



National Technical University of Athens School of Civil Engineering Department of Transportation Planning and Engineering

Traffic and safety behaviour of drivers with neurological diseases affecting cognitive functions PART 1/2 A Doctoral Thesis presentation by

Dimosthenis I. Pavlou

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Objectives and scope of the PhD thesis

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covers a field of research with an **obvious and unique interdisciplinary nature**, which has not been examined in the past.

Inter-disciplinary

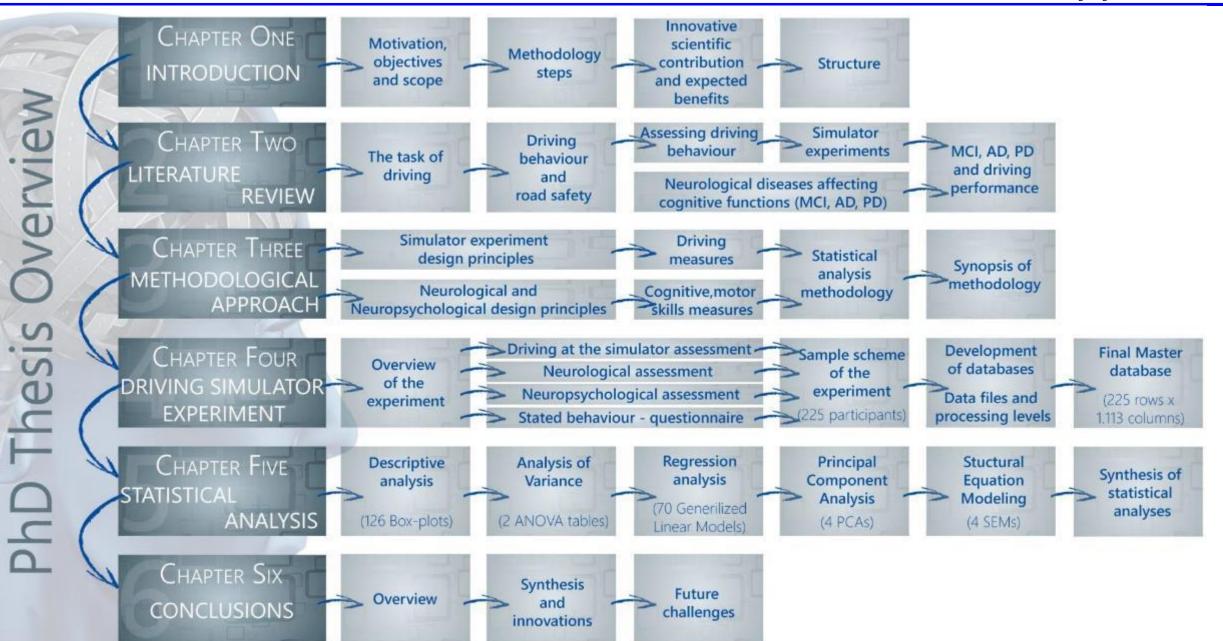
Traffic and safety behaviour of drivers with Neurological diseases affecting cognitive functions Mild Cognitive Impairment (MCI)

> Alzheimer's Disease (AD)

Parkinson's Disease (PD)

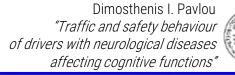
PhD Overview





Driving Behaviour and Road Safety

- » Driving in traffic is more than just knowing how to operate the mechanisms which control the vehicle
- » Road accidents constitute a major social problem in modern societies (eighth leading cause of fatalities globally and the leading cause of fatalities for young people aged 15-29 years), in 2015:
 - » 1.2 million fatalities worldwide
 - » 26.000 in the European Union
 - » 805 in Greece



Human factors and driving behaviour





- Human factors are the basic causes in 65-95% of road accidents
 - Human factors involve a large number of specific factors that may be considered as accident causes, including:
 - » 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 (mobile phone use, conversation with passenger etc.)
 - » Driver impairment (cerebral diseases, alcohol, fatigue etc.)

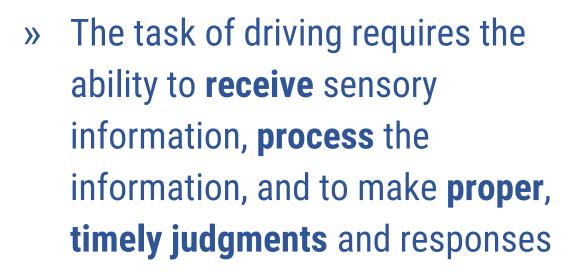
Types of assessing driving performance



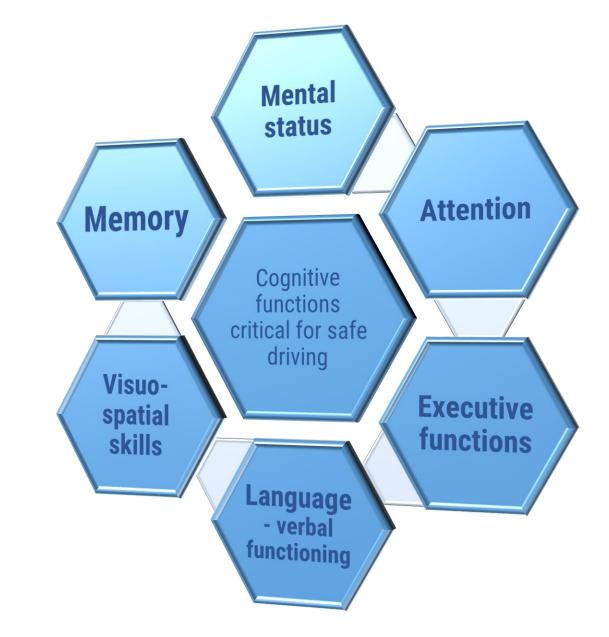
Experiment type	Method / tools	Advantages	Limitations
	Instrumented vehicle	 » Large degree of control over the variables, » Examination of driver competency 	
Naturalistic driving	Systems installed in participants' own vehicles	» Understanding normal traffic,» Observation of conflicts	 » No experimental control of variables, » Traffic incidents are very rare, » Driver behaviour may not be representative,
Driving simulator experiments	Driving simulator	 » Safe environment, » Greater experimental control, » Large range of test conditions 	 » Learning effect, » Simulator sickness, » Very expensive
In-depth accident investigation	Trained experts investigate the causes of an actual accident	 » Identification of the factors contributing to an accident, » Research into injury prevention 	 » Insufficient reconstruction evidence, » Long time period
Surveys on opinion and stated behaviour	Questionnaire	 » Investigate new situations, » Large amount of data in a short time, » Low cost 	 » Hypothetical questions, » Data lack details, » Self-reported data

Cognitive functions critical for safe driving

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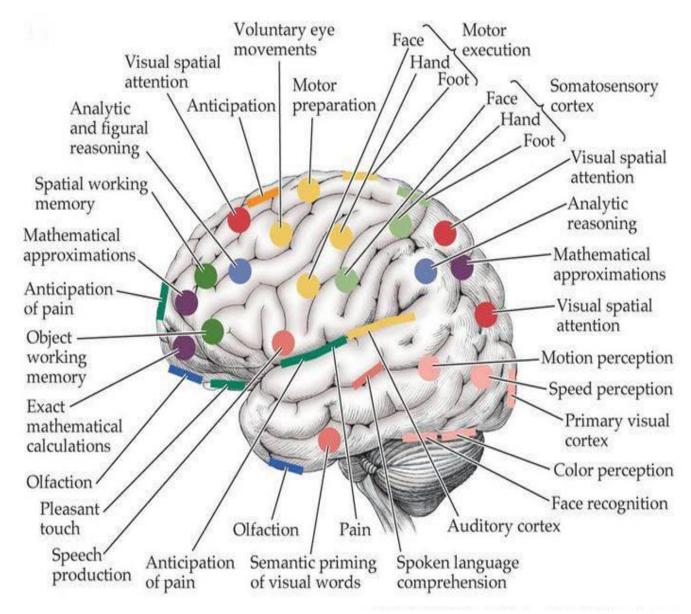
 » Cognitive functions related to driving may be categorized into six neuropsychological domains



Cognitive functions



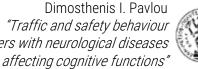
- » Cognition is "the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses."
- It encompasses processes such as **>>** knowledge, attention, memory and working memory, judgment and evaluation, reasoning and "computation", problem solving and decision making, comprehension and production of language, etc.



Neurological diseases affecting cognitive functions of drivers with neurological diseases

>>

>>



- **Mild Cognitive >>** Impairment (MCI) is the cognitive state that lies between normal aging and dementia
- A typical MCI patient is **>>** one who has a memory impairment beyond what is felt to be normal for age, but is relatively intact in other cognitive domains
- MCI can evolve as a result **>>** of a neurodegenerative process, such as Alzheimer's disease

Alzheimer's disease (AD) is **>>** increasingly being recognized as one of the most important medical and social problems in older >> people and accounts for 60% to 70% of cases of dementia It is a chronic neurodegenerative disease that usually starts slowly and gets worse over time. The most common early symptom is difficulty in remembering recent events (short-term memory loss)

Parkinson's disease (PD) is a degenerative disease of central nervous system that has an impact mainly on motor function Symptoms: tremor, slowness of movement, rigidity, impaired posture and balance

Thinking and behavioural problems may arise, with dementia commonly occurring in the advanced stages of the disease

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Mild Cognitive Impairment and driving

- » Reviewing studies about drivers with MCI: Studies assessing driving performance through on road testing, indicate that although MCI patients experience subtle changes in their driving competence, they are still able to drive.
- » However, a level of impairment compared to healthy controls is generally being reported meaning that they still constitute a population at risk that warrants close supervision.
- » Studies on simulator environments have demonstrated that individuals with MCI are deficient in a number of variables compared to their healthy counterparts.



Alzheimer's Disease and driving



- » Reviewing studies about drivers with AD, driving performance declines considerably in individuals with AD and several on-road and simulator studies indicated worse driving performance for AD group compared to healthy controls in several driving measures.
- » Early AD patients may attempt to compensate for their reduced driving skills by limiting the number and length of own driving trips, by avoiding demanding driving situations and by driving at reduced speeds.
- » Ideally, neuropsychological tests should be used in combination with other measures, such as findings from a neurological assessment and the administration of actual or simulated road tests, to allow for driving recommendations.

Parkinson's Disease and driving

- » Reviewing studies about drivers with PD: driving capacity in patients with PD is mainly compromised due to cognitive deficits.
- » Pronounced difficulties in several indexes of driving performance appear in drivers with PD under demanding driving conditions that involve increased cognitive load.
- » The use of multiple measures, apart from driving experiments, that assess various driving domains appears to be essential.



Driving performance of drivers with MCI, AD, Portuge of diseases affecting cognitive functions"

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		Diagnosis		Sampl	le			Тур	e of				[Drivin	g Perf	ormai	nce Me	easure	S						
Diagnosis		Schem	e			assess	ments					with	Signi	ficant	differ	ences									
Authors		MCI	AD	PD	Controls	sample size	age <55	age >55	on road	driving simulator	neurological /neuropsychological	questionnaire	driving errors	speed (+ variability)	lateral position (+variability)	reaction time	accident risk	headway	left turns	time to collision	confusion or disorientation	seat-belt use	significant differences only in neuropsychological tests	overall worse driving	perform ance
1 Wadley et al.	2009	•	-	-	•	105 (46+59)	-	•	•	-	•	•			•				•					•	
2 Snellgrove	2005	•	-	-	-	115	-	•	•	-	•	-	•	•	•									•	
3 Griffith et al.	2013	•	-	-	•	49 (15+34)	-	•	•	-	•	•	•		•									•	5/8
4 Bowers	2013	•	-	-	-	47	-	•	•	-	•	-	•	•										•	S.
5 Devlin et al.	2012	•	-	-	•	28 (14+14)	-	•	-	•	•	•	-	-	-	-		-	-	-				-	MCI:
6 Kawano et al.	2012	•	-	-	•	57 (12+45)	•	•	-	•	•	•				-		•						0	Ξ
7 Fritteli et al.	2009	•	•	-	•	60	-	•	-	•	•	•	•			•				•				•*	
8 Pavlou et al.	2015	•	•	-	•	75	-	•	-	•	•	•		•	•	•		•						•	
9 Hunt et al.	1997	-	•	-	•	123 (65+58)	-	•	•	-	•	-	•											•	
10 Fitten	1995	-	•	-	•	69 (27+42)	•	•	•	-	•	-	•											•	
11 Bieliauskas et al.	1998	-	•	-	•	18 (9+9)	-	•	•	-	•	-	•			•								•	
12 Uc et al.	2004	-	•	-	•	168	-	•	-	•	•	-	•						•		•			•	<u></u>
13 Ott et al.	2008	-	•	-	•	128 (84+44)	-	•	•	-	•	•					•							•	12/13
14 Dawson et al.	2009	-	•	-	•	165	-	•	-	•	•	•	•											•	12
15 Eby et al.	2012	-	•	-	•	43 (17+26)	-	•	•	-	•	•		•							•	•		-	AD:
16 Cox et al.	1998	-	•	-	•	50 (29+21)	-	•	-	•	•	•	•	•					•		•			•	A
17 Rizzo et al.	2001	-	•	-	•	30 (18+12)	-	•	-	•	•	-				•	•							•	
18 Uc et al.	2006	-	•	-	•	176	-	•	-	•	•	-		•	•	•	•			•				•	
19 Vaux et al.	2010	-	•	•	•	32 (6+8+18)	-	•	-	•	•	-								•				•	
20 Ranchet et al.	2013	-	-	•	•	40 (19+21)	-	•	•	-	•	•		•	•		•	•						•	
21 Heikkila et al.	1998	-	-	•	•	40 (20+20)	-	•	•	-	•	•	•											•	
22 Grace et al.	2005	-	-	•	•	39 (18+21)	-	•	•	-	•	•											•	-	0
23 Uc et al.	2006	-	-	•	•	230	-	•	•	-	•	•	•										•	•	8/10
24 Uc et al.	2009	-	-	•	•	168	-	•	•	-	•	•	•											•	00
25 Singh et al.	2007	-	-	•	-	154	-	٠	•	-	•	•				0								0	ä
26 Lee et al.	2007	-	-	•	•	200	-	٠	•	•	•	•	•	•	•		•							•	
27 Classen et al.	2011	-	-	•	•	82 (41+41)	-	•	•	-	•	•	•											•	
28 Pavlou et al.	2015	-	-	•	•	62 (21+41)	-	•	-	•	•	•	•	•	•	•	•	•						•	
*only for the AD group	Total	8	13	10					17	12			16	9	8	6	6	4	3	3	3	1	2		

Methodological Approach



- » Driver behaviour of patients with cerebral diseases is a multidimensional phenomenon which means that no single driving measure can capture all effects
- A lot of different methods and measures exist for evaluating driving performance including lateral control, longitudinal control, reaction time, eye movement and workload measures
- » The neurological experimental design should deal with several domains (memory, orientation in time/space, motor system, daily activities, emotional state, sleep behavior and motor abilities)
- » The neuropsychological experimental design should deal with several cognitive domains (global cognitive status, verbal memory and learning, verbal working memory, visual scanning and spatial memory and learning, visuospatial perception and working memory, constructional ability, attention/information processing speed/perception, selective and divided attention, executive functions and psychomotor vigilance)

Statistical Approach

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Statistical Approach

Statistical approach in international literature regards **descriptive statistics, t-tests and «pass or fail» results**.

Latent model analysis and especially structural equation models have never been implemented in the field of driver behaviour of patients with brain pathologies

Driving Simulator Experiment

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The objective of the **>>** following slides is to present the experiment design both in terms of conceptual framework and implementation as well as to record basic parameters regarding the data storage/processing and sample characteristics.

Inter-disciplinary driving simulator experiment or

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» Driving at the simulator:

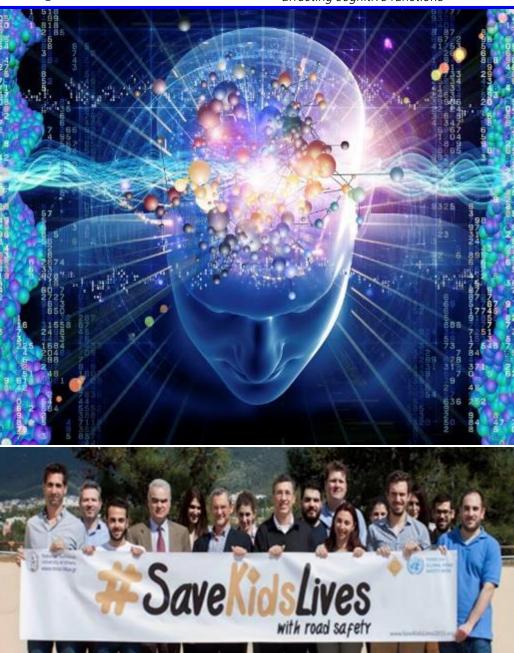
» a set of driving tasks into a driving simulator for different driving scenarios

» Medical/neurological assessment:

» administration of a full clinical medical, ophthalmological and neurological evaluation, in order to well document the characteristics of each of these disorders

» Neuropsychological assessment:

» administration of a series of neuropsychological tests and psychological - behavioural questionnaires to the participants which cover a large spectrum of Cognitive Functions: visuospatial and verbal episodic and working memory, general selective and divided attention, reaction time, processing speed, psychomotor speed etc.



Inclusion criteria and ethical issues

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All participants should:

- » have driving experience of more than 3 years
- » have driven more than 2500km during the last year
- » have driven at least 10km/week during the last year
- » not have important psychiatric history for psychosis
- » not have any important kinetic disorder that prevent them from basic driving moves
- » not have dizziness or nausea
- » not be pregnant
- » not be an alcoholic or had any other drug addiction
- » not have any important eye disorder that prevent him from driving safely
- » not have any disease of the Central Nervous System

- » The study was approved by the Ethics Committee of the University General Hospital "ATTIKON".
 - » it was explained to them that participation was on a voluntary basis and that they had the right to withdraw any time they wished to.
 - » participants were ensured of the anonymity and confidentiality of the procedure.
 - » no compensation was offered.

Driving simulator

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» Quarter-cab driving simulator manufactured by the FOERST Company

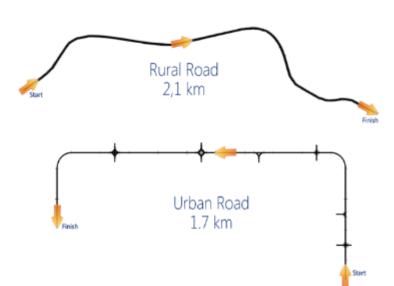
3 LCD wide screens 42" (full HD: 1920x1080pixels) - total field of view 170 degrees

» Validated against a real world environment

"Driving at the simulator assessment"



- » **1 practice drive** (usually 15-20 minutes)
- » **1 rural route** (2,1km long, single carriageway, 3m lane width)
- **1 urban route** (1,7km long, at its bigger part dual carriageway, 3.5m lane width)
- » 2 traffic scenarios for each route:
 - » **Q**_L: Moderate traffic conditions (Q=300 vehicles/hour)
 - » **Q**_H: High traffic conditions (Q=600 vehicles/hour)
- » 3 distraction conditions for each route:
 - » Undistracted driving
 - » Driving while conversing with a passenger
 - » Driving while conversing on a hand-held mobile phone
- **» 2 unexpected incidents** scheduled to occur during the trial:
 - » Sudden appearance of an **animal** (deer or donkey) on the roadway
 - » Sudden appearance of a child chasing a ball on the roadway or of a car suddenly getting out of a parking position.





Scenarios design



» Sequence of trials - Randomized » The purpose of randomization is to remove bias and other sources of extraneous variation, which are not controllable

- » Full factorial within-subject design
 - » 12 trials in total
 - » 40 minutes of driving

	Road Traffic Conditions						
	Urban	Area					
Distraction Sources	Low traffic	High traffic	Low traffic	High traffic			
No distraction condition	*	*	*	*			
Conversation with passenger	*	*	*	*			
Conversation through mobile phone	*	*	*	*			

"Driving at the simulator assessment"

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» VIDEO

Neurological Assessment

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The Medical/Neurological **>>** assessment concerns the administration of a full medical, clinical and neurological evaluation including a thorough medical and neurological examination and taking of a detailed background history of all the participants, in order to identify the existence of disorders (MCI, AD and PD) affecting cognitive functions.

» The Clinical Neurological Assessment includes the completion of the following 14 neurological scales + 4 motor ability test + ophthalmological examination (2.5 hours of testing)

Domain	Tests
Memory, orientation in time/space, judgment and problem solving, community affairs, home activities	Clinical Dementia Rating Scale (CDR)
Differentiation of the commonest dementia types	Hachinski Ischemic Scale
Motor system	Unified Parkinson's Disease Rating Scale-motor (UPDRS-Motor), Hoehn & Yahr Scale (H&Y)
Behavior in relation to brain diseases	Neuropsychological Inventory (NPI) Frontal Behavior Inventory (FBI)
Daily activities	Instrumental Activities of Daily Living (IADL), Functional Activities Questionnaire (FAQ), Informant Questionnaire on Cognitive Decline in Elderly (IQ-CODE)
Emotional state	Geriatric Depression Scale (GDS), PHQ-9
Sleep behavior	Parkinson's Disease Sleeping Scale-2 (PDSS-2), Athens Insomnia Scale (AIS), Epworth Sleepiness Scale
Motor abilities: Gait-balance-speed	Rapid Paced Walk
Motor abilities: Visual field, Ability to perceive objects in field of view, Time of reaction.	Head and Trunk rotation task (modified)
Motor abilities: Balance, movement coordination, mistakes and time of execution	Alternate foot tapping (modified), Tandem Walking at 2 meter distance

Neuropsychological Assessment



- The neuropsychological assessment **>>** includes a detailed screening of various cognitive domains with the use of appropriate tools. The elected neuropsychological tests cover a large spectrum of cognitive functions: visuo-spatial and verbal episodic memory, working memory, general, sustained, selective and divided attention, reaction time, psychomotor speed, mental flexibility and task shifting etc.
- » More specifically, the following 20 neuropsychological tests (2.5 hours of testing) were administered to all participants

Cognitive Domain	Tests
Global Cognitive Status	Mini Mental State Examination, Montreal Cognitive Assessment test
Verbal Memory and Learning	The Hopkins Verbal Learning Test - Revised
Verbal Working Memory	Letter Number Sequencing task - Wechsler Adult Intelligence Scale-IV
Visual Scanning and Spatial Memory and Learning	The Brief Visuospatial Memory Test-Revised Driving Scenes Test - Neuropsychological Assessment Battery
Visuospatial Perception	Line Orientation Test - Repeatable Battery of Neuropsychological Screening, Clock Drawing Test
Visuospatial Working Memory	Spatial Span Task - Wechsler Memory Scale Driving Scenes Test - Neuropsychological Assessment Battery
Constructional ability	Clock Drawing Test
Attention/Information Processing Speed/Perception	Trail Making Test - part A, Comprehensive Trail Making Test, Symbol Digit Modalities Test, Useful Field of View, Witkin's - Embedded Figures Test
Selective and Divided Attention	Useful Field of View Driving Scenes Test-Neuropsychological Assessment Battery
Executive Functions	Frontal Assessment Battery, Trail Making Test-part B, Spatial Addition Task - Wechsler Memory Scale, Clock Drawing Test
Psychomotor vigilance	Psychomotor Vigilance Test

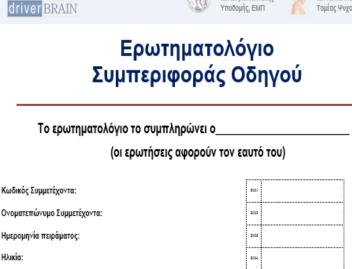
Self-stated driving behaviour questionnaire

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και Συγκοινωνιακής



- Driving experience car use **>>**
- » Self assessment of the older driver
- **Distraction-related driving habits >>**
- Emotions and behaviour of the driver **>>**
- Anger expression inventory during driving \rightarrow
- History of accidents, near misses, and traffic **>>** violations



Φύλο (κικλώσε):

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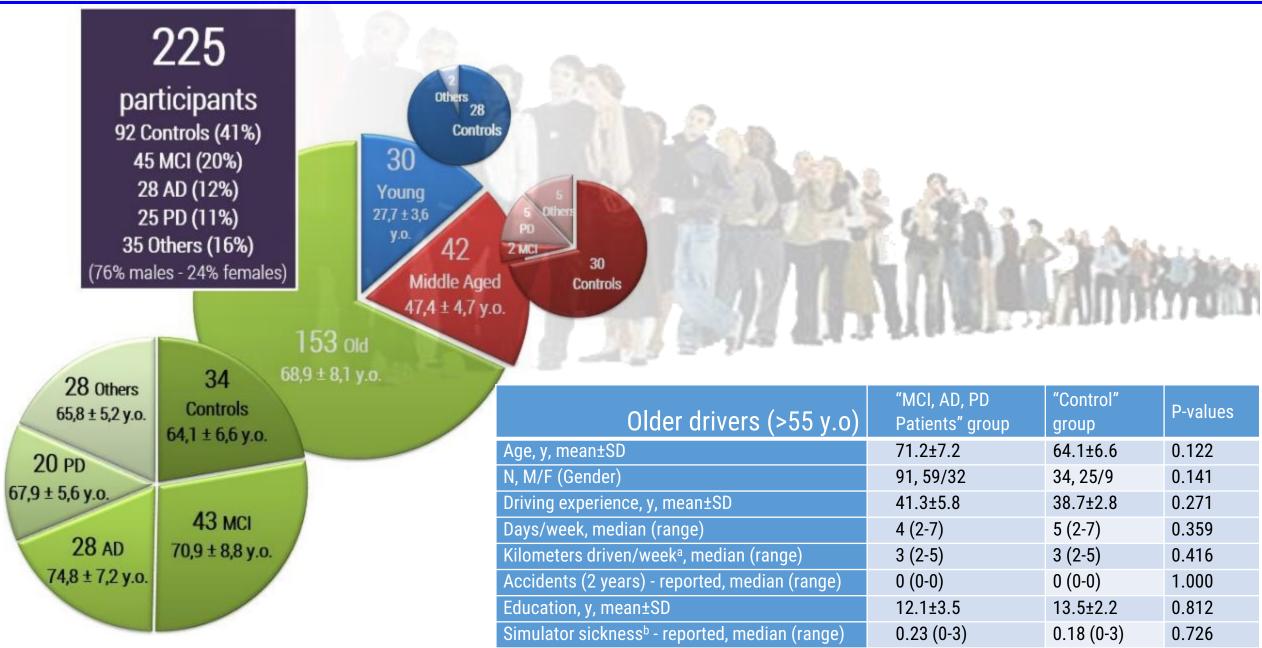
Α. ΟΔΗΓΙΚΗ ΕΜΠΕΙΡΙΑ - ΜΕΤΑΚΙΝΗΣΕΙΣ

1. Πόσα χρόνια οδηγείτε;	50		
2. Σας αρέσει η οδήγηση (κικιώστε);	513	Ναι ο	
3. Πότε αποκτήσατε την άδεια οδήγησης σας;	513	M2	
4. Πότε λήγει η άδεια οδήγησης σας;	ы		
5. Είσαστε ή ήσασταν επαγγελματίας οδηγός κωκώστα;	813	Ναι το	
 Πόσες ημέρες την εβδομάδα χρησιμοποιείτε το αυτοκίνητό σας (motion); 	518	1	2
 Πόσα χιλιόμετρα περίπου οδηγείτε την εβδομάδα (κυκώστε); 	ыr	<20	20- 50
8. Πόσες διαδρομές πραγματοποιείτε την ημέρα ως οδηγός ιανώστι;	513	1	2
9. Υποδείξτε το μέσο μήκος των διαδρομών σας σε χιλιόμετρα (molarry):	610	1-2	3-5
10. Σε σχέση με πέντε χρόνια πριν η οδήγησή σας μαιώση:	846	Έχ περιορ (1	10861

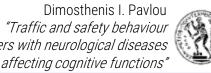
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Sample Scheme





Development of databases - data files and processing levels "Traffic and safety behaviour "Traffic and safety behaviour



6 discrete Driving Simulator Data Processing Levels (PL) were developed, in order to suitably deal with the large and diversified amount of data collected (6GB of data):

- PL0. Traffic Session Original Log Files **>>** (900 .txt files in total ~ 60.000 rows each)
- PL1. Driver Original Data Excel Files **>>**
 - (225 .xls files in total~4 sheets~60.000 rows each)
- PL2. Driver Processed Data Excel Files **>>** (225 .xls files in total~2 sheets~60.000 rows each)
- PL3, All Drivers Processed Data Excel File **>>**

(1 .accdb file ~ 20 million rows x 40 columns)

PL4. All Drivers Summary Data Excel File **>>**

(1 .xls file ~ 2.700 rows x 40 columns)

PL5. All Drivers and All Assessments Processed Data File **>>** (1 .xls file~225 rows x 1.113 columns)

		5 5
	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	ErrlVal	state date belonging to the failure, content varies according to type of failure.
30	Err2No	number of the next driving failure (maybe empty).
31	Err2Val	additional date to failure 2.
32	Err3No	number of a further driving failure (maybe empty).
33	Err3Val	additional date to failure 3.