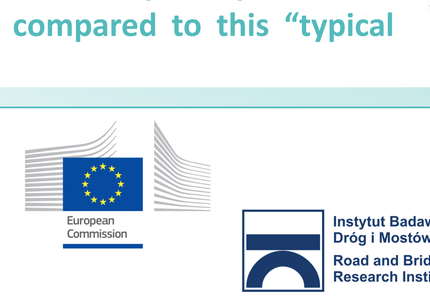
Overview of the experiment

- **Medical/neurological assessment**: a full clinical medical, ophthalmological and neurological evaluation
- **Neuropsychological assessment**: a series of neuropsychological tests and psychological - behavioural questionnaires to the participants
- **Driving at the simulator**: assessing the driving behaviour of participants by means of programming of a set of driving tasks into a driving simulator for different driving scenarios.

Driving at the simulator assessment

- **Quarter-cab driving simulator** manufactured by the FOERST Company
  - 3 LCD wide screens 42'', full HD: 1920x1080pixels
  - total field of view 170 degrees, validated against a real world environment
- At first, **one practice drive** (usually 10-15 minutes)
- Afterwards, the participant drives **two sessions** (approx. 10 minutes each)
- Each session corresponds to a different road environment:
  - **a rural route**, single carriageway, zero gradient, mild horizontal curves
  - **an urban route**, at its bigger part dual carriageway, separated by guardrails. Two traffic controlled junctions, one stop-controlled junction and one roundabout are placed along the route.
- During each trial, **2 unexpected incidents** are scheduled to occur:
  - sudden appearance of an animal (deer or donkey) on the roadway
  - appearance of a child chasing a ball on the roadway or of a car suddenly getting out of a parking position.



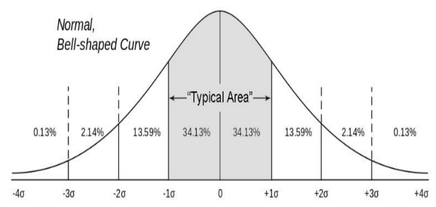


Sampling size

- **140 participants** (all more than 55 y.o. and of similar demographic characteristics):
- **31 Healthy Controls** (aver. 64.5 y.o., 20 males)
- **109 Patients** (aver. 69.0 y.o., 80 males):
- 25 AD (aver. 75.4 y.o.), 59 MCI (aver. 70.1 y.o.), 25 PD (aver. 66.1 y.o.)

Analysis method

Control groups' mean values minus one standard deviation and plus one standard deviation include 68.26% of the values of healthy controls (according to the normal distribution). This area is defined by our research team as the **"typical area"**. **The individual driving indexes of all participants with cerebral diseases were compared to this "typical area".**



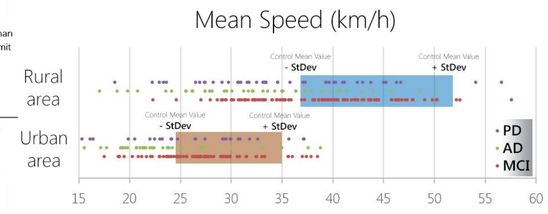
Results

The between-group comparisons in the 7 key driving performance indexes indicated **significant differences** between the two groups in **mean speed in both driving areas, headway in rural area, and reaction time**. Patients with brain pathologies drove at lower speeds, had less variability in their mean speed, kept larger headways and had significantly worse reaction times than their cognitively intact counterparts.

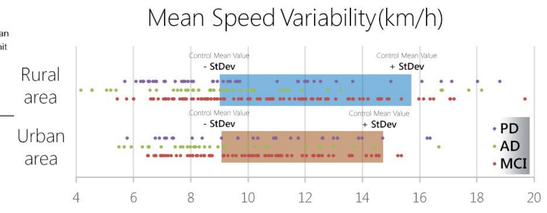
Comparison of patients with brain pathologies and of a Control group without neurological history on the 7 driving measures in rural and urban area, with the use of the Wilcoxon Rank Sum Test

	Group of patients	Control group	P-values
Mean Speed - Rural	36.5±8.0	44.3±7.5	**0.010****
Mean Speed - Urban	25.8±5.6	29.7±5.2	**0.041****
Mean Speed Variability - Rural	10.3±3.3	12.4±3.3	0.071*
Mean Speed Variability - Urban	10.1±2.7	11.9±2.8	0.113
Time Headway - Rural	63.9±42.8	39.1±23.6	**0.021****
Time Headway - Urban	42.9±21.4	40.6±30.0	0.090*
Time Headway Variability - Rural	179.8±117.1	170.0±102.5	0.113
Time Headway Variability - Urban	248.7±136.6	249.2±168.8	0.467
Lateral Position - Rural	1.5±0.2	1.5±0.1	1.000
Lateral Position - Urban	3.4±0.6	3.1±0.6	0.545
Lateral Position Variability -Rural	0.3±0.1	0.3±0.1	1.000
Lateral Position Variability - Urban	1.9±0.5	1.6±0.6	0.189
Reaction Time - Rural	2207.2±728.8	1644.4±531.5	**0.001****
Reaction Time - Urban	1618.2±361.9	1360.6±418.9	**0.001****

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%



StDev of Mean Speed		below lower limit	inside the "typical area"	higher than upper limit
Rural Area	PD	50%	39%	11%
	AD	49%	42%	9%
	MCI	37%	55%	8%
Urban Area	PD	32%	61%	7%
	AD	59%	38%	3%
	MCI	32%	65%	3%

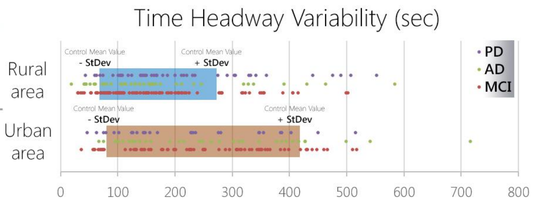


- Drivers with cerebral diseases were found to drive at **lower speeds** compared to the healthy control group drivers.
- AD patients drive significantly slower than the controls at the **68%** of the cases.
- Patients had significantly lower speed variability (**43%** of the cases) than the group of controls.

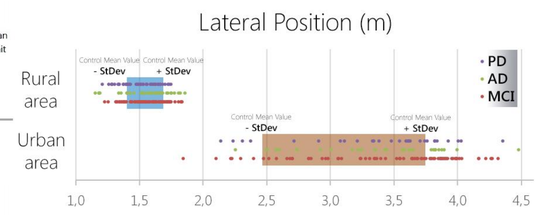
- **44%** of the drivers with a brain pathology in rural area have keep very large time headways
- In urban area this percentage is significantly lower (**12%**)
- **20%** of the patients have very large variability in their time headways whereas **12%** has significantly lower

Time Headway		below lower limit	inside the "typical area"	higher than upper limit
Rural Area	PD	0%	48%	52%
	AD	0%	51%	49%
	MCI	5%	63%	32%
Urban Area	PD	0%	93%	7%
	AD	0%	75%	25%
	MCI	1%	95%	4%

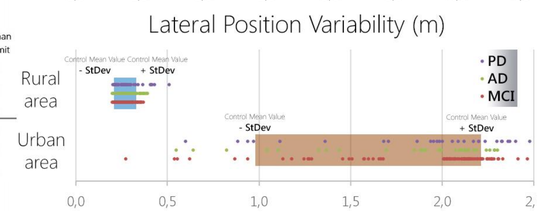
StDev of Time Headway		below lower limit	inside the "typical area"	higher than upper limit
Rural Area	PD	7%	64%	30%
	AD	19%	65%	16%
	MCI	10%	71%	19%
Urban Area	PD	14%	79%	7%
	AD	6%	78%	16%
	MCI	13%	75%	12%



Lateral Position		below lower limit	inside the "typical area"	higher than upper limit
Rural Area	PD	30%	61%	9%
	AD	14%	67%	19%
	MCI	15%	66%	19%
Urban Area	PD	14%	57%	29%
	AD	3%	69%	28%
	MCI	8%	52%	40%



StDev of Lateral Position		below lower limit	inside the "typical area"	higher than upper limit
Rural Area	PD	7%	77%	16%
	AD	7%	63%	30%
	MCI	7%	81%	12%
Urban Area	PD	14%	57%	29%
	AD	9%	75%	16%
	MCI	8%	71%	21%

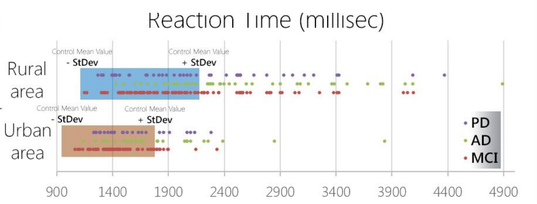


- Urban and rural areas cannot be compared because of different road width

- **32%** of patients in urban area drive closer to the right border of the road
- Overall, **40%** of drivers with cerebral disease are out of the typical value
- **21%** of the patients have very large variability in their lateral position

- **45%** of the patients in rural area and **26%** in urban area have larger reaction times than the control group (especially the AD group: **50%**)

Rection Time		below lower limit	inside the "typical area"	higher than upper limit
Rural Area	PD	0%	57%	43%
	AD	0%	40%	60%
	MCI	0%	69%	31%
Urban Area	PD	0%	74%	26%
	AD	0%	60%	40%
	MCI	0%	87%	13%



Conclusions

- The low mean speed of the group of patients and their low variabilities, indicate **conservative driving behaviour and self-regulation** of their driving behaviour.
- **The more complex the driving environment is**, the more difficult is for the patients to maintain the position of the vehicle in the lane.
- Participants with brain pathologies **had significantly longer reaction times** in both rural and urban areas in comparison to the control group.
- 70% of the patients with cerebral diseases had **reaction times larger than 2 sec**.
- **The critical road safety measures** to assess the driving performance of drivers with brain pathologies are the **mean speed, the lateral position variability and the reaction time**, but more importantly the critical measure is the **combined assessment**, in order to have a complete driving profile of each driver.
- This driving performance profile could provide quite **useful information for the formulation of efficient driving recommendations** which have the capacity to reduce the accident risk in a sensitive group of car drivers, such as MCI, AD or PD.

Acknowledgements

This paper is based on two research projects implemented within the framework of the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF), namely the Research Funding Program: THALES. Investing in knowledge society through the European Social Fund, and the Action: ARISTEIA (Action's Beneficiary General Secretariat for Research and Technology), co-financed by the European Union (European Social Fund) and Greek national funds.

ORGANISERS: MINISTRY OF INFRASTRUCTURE AND CONSTRUCTION; European Commission; Instytut Badawczy Dróg i Mostów, Road and Bridge Research Institute; CEDR Conférence Européenne des Directeurs des Routes, Conference of European Directors of Roads; ERTRAC European Road Transport Research Advisory Council

SUPPORTED BY: ERRAC The European Rail Research Advisory Council; WATERBORNE TP; alice Alliance for Logistics Innovation through Collaboration in Europe; ETRA; ECTP INNOVATIVE BUILT ENVIRONMENT; The National Centre for Research and Development