The detrimental effect of mobile phone use on the driving competence of patients with neurological diseases affecting cognitive functions

D. Pavlou[1*], P. Papantoniou[1], G. Yannis[1], S.G. Papageorgiou[2]

[1]Department of Transportation Planning and Engineering, National Technical University of Athens, Athens, Greece
[2]2nd University Behavioral Neurology and Neuropsychology Unit, University General Hospital 'ATTIKON', Athens, Greece

*e-mail: dpavlou@central.ntua.gr

Paris, 22/03/2017

Structure of the presentation

- Background
- Objective
- Experiment Design
  - Data
  - Analysis methods
- Results
- Discussion & Conclusions

Driving Behaviour and Road Safety

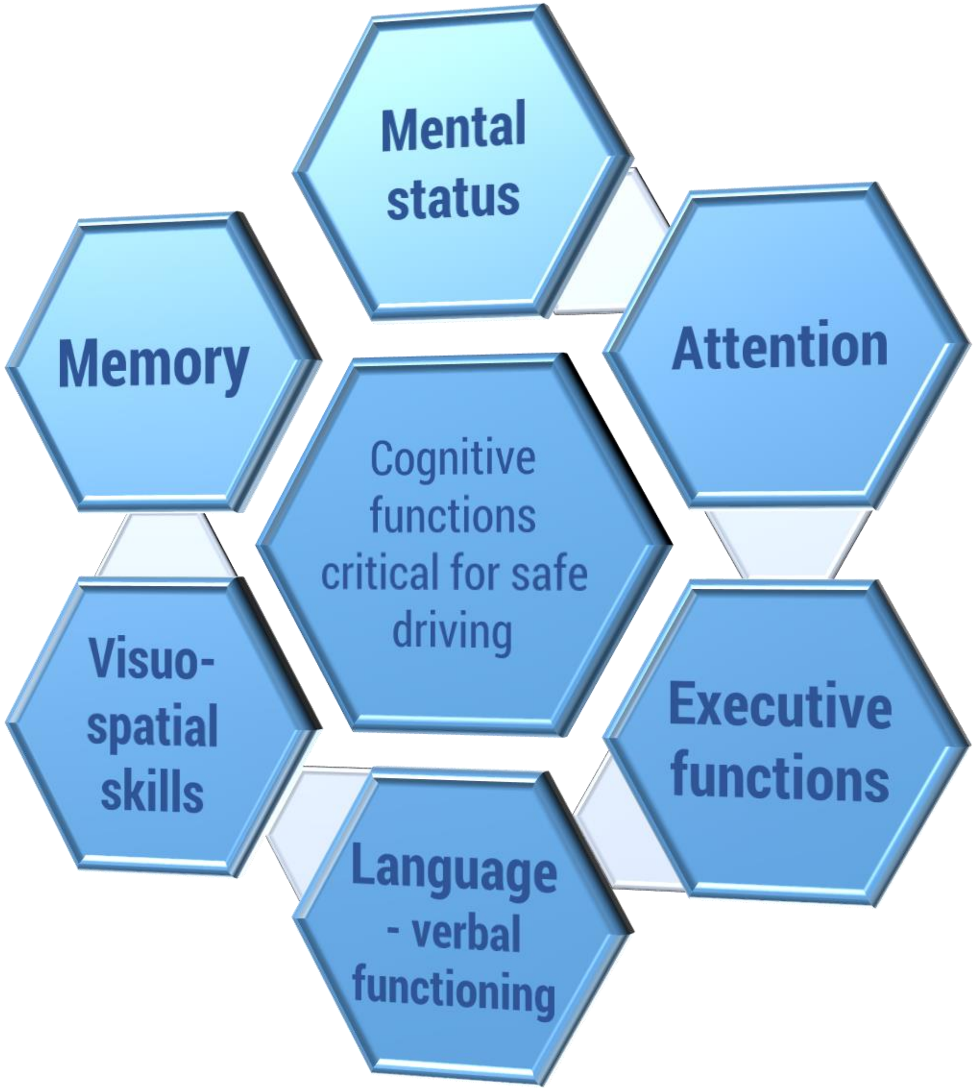
- **Driving in traffic** is more than just knowing how to operate the mechanisms which control the vehicle

- Road accidents constitute a major social problem in modern societies (**8th 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

Cognitive functions critical for safe driving

- The task of driving requires the ability to **receive** sensory information, **process** the information, and to make **proper**, **timely judgments** and responses

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



Cerebral diseases and driver distraction

- Diseases affecting a person's brain functioning affect the ability to drive and **lead to reduced driver fitness and increased accident risk**
- **Driver distraction** is estimated to be an important cause of vehicle accidents, and when combined with a brain pathology it can lead to significant deterioration in driving performance
- **The interaction of brain disorders and driver distraction**, which has not been adequately investigated so far, makes the assessment of their driving competence **a very challenging task**

Objectives

- The **analysis and quantification of the effect of mobile phone** use on the driving competence of patients with Mild Cognitive Impairment (MCI), Alzheimer's Disease (AD), and Parkinson's Disease (PD).
- Basic research hypothesis is that the effect of the mobile phone use is **detrimental** on their driving performance and the question is **to what extend** their driving competence is compromised by this type of distraction.

Experiment Design

- **Distract** and **DriverBRAIN** research projects
- **Neurologists - Medical/neurological assessment**:
  - administration of a full clinical medical, ophthalmological and neurological evaluation
- **Neuropsychologists - Neuropsychological assessment**:
  - administration of a series of neuropsychological tests and psychological - behavioural questionnaires to the participants which cover a large spectrum of Cognitive Functions
- **Transportation Engineers - Driving at the simulator**

distrACT

http://www.nrso.ntua.gr/distract/
http://www.nrso.ntua.gr/driverbrain/

driverBRAIN

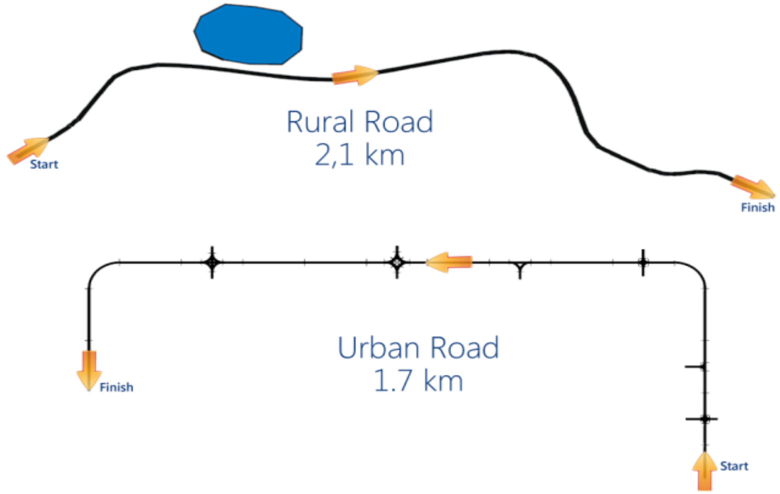
European Union, European Social Fund. Operational Programme Education and Lifelong Learning. NSRF 2007-2013. Co-financed by Greece and the European Union

Driving simulator

- Concerns the **assessment of driving behaviour** by means of programming of a set of driving tasks for different driving scenarios
- **Quarter-cab driving simulator** manufactured by the FOERST Company
- **3 LCD wide screens** 42" (full HD: 1920x1080pixels) - total F.O.V. 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** occur during each trial:
  - Sudden appearance of an animal on the roadway
  - Sudden appearance of a child chasing a ball or of a car suddenly getting out of a parking position.



Sample

125 participants (all more than 55 years of age and of similar demographic characteristics):

- **34 Healthy Controls** (aver. 64.1 y.o., 25 males)
- **91 Patients** (aver. 71.2 y.o., 59 males):
  - **43 MCI patients** (aver. 70.1 y.o.)
  - **28 AD patients** (aver. 75.4 y.o.)
  - **20 PD patients** (aver. 66.1 y.o.)

Table 1 Comparison of patients with neurological diseases affecting cognitive functions and of the Control group without neurological history on various demographics with the use of the Wilcoxon Rank Sum Test (age >55 y.o.)

	"MCI, AD, PD Patients" group	"Control" group	**P-values**
Age, y, mean±SD	71.2±7.2	64.1±6.6	0.122
N, M/F (Gender)	91, 59/32	34, 25/9	0.141
Driving experience, y, mean±SD	41.3±5.8	38.7±2.8	0.271
Days/week, median (range)	4 (2-7)	5 (2-7)	0.359
Kilometers driven/week[a], median (range)	3 (2-5)	3 (2-5)	0.416
Accidents (2 years) - reported, median (range)	0 (0-0)	0 (0-0)	1.000
Education, y, mean±SD	12.1±3.5	13.5±2.2	0.812
Simulator sickness[b] - reported, median (range)	0.23 (0-3)	0.18 (0-3)	0.726

[a] 1=1-20km; 2=21-50km; 3=50-100km; 4=100-150 and 5>150
[b] Question: Did you feel dizzy at the simulator? 0=Not at all, 1=Just a little, 2=To some extent, 3=A lot

Analysis Overview

- 4 group of participants
  - **Controls vs. MCI vs. AD vs. PD**
- 2 driving environments
  - **Rural and Urban**
- 3 distraction conditions
  - **No distraction condition**
  - **Conversation with passenger**
  - **Conversation through handheld mobile phone**
- 3 critical driving performance measures
  - **Mean speed**
  - **Reaction time**
  - **Accident probability**
- Regression analysis method:
  - **generalized linear modeling (GLM) techniques**

Results - Controls

In general terms, the distraction conditions (even the mobile phone use while driving) **don't have a significant impact** on mean speed, reaction time and accident probability in the group of controls overall, compared to their undistracted driving performance

Parameter Estimates of the GLM
Dependent variable: Mean Speed (km/h)
Model: (Intercept), Distractor

Control group

Rural Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	44,43	0,7	4117,9	1	0,000
Conversation	0,11	1,0	0,0	1	,910
Mobile phone	-2,01	1,2	2,9	1	,088
No distraction	0[a]				
(Scale)	53,681[b]	4,6			

Urban Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	29,90	0,5	3020,5	1	0,000
Conversation	-0,42	0,8	0,3	1	,593
Mobile phone	0,15	1,0	0,0	1	,878
No distraction	0[a]				
(Scale)	25,758[b]	2,5			

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.

Parameter Estimates of the GLM
Dependent variable: Accident Probability
Model: (Intercept), Distractor

Control group

Rural Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	0,08	0,0	20,7	1	0,000
Conversation	0,02	0,1	0,3	1	,593
Mobile phone	-0,05	0,1	1,8	1	,176
No distraction	0[a]				
(Scale)	,041[b]	0,0			

Urban Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	0,09	0,0	24,6	1	0,000
Conversation	-0,06	0,1	5,4	1	,020
Mobile phone	-0,04	0,1	1,3	1	,262
No distraction	0[a]				
(Scale)	,025[b]	0,0			

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

Results - MCI

In rural area mobile phone use leads to:

- **8% lower speeds**,
- **0,34 sec worse reaction time**
- **20% higher accident risk**

for the MCI group compared to their undistracted driving

In urban area mobile phone use leads to:

- **23% higher accident probability**

The effect of conversation with passenger **isn't that detrimental**

Parameter Estimates of the GLM
Dependent variable: Mean Speed (km/h)
Model: (Intercept), Distractor

MCI group

Area	Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
Rural Area	(Intercept)	38,20	0,8	2144,2	1	0,000
	Conversation	-1,20	1,2	1,1	1	,304
	Mobile phone	-2,95	1,5	3,7	1	,056
	No distraction	0[a]				
	(Scale)	55,815[b]	5,6			
Urban Area	(Intercept)	26,76	0,6	2144,0	1	0,000
	Conversation	-0,37	0,8	0,2	1	,660
	Mobile phone	0,91	1,3	0,5	1	,475
	No distraction	0[a]				
	(Scale)	22,041[b]	2,6			

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

MCI group

Area	Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
Rural Area	(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	(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: Accident Probability
Model: (Intercept), Distractor

MCI group

Area	Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
Rural Area	(Intercept)	0,12	0,0	14,4	1	0,000
	Conversation	-0,01	0,0	0,0	1	,888
	Mobile phone	0,19	0,1	10,3	1	,001
	No distraction	0[a]				
	(Scale)	,065b	0,0			
Urban Area	(Intercept)	0,26	0,0	77,5	1	0,000
	Conversation	0,21	0,0	25,6	1	,000
	Mobile phone	0,23	0,1	13,1	1	,000
	No distraction	0[a]				
	(Scale)	,051b	0,0			

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

Results - AD

Mobile phone use **worsen the reaction times of AD patients by 1.2 sec** and more importantly **catapults their accident probability to more than 40%**.

In urban area no significant differences were detected regarding the effect of distraction to the driving competence of the AD group.

Parameter Estimates of the GLM
Dependent variable: Mean Speed (km/h)
Model: (Intercept), Distractor

AD group

Rural Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	33,89	1,2	864,0	1	0,000
Conversation	0,06	1,6	0,0	1	,969
Mobile phone	-3,82	3,4	1,2	1	,265
No distraction	0[a]				
(Scale)	62,480[b]	8,8			

Urban Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	24,80	0,9	772,7	1	0,000
Conversation	-1,06	1,4	0,6	1	,440
Mobile phone	-0,11	2,4	0,0	1	,962
No distraction	0[a]				
(Scale)	28,655[b]	4,9			

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: Accident Probability
Model: (Intercept), Distractor

AD group

Rural Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	0,27	0,0	31,4	1	0,000
Conversation	-0,09	0,1	1,5	1	,219
Mobile phone	0,43	0,2	7,6	1	,006
No distraction	0[a]				
(Scale)	,109b	0,0			

Urban Area

Parameter	B	Std. Error	Hypothesis Test: Wald Chi-Square	df	Sig.
(Intercept)	0,30	0,1	29,7	1	0,000
Conversation	-0,12	0,1	1,7	1	,196
Mobile phone	-0,14	0,1	0,9	1	,336
No distraction	0[a]				
(Scale)	,102b	0,0			

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

Results - PD

5th international conference on Driver Distraction and Inattention
March 20-22, 2017 | Paris, France
http://ddi2017.sciencesconf.org

PD patients in rural area, when using the mobile phone, have **0.8 sec larger reaction time and 40% higher accident probability** compared to the undistracted driving.

In urban area, they have significantly larger reaction time and higher accident probability compared to the undistracted driving, but not when using their mobile phone.

Parameter Estimates of the GLM
Dependent variable: Mean Speed (km/h)
Model: (Intercept), Distractor

PD group

Area	Parameter	B	Std. Error	Wald Chi-Square	df	Sig.
				Hypothesis Test		
Rural Area	(Intercept)	35,69	1,5	585,5	1	0,000
Rural Area	Conversation	-1,22	2,1	0,3	1	,567
Rural Area	Mobile phone	0,05	3,0	0,0	1	,986
Rural Area	No distraction	0[a]				
Rural Area	(Scale)	95,691[b]	13,7			
Urban Area	(Intercept)	26,10	1,3	377,9	1	0,000
Urban Area	Conversation	0,25	1,9	0,0	1	,894
Urban Area	Mobile phone	2,53	3,2	0,6	1	,428
Urban Area	No distraction	0[a]				
Urban Area	(Scale)	50,459[b]	9,1			

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

Area	Parameter	B	Std. Error	Wald Chi-Square	df	Sig.
				Hypothesis Test		
Rural Area	(Intercept)	2217	156,1	201,6	1	0,000
Rural Area	Conversation	37	225,0	0,0	1	,869
Rural Area	Mobile phone	792	312,2	6,4	1	,011
Rural Area	No distraction	0[a]				
Rural Area	(Scale)	023341,347	148482,0			
Urban Area	(Intercept)	1579	87,0	329,1	1	0,000
Urban Area	Conversation	487	129,9	14,1	1	,000
Urban Area	Mobile phone	-14	204,1	0,0	1	,946
Urban Area	No distraction	0[a]				
Urban Area	(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: Accident Probability
Model: (Intercept), Distractor

PD group

Area	Parameter	B	Std. Error	Wald Chi-Square	df	Sig.
				Hypothesis Test		
Rural Area	(Intercept)	0,08	0,0	3,6	1	0,057
Rural Area	Conversation	0,06	0,1	0,8	1	,361
Rural Area	Mobile phone	0,38	0,1	18,9	1	,000
Rural Area	No distraction	0[a]				
Rural Area	(Scale)	,087b	0,0			
Urban Area	(Intercept)	0,22	0,0	27,6	1	0,000
Urban Area	Conversation	0,14	0,1	4,7	1	,030
Urban Area	Mobile phone	-0,14	0,1	2,0	1	,161
Urban Area	No distraction	0[a]				
Urban Area	(Scale)	,053b	0,0			

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

Conclusions 1/2

Drivers with MCI, AD or PD **tried to compensate their driving behaviour** by reducing, at an important extent, their speed **when using a mobile phone**, but this self-regulated strategy was unsuccessful.

Conversation with a passenger, had a detrimental effect, but only for the MCI and the PD groups in urban area.

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
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 execution of two tasks simultaneously, namely of driving and using a hand-held mobile phone, placed the group of drivers with neurological diseases affecting cognition **in a vulnerable position** due to the need to effectively divide their attention under this demanding driving condition, confirming our initial research hypothesis.

Conclusions 2/2

The presence of an in-vehicle distractor while driving such as conversing through a handheld mobile phone, has **a significantly deleterious effect on accident probability** of drivers with cognitive impairments (AD, PD and in a lesser extend MCI).

Observations of considerable practical importance as they provide quite useful information for the development of policies that aim at reducing the risk for car accidents and at improving aspects of driving performance (**restrictive measures, training and licensing, information campaigns, medical and neuropsychological monitoring**), especially in a sensitive group of car drivers, such that of drivers with MCI, AD or PD

5th international conference on
Driver Distraction and Inattention
March 20-22, 2017 | Paris, France

IFSTTAR SAFER arrb
http://ddi2017.sciencesconf.org

The detrimental effect of mobile phone use on the driving competence of patients with neurological diseases affecting cognitive functions

D. Pavlou[1*], P. Papantoniou[1], G. Yannis[1], S.G. Papageorgiou[2]

[1]Department of Transportation Planning and Engineering, National Technical University of Athens, Athens, Greece
[2]2nd University Behavioral Neurology and Neuropsychology Unit, University General Hospital 'ATTIKON', Athens, Greece

*e-mail: dpavlou@central.ntua.gr

Paris, 22/03/2017