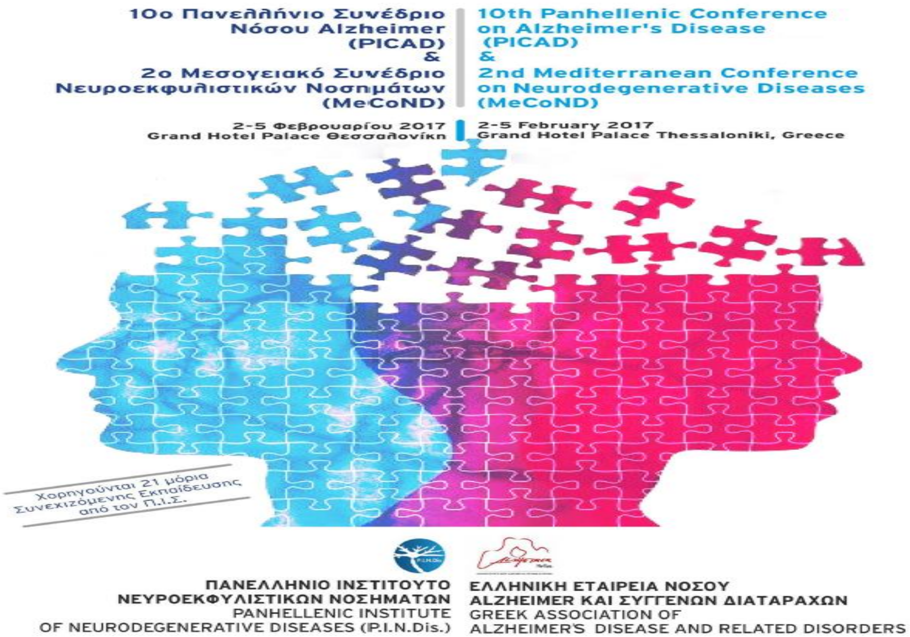
Drivers with AD and MCI: The predictive value of neurological and neuropsychological measures



Ion N. Beratis[1], Dimosthenis Pavlou[2], Nikos Andronas[1]
George Yannis[2], S.G. Papageorgiou[1]

[1]Department of Neurology, Medical School, National and Kapodistrian University of Athens, "Attikon" General University Hospital, Greece

[2]National Technical University of Athens, School of Civil Engineering, Department of Transportation Planning and Engineering

Senior drivers: general information

- **13%** of drivers > 65 years old (2009)
- **23% increase** between1999 and 2009
- Elderly individuals keep their driving license longer and drive larger distances
- During 2013, 6.500 older drivers lost their lives in car accidents (Eurostat, 2014)
- Life loss in elderly represent the 26% of all road fatalities in the EU (Eurostat, 2014)

- <u>The percentage of older drivers that are at risk due to cognitive or physical impairments remains unknown</u>

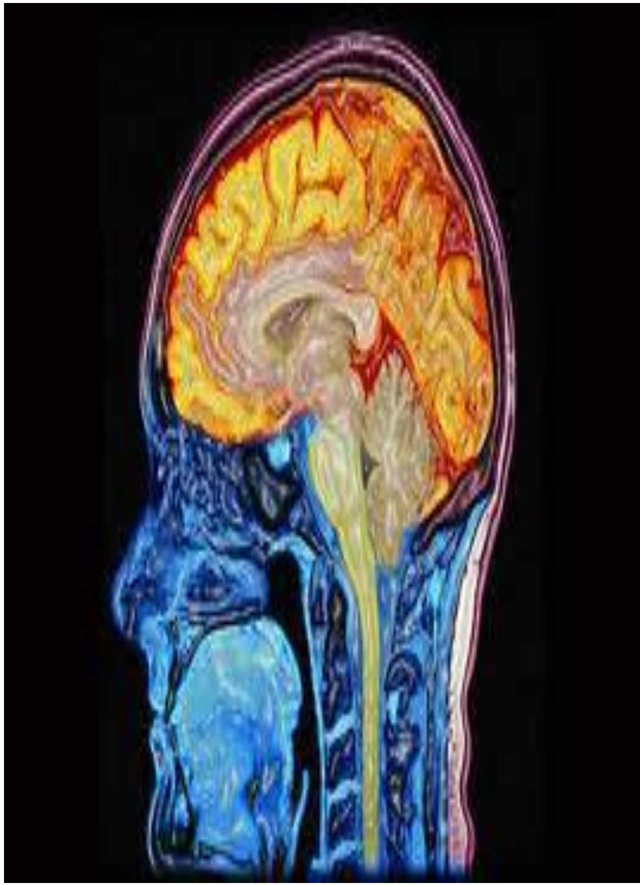
Cognitive functions critical for safe driving

1. Attention
2. quick perception of the environment

3. Executive functions
4. process multiple simultaneous environmental cues
5. make rapid, accurate and safe decisions

6. Visuo-spatial skills
7. position the car accurately on the road
8. manoeuvre the vehicle correctly
9. judging distances and predicting the development of traffic situations

10. Memory
11. journey planning
12. adapting behaviour



(Reger et al., 2004)

Cognitive Disorders and Driving

Alzheimer disease and accident risk

AD patients are 2.5 to 4.7 times more likely to be involved in a car crash than age-matched controls

(Brown and Ott 2004; Dobbs et al. 2002; Ernst et al. 2010; Withaar et al. 2000, Brorsson, 1989; Massie & Campbell, 1993; Tuokko et al., 1995)

But ~ 50% of patients with AD continue driving for at least three years after their initial diagnosis *(Adler and Kuskowski 2003; Seiler et al.2012,* Johansson and Lundberg, 1997; Dubinsky et al., 1992; Rizzo et al., 2001; Charlton et al., 2004; Uc et al., 2005; Uc et al., 2006; Ott 2008; Ernst et al. 2010)

However, certain drivers with AD maintain adequate driving fitness at the initial stages of the disease (Carr et al., 2000; Perkinson et al., 2005)

Driving Predictors-Alzheimer Disease

Performance on neuropsychological measures assessing

- visuospatial skills,
- attention,
- executive functioning
- And probably memory

Appear to be related with the driving fitness of patients with AD (Brown et al., 2005; Grace et al., 2005; Ott et al., 2008; Uc et al., 2005)

Neuropsychological and neurological measures in combination with driving evaluations (on-road or simulator environment) could be used for providing effective recommendations in drivers with AD (Frittelli et al., 2009; Ott et al., 2008; Ott et al., 2003; Rizzo et al., 1997)

Published Ahead of Print on April 12, 2010 as 10.1212/WNL.0b013e3181da3b0f

SPECIAL ARTICLE

AMERICAN ACADEMY OF NEUROLOGY

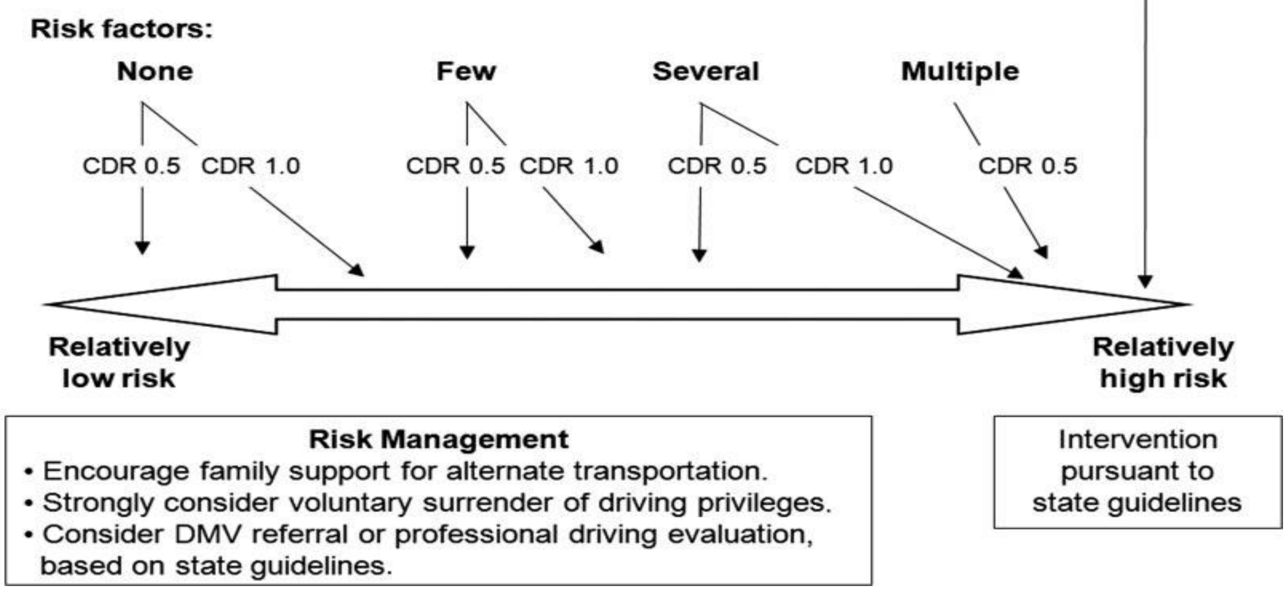
Practice Parameter update: Evaluation and management of driving risk in dementia

Report of the Quality Standards Subcommittee of the American Academy of Neurology

CDR 0.5-1.0 → **Evaluate for risk factors**

CDR 2.0

	Risk factors
Level B evidence	Caregiver report of marginal or unsafe skills
Level C evidence	History of citations
	History of crashes
	Driving < 60 miles / week
	Situational avoidance
	Aggression, impulsivity
	MMSE ≤24
Other	Alcohol, medications, sleep disorders, visual impairment, motor impairment



MCI and driving: a controversial issue

↔ Driving Ability

- Wadley et al., 2009
  on-road
- Devlin et al., 2012
  simulator
- Jeong et al., 2012
  questionnaire

↓ Driving Ability

- Snellgrove et al., 2005
  on-road (50% of MCI failed the on-road test)
- Kawano et al., 2012
  simulator
- O' Connor et al., 2010
  questionnaire

Predictors of driving behavior in MCI

- Measures associated with driving performance in patients with MCI
- Cognitive domains:
- mental flexibility (TMT-B)
- Inhibitory control (modified Stroop test)
- visual attention (TMT-A)

- When controlling for memory impairment, TMT-B seemed to be the best predictor

(Kawano et al., 2012)

Interdisciplinary Research Project 2012-2015

distrACT driverBRAIN

- Driving simulator experiment focusing on drivers with cognitive disorders [MCI (N=59), AD (N=25), PD (N=25)]

- Majority of drivers >55 years old (N=154)

- Cognitively healthy drivers of similar age and driving experience were also included

- Interdisciplinary research team (neurologists, psychiatrists, neuropsychologists, transportation research scientists

Procedure

- **Part 1. Medical, Clinical & Neurological evaluation**

  Attikon General Hospital, (~1,5 hours)

- **Part 2. Neuropsychological Assessment**

  Attikon General Hospital, (~2 hours)

- Questionnaire on driving habits

  At home (~20 minutes)

- **Part 3. Driving simulation experiment**

  NTUA Driving Simulator (~1,5 hour)

- Part 1B. Medical evaluation, Part 2B. Neuropsychological Assessment

  Attikon General Hospital, (~1 hours)

Medical/Neurological Assessment

Comprehensive Clinical Evaluation (general medical and neurological)

- Present & past history, pharmacological treatment, life habits (alcohol consumption, smoking, etc)
- Detailed neurological examination (neurological signs: markers for a disease)
- Psychiatric assessment for depression, anxiety, behavioral disturbances
- Ophthalmological evaluation: visual acquity, visual fields, fundoscopy

- **Motor ability-tests in Fitness to Drive**: Specific clinical tests examining motor control, balance, visual fields etc. related to driving skills

Neuropsychological Assessment

General Cognitive Functioning : MMSE, MOCA

Working memory/attention: Letter-Number Sequencing, Spatial Span, Spatial Addition (WMS), Neuropsychological Assessment Battery - Driving Scenes Test.

Episodic Memory: Hopkins Verbal Learning Test, Brief Visuospatial Memory Test.

Visual Perception: Benton’s Judgment of Line Orientation, Witkin’s Embedded Figure Test.

Executive function/processing speed: Frontal Assessment Battery, Trail Making Test, Comprehensive Trail Making Test, Symbol Digit Modalities Test.

Computerized tests: Useful Field of View, Psychomotor Vigilance Test.

Outcome Measures

- **Indexes of Driving Performance**

a) Average Speed
b) Speed Variation
c) Lateral Position
d) Variation of Lateral Position
e) Headway Distance
f) Variation of Headway Distance
g) Hits of side bars
h) Speed limit violations
i) Accident Risk
j) Reaction time

Driving Simulator Environment: Urban and Rural Area

<u>Driving Simulator Assessment:</u>

- Rural and urban area
- two traffic scenarios (low and high traffic volumes)
- three distraction conditions (undistracted driving, driving while conversing with a passenger and driving while conversing on a mobile phone)

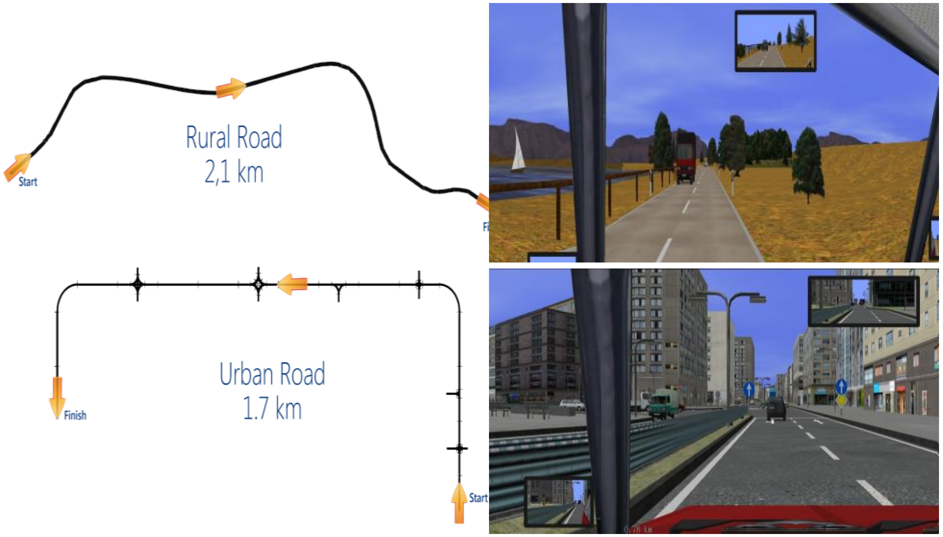


Figure 1. The two plans of the driving routes (rural and urban) and two screenshots for each driving environment

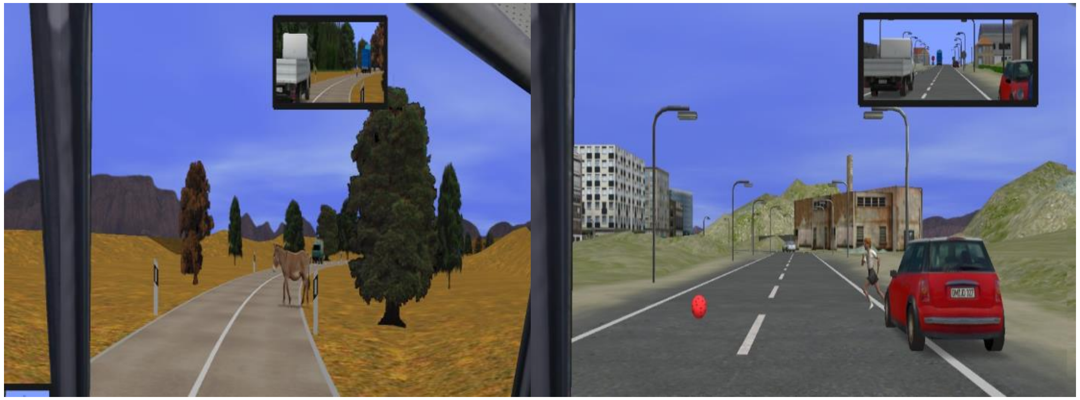


Figure 2. Two incidents screenshots - donkey entering the road in rural area and a child chasing a ball in urban area

MCI & driving: current findings

Predictors of driving performance in individuals with MCI: preliminary results

Sokratis Papageorgiou[1], Ion Beratis[1], Nikolaos Andronas[1], Alexandra Economou[2], Dimosthenis Pavlou[3], Anastasios Bonakis[1], George Tsivgoulis[1], Leonidas Stefanis[1], George Yannis[3]

[1]2nd University Department of Neurology, "Attikon" University General Hospital,
[2]Department of Psychology, University of Athens,
[3]Department of Transportation Planning & Engineering, National Technical University of Athens

Results (Average Speed)

Outcome: **Driving Speed**

Predictors:

(1st level) **general cognitive functioning (MMSE)**

(2nd level) balance and movement coordination (**Tandem Walking**, β=-.63, p=.007)

The model explained 55.9% of the variance in average driving speed

R^2=.559, F(2,13)=8.25, p=.005.

- In the cognitively intact group the same regression model did not contribute to the prediction of average driving speed

R^2=.166, F(2,11)=1.10, p=.368

Normal Group (*Mean*=43.62, *SD*=7.33) vs MCI Group(*Mean*=42.24, *SD*=7.46)

t(28)=.51, p=.614

Results (Number of Crashes)

Outcome: **Number of Crashes**
Predictors:
(1st level) general cognitive functioning (**MMSE**)
(2nd level) visuospatial memory (**BVMT_Recognition**, β=-.40, p=.056) and speed of **attention** (UFV_1, β=.48, p=.027)

The model explained 77.3% of the variance in number of crashes

R^2=.773, F(3,10)=11.35, p=.001

- In the cognitively intact group the same regression model did not contribute to the prediction of number of crashes

R^2=.279, F(3,10)=1.29, p=.330

Normal Group (*Mean*=.43, *SD*=.65) vs MCI Group(*Mean*=.56, *SD*=.81)
t(28)=.49, p=.25

Results (Reaction Time)

Outcome: Reaction Time

Predictors:

(1st level) general cognitive functioning (**MMSE**)

(2nd level) **information processing speed** (SDMT, β=-.60, p=.014) and **balance and movement coordination** (Tandem Walking_RNC, β=.54, p=.007)

The model explained 73.2% of the variance in reaction time

R^2 =.732, $F(3,12)$=10.92, p=.001

- In the cognitively intact group the same regression model did not contribute to the prediction of reaction time

R^2=.119, $F(3,10)$=.45, p=.772

Normal Group (*Mean*=1.78, *SD*=.28) vs MCI Group (*Mean*=1.89, *SD*=.46)

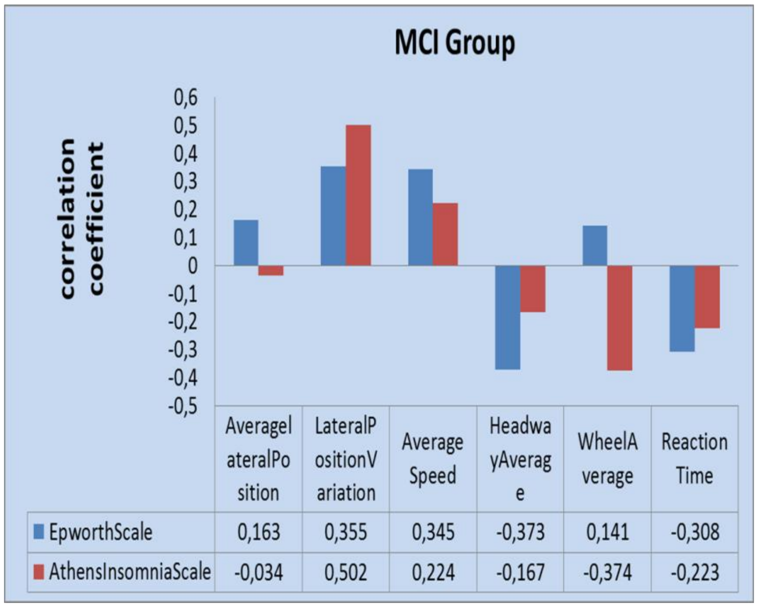
$t(28)$=.80, p=.43

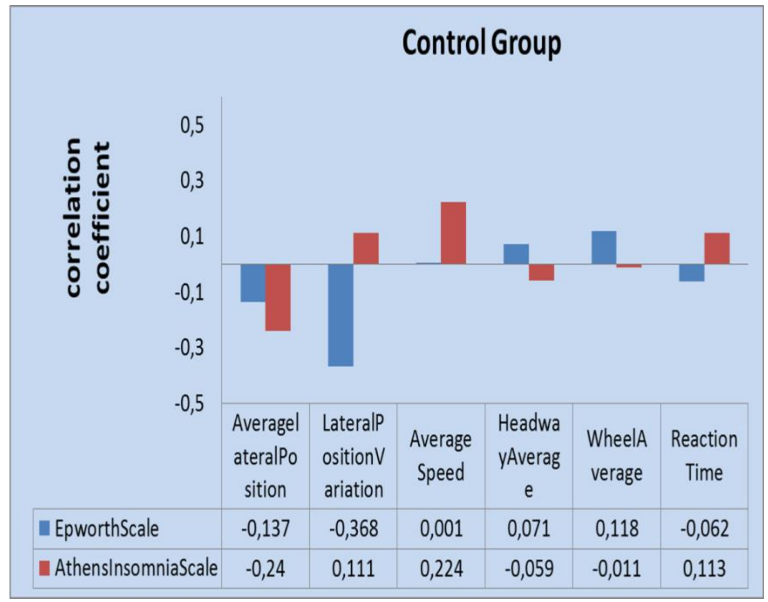
The role of sleeping abnormalities on the driving performance of individuals with Mild Cognitive Impairment

I. N. Beratis, N. Andronas , E. Papadimitriou, D. Kontaxopoulou, S. Fragkiadaki, C. Koros, A.Bonakis, A. Economou, S. G. Papageorgiou (EAN Berlin 2015)

- 27 cognitively intact individuals (Age: 63.4±7.2 years)
- 33 individuals with MCI (Age: 66.4±7.4 years)

Figure 1. Correlation coefficients between driving indexes and sleeping abnormalities in the control and MCI group





- The current findings indicate a stronger association between sleeping abnormalities and driving behavior in the MCI group as compared to the group of cognitively intact individuals
- In the MCI group, sleepiness was positively associated with lateral position variation and average speed, and negatively associated with average headway distance
- In the MCI group, insomnia symptoms were positively associated with lateral position variation, and negatively with the average wheel position

Traffic Inj Prev. 2016 Dec 12:0. [Epub ahead of print]

Driving in Mild Cognitive Impairment: The role of depressive symptoms.

Beratis IN[1], Andronas N[1], Kontaxopoulou D[1], Fragkiadaki S[1], Pavlou D[2], Papatriantafyllou J[1], Economou A[3], Yannis G[2], Papageorgiou SG[1].

Author information

Abstract

OBJECTIVES: Previous studies indicate a negative association between depression and driving fitness in the general population. Our goal was to cover a gap in the literature and to explore the link between depressive symptoms and driving behavior in individuals with Mild Cognitive Impairment (MCI) through the use of a driving simulator experiment.

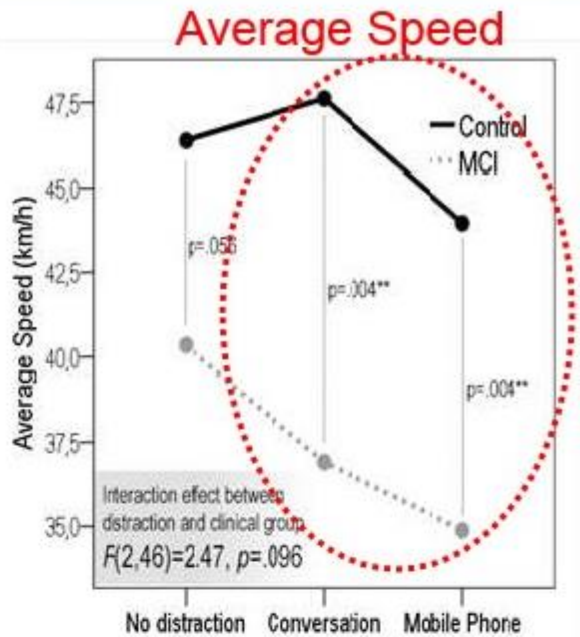
METHODS: Twenty-four individuals with MCI (Age: Mean = 67.42, SD = 7.13) and 23 cognitively healthy individuals (Age: Mean = 65.13, SD = 7.21) were introduced in the study. A valid driving license and regular car use served as main inclusion criteria. Data collection included a neurological/neuropsychological assessment and a driving simulator evaluation. Depressive symptomatology was assessed with the Patient Health Questionnaire (PHQ-9).

RESULTS: Significant interaction effects indicating a greater negative impact of depressive symptoms in drivers with MCI than in cognitively healthy drivers were observed in the case of various driving indexes, namely average speed, accident risk, side bar hits, headway distance, headway distance variation, and lateral position variation. The associations between depressive symptoms and driving behavior remained significant after controlling for daytime sleepiness and cognition.

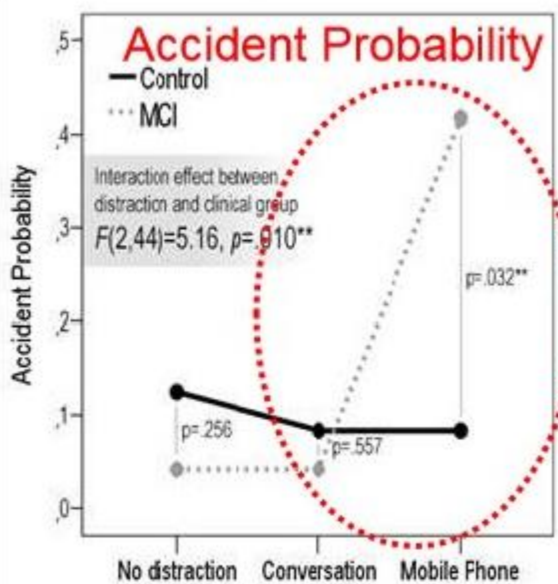
CONCLUSIONS: Depressive symptoms could be a factor explaining why certain patients with MCI present altered driving skills. Therefore, interventions for treating the depressive symptoms of individuals with MCI could prove to be beneficial regarding their driving performance.

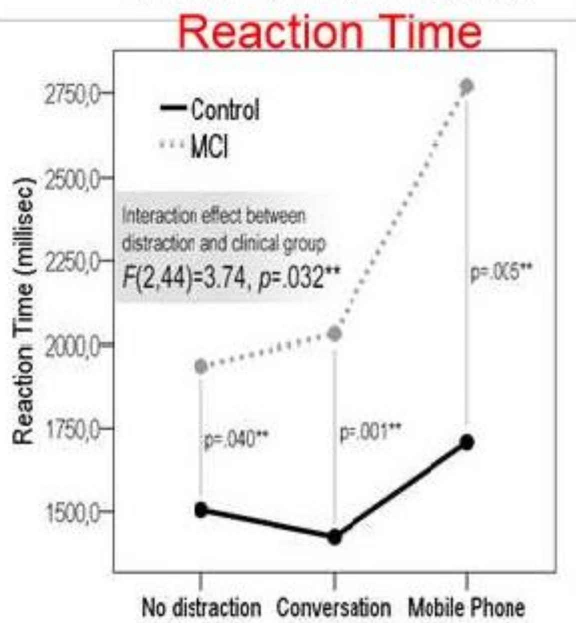
Mild Cognitive Impairment and driving: Does in-vehicle distraction affect driving performance?

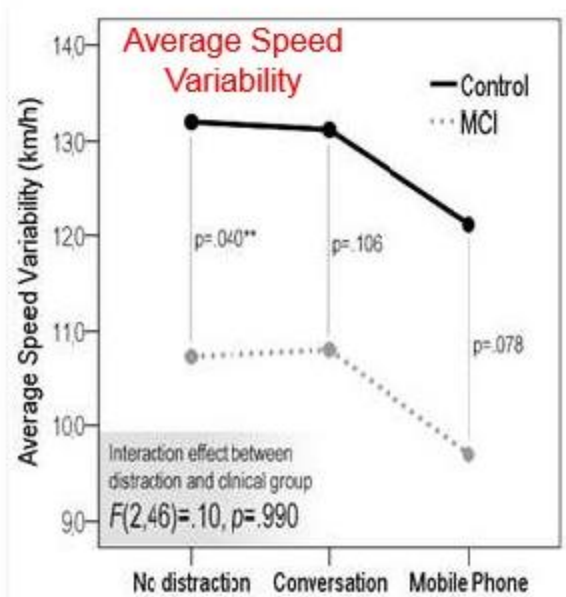
Ion N. Beratis, Dimosthenis Pavlou, Eleonora Papadimitriou, Nikolaos Andronas, Dionysia Kontaxopoulou, Stella Fragkiadaki, George Yannis, S. G. Papageorgiou



Submitted, (2016)







- The mixed ANOVA revealed a greater effect of distraction on MCI patients.
- Specifically, the use of mobile phone induced a more pronounced impact on reaction time and accident probability in the group of patients, as compared to healthy controls.
- Also, a greater negative effect of "conversing with passenger" was observed in the group of drivers with MCI, but of a lesser extent than in the case of the mobile-phone condition.
- Notably, the aforementioned findings were observed despite the effort of the drivers with MCI to apply a compensatory strategy by reducing significantly their speed.

AD & driving: current findings

Mini Mental State Examination and Montreal Cognitive Assessment: which is the best predictor of Driving Ability?

D. Kontaxopoulou[1], I. N. Beratis[1], S. Fragkiadaki[1], N. Andronas[1], D. Pavlou[2], G. Yannis[2], J. Papatriantafyllou[3], L. Stefanis[1], A. Economou[4], S. G. Papageorgiou[1]

[1]2nd University Department of Neurology "Attikon" University General Hospital, [2]Department of Transportation Planning & Engineering, National Technical University of Athens, [3]General Hospital of Athens G. Gennimatas, [4]Department of Psychology, National and Kapodistrian University of Athens

Correspondence: sokpapa@med.uoa.gr

INTRODUCTION

Mini Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) are the most commonly used screening tests for the evaluation of general cognitive ability. Previous research suggests that MMSE and MoCA could be used as predictors of driving ability.

In regards to MMSE, previous studies which have investigated performance on the MMSE in relation to driving abilities have revealed contradictory results. Although the inconsistency of the MMSE as a predictor of driving ability is shown in a number of studies (Adler et al., 2003; Lesikar et al., 2002; Paccalin et al., 2005; Uc et al., 2005), some studies suggest a consistent relationship between the two (Lesikar et al., 2002; Uc et al., 2005).

Hollis et al. (2015) examined the comparison between MMSE and MoCA in order to predict driving performance. The study's findings suggested that the MoCA was a useful screening test for identifying individuals with cognitive impairment who are at driving risk.

AIM

The present study compared the capacity MMSE and MoCA to predict specific driving indexes in patients with aMCI, mild AD and healthy individuals.

METHODS

Participants:

- 44 patients with aMCI
- 23 patients with mild AD
- 44 healthy individuals

The diagnosis of aMCI was made by the Petersen et al. (2005) criteria. The diagnosis of mild AD was made by the McKhann et al. (2011) criteria

Inclusion & Exclusion Criteria:

- have a valid driving license
- regular drivers
- CDR: MCI ≤ 0.5 , AD ≤ 1
- not have significant psychiatric history of psychosis
- not have any significant motor disorder
- not have any significant visual disorder

Procedure

(a) All the participants underwent a complete neurological, neuropsychological and othalmological assessment. General cognitive ability was measured by the administration of MMSE & MoCA

(b) The participants went through a driving simulator experiment:

- Phase 1: Practice session (5-10 min.)
- Phase 2: Two driving sessions (about 20 min. each) on urban streets with multiple lanes, and on a two-lane rural road. An unexpected incident occurs in each of the two sessions (sudden appearance of pedestrian or child on the road, sudden appearance of an animal on the rural road)
- Driving was assessed with a Foerst FPF driving simulator, in different conditions

Driving Indexes:

- Average speed
- Lateral position
- Head way distance
- Reaction time
- Accident probability
- Speed limit violations

RESULTS

Table 1. Correlations between MMSE, MoCA and Driving Indexes in aMCI patients

Driving Indexes	Rural Area				Urban Area			
	MMSE		MoCA		MMSE		MoCA	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value
Average speed	.01	.94	-.05	.77	-.01	.96	.09	.61
Lateral position	-.10	.55	-.33	.055	.22	.22	.18	.32
Head way distance	.02	.91	.04	.83	-.16	.38	.01	.94
Reaction time	-.33	.045*	-.42	-.01*	-.78	.000**	-.47	.02*
Accident probability	-.34	.041*	-.046	.006*	-.56	.003*	-.47	.02
Speed limit violations	-.25	.18	-.39	.02*	.20	.27	.54	.059

Table 2. Correlations between MMSE, MoCA and Driving Indexes in mild AD patients

Driving Indexes	Rural Area				Urban Area			
	MMSE		MoCA		MMSE		MoCA	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value
Average speed	.41	.09	.48	.044*	.29	.26	.34	.21
Lateral position	.22	.37	.06	.79	.21	.43	-.04	.88
Head way distance	-.53	.024*	-.57	.014*	-.26	.29	-.26	.32
Reaction time	.07	.77	-.09	.69	-.16	.59	.13	.68
Accident probability	.21	.39	.13	.61	-.54	.03*	-.53	.037*
Speed limit violations[a]	-	-	-	-	-	-	-	-

$^*p = .05$, $^{**}p < .001$

[a] In the AD group, no speed limit violations were recorded

➢ In the healthy individuals the MMSE and the MoCa were not associated with any of the driving indexes

CONCLUSION

- Our findings indicated that both MMSE and MoCA associated with various driving indexes could be useful screening measures in order to assess driving fitness briefly.
- Both routine cognitive screening tests were correlated with the critical driving indexes of reaction time and accident probability in the groups of driver with MCI and AD
- In the mild AD group, both the MMSE and the MoCA achieved similar levels of predicted capacity in terms of driving behavior. Thus, the aforementioned screening tools could be alternatively utilized in order to obtain an indication of the driving fitness in patients with mild AD.
- However, in the case of aMCI, MoCA was correlated with more driving variables than the MMSE.
- Thus, MoCA seems to be a more useful source of information for facilitating decisions about driving ability. This finding could be linked to the fact that MoCA has proved to be a better screening test in detection of patients with MCI (Dong, et al., 2012).

REFERENCES/ACKNOWLEDGEMENTS

- Adler G., Kuskowski, M. (2003). Driving cessation in older men with dementia. *Alzheimer Disease and Associated Disorders*, 17, 68-71.
- Dong, et al. (2012). The Montreal Cognitive Assessment is superior to the Mini-Mental State Examination in detecting patients at higher risk of dementia. *International Psychogeriatrics*, 24(11):1749-55.
- Hollis, A. M., et al. (2015). Validity of the Mini-mental State Examination and the Montreal Cognitive Assessment in the Prediction of Driving Test Outcome. *Journal of the American Geriatrics Society*, 63(5):988-992.
- Lesikar, S. E, Gallo J. J, Rebok G. W, Keyl P. M (2002) Prospective study of brief neuropsychological measures to assess crash risk in older primary care patients. *J Am Board Fam Pract*, 15, 11-19.
- Paccalin, M., et al. (2005). Automobile driving among patients with dementia. Survey in the Poitou-Charentes region. *Presse Med*, 34, 919-922.
- Uc E.Y, et al. (2005) Driver landmark and traffic sign identification in early Alzheimer's disease. *J Neurol Neurosurg Psychiatry*, 76, 764-768.

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 – ESF) and Greek national funds".

Control vs. AD Group on Driving Indexes

Rural Area - Condition Without Distraction

	AD group		Control group		t-test	
	Mean	SD	Mean	SD	T	p
Average Speed	32.8	7.8	40.3	7.6	3.11	.004**
Average Speed Variation	9.7	3.8	10.7	2.8	.94	.352
Lateral Position	1.5	.17	1.5	.09	-.632	.531
Lateral Positon Variation	.29	.05	.27	.06	-1.42	,164
Headway Average	610.8	181.2	503.5	111.5	-2.28	,028*
Headway Average Variation	273.8	100.8	222.1	54.9	-2.04	.048*
Wheel Average	-1.3	1.5	-1.7	0.5	-1.31	.196
Wheel Average Variation	16.9	2.5	16.7	2.2	-.26	.796
Reaction Time	2457.6	967.8	1511.9	442.6	-4.04	.000**
Number of Crashes	.53	.77	.09	.31	-2.37	.023*
Speed Limit Violation	.05	.23	.09	.31	.50	.620

Control vs. AD Group on Driving Indexes

Urban Area - Condition Without Distraction

	AD group		Control group		t-test	
	Mean	SD	Mean	SD	T	p
Average Speed	24.7	6.7	27.9	5.3	1.45	.158
Average Speed Variation	9.2	2.4	11.5	2.9	2.31	.028*
Lateral Position	3.2	.63	2.9	.74	-1.32	.165
Lateral Positon Variation	1.7	.54	1.5	.65	-1.07	,292
Headway Average	125.3	26.1	129.2	36.1	.35	,732
Headway Average Variation	56.9	8.4	54.2	11.6	-.770	.448
Wheel Average	7.6	1.4	6.3	1.6	-2.28	.030*
Wheel Average Variation	24.6	11.1	27.3	11.4	.67	.508
Reaction Time	1683.6	460.5	1196.8	427.9	-2.85	.008**
Number of Crashes	.62	.81	.00	.00	-2.67	.013*

Average Speed

- **47%** of AD patients were on the range (±1SD) of normal performance

	AD (normal performance) N=8		AD (impaired performance) N=10		t-test	
	Mean	SD	Mean	SD	T	p
MMSE	24.6	3.2	21.6	3.7	1.80	.090
CTMT1	103.8	29.6	176.9	77.8	-2.46	.029*
CTMT2	106.5	43.2	214.3	55.2	-4.24	.001**
CTMT3	122.1	41.4	229.5	72.4	-3.59	,003**
CTMT4	134.7	61.7	246.4	48.9	-3.84	,002**
CTMT5	246.6	52.1	315.7	38.9	-2.87	.013*
Incidental memory	4.7	1.1	6.0	1.1	-2.09	.060

Conclusions

INTERNATIONAL JOURNAL OF CLINICAL NEUROSCIENCES AND MENTAL HEALTH

REVIEW

Does the diagnosis of Alzheimer's Disease imply immediate revocation of a driving license?

Sokratis G. Papageorgiou[1], Ion N. Beratis[1], Dionysia Kontaxopoulou[1], Stella Fragkiadaki[1], Dimosthenis Pavlou[2], and George Yannis[2]

Special Issue on Controversies in Neurology. From the 10th World Congress on Controversies in Neurology (CONy), Lisbon, Portugal. 17–20 March 2016.

Abstract

Driving competence is strongly related to the autonomy and the feelings of self-worth of advanced agers. At present, older drivers appear to retain their driving license for longer periods of time as well as to drive more commonly and to cover longer distances as compared to the past. Nonetheless according to epidemiological data, older individuals appear to be a vulnerable driving group that manifests increased rates of road fatalities. Along this vein, several lines of previous research have focused on exploring the driving behavior of individuals with two common cognitive disorders, namely Alzheimer-dementia (AD) and Mild Cognitive Impairment (MCI). Based on previous findings, patients with AD commonly present increased driving difficulties at a level that clearly supports the discontinuation of driving. Nonetheless, some patients with AD, especially in the mild stages, retain adequate driving skills that are similar to those of cognitively intact individuals of similar age. As concern the group of drivers with MCI, it seems that there is an accentuated risk to develop driving difficulties, but their performance is not consistently worse than that of healthy control drivers. Nonetheless, additional studies are warranted for detecting useful predictors of driving behavior in the specific clinical group. Under this perspective and by integrating the previous findings, we suggest the need for implementing a personalized approach when taking decisions about the driving competence of drivers with AD and MCI that is based on the effective synthesis of multimodal driving-related indexes by the specialties of neurology, neuropsychology and transportation engineering.

Keywords: Driving, Dementia, Alzheimer disease, Mild Cognitive Impairment, Driving behavior.

Figure 1. Proposed evaluation of drivers with AD or MCI.

AD = Alzheimer's disease; MCI = Mild Cognitive Impairment

References I

Akinwuntan, A. E., Feys, H., De Weerdt, W., Baten, G., Arno, P., & Kiekens, C. (2006). Prediction of driving after stroke: a prospective study. Neurorehabilitation and Neural Repair, 20, 417-423.

Akinwuntan, A. E., Feys, H., DeWeerdt, W., Pauwels, J., Baten, G., & Strypstein, E. (2002). Determinants of driving after stroke. Archives of Physical Medicine and Rehabilitation, 83, 334-341.

Amick, M. M., Grace, J., & Ott, B. R. (2007). Visual and cognitive predictors of driving safety in Parkinson's disease patients.Archives of Clinical Neuropsychology, 22, 957-967.

Brorsson, B. (1989). The risk of accidents among older drivers. *Scandinavian Journal of Social Medicine, 17,* 253-256.

Brown, L. B., Ott, B. R., Papandonatos, G. D., Sui, Y., Ready, R. E., & Morris, J. C. (2005). Prediction of on-road driving performance in patients with early Alzheimer's disease. *Journal of the American Geriatrics Society 53,* 94-98.

Classen, S., McCarthy, D. P., Shechtman, O., Awadzi, K. D., Lanford, D. N., Okun, M. S., Rodriguez, R. L., Romrell, J., Bridges, S., Kluger, B., & Fernandez, H. H. (2009). Useful field of view as a reliable screening measure of driving performance in people with Parkinson's disease: results of a pilot study.*Traffic Injury Prevention, 10,* 593-598.

Classen, S., Witter, D. P., Lanford, D. N., Okun, M. S., Rodriguez, R. L., Romrell, J., Malaty, I., & Fernandez, H. H. (2011). Usefulness of screening tools for predicting driving performance in people with Parkinson's disease.*The American Journal of Occupational Therapy, 65,* 579-588.

Devos, H., Vandenberghe, W., Nieuwboer, A., Tant, M., Baten, G., & De Weerdt, W. (2007). Predictors of fitness to drive in people with Parkinson disease.Neurology, 69, 1434-1441.

Dubinsky, R. M., Gray, C, Husted, D., Busenbark, K., Vetere-Overfield, B, Wiltfong, D., Parrish, D., & Koller, W. C. (1991). Driving in Parkinson's disease. *Neurology, 41,* 517-520.

Dubinsky R. M., Stein A. C., & Lyons K. (2001). Practice parameter: risk of driving and Alzheimer's disease (an evidenced-based review). *Neurology, 54,* 2205-2211.

Fisk, G. D., Owsley, C., & Mennemeier, M. (2002). Vision, attention, and self-reported driving behaviors in community-dwelling stroke survivors. *Archives of Physical Medicine and Rehabilitation, 83,* 469–477.

Frittelli, C., Borghetti, D., Iudice, G., Bonanni, E., Maestri, M., Tognoni, G., Pasquali, L., & Iudice, A (2009). Effects of Alzheimer's disease and mild cognitive impairment on driving ability: a controlled clinical study by simulated driving test. *International Journal of Geriatric Psychiatry, 24,* 232–238.

Grace, J., Amick, M. M., DAbreu, A., Festa, E. K., Heindel, W. C., & Ott, B. R. (2005). Neuropsychological deficits associated with driving performance in Parkinson's and Alzheimer's disease. *Journal of the International Neuropsychological Society, 11, 766-75.*

George, S., & Crotty, M. (2010). Establishing criterion validity of the Useful Field of View assessment and Stroke Drivers' Screening Assessment: comparison to the result of on-road assessment. *The American Journal of Occupational Therapy, 64,* 114-22.

Hughes C. P., Berg L., Danziger W. L., et al. (1982). A new clinical scale for the staging of dementia. *The British Journal of Psychiatry, 140, 566-572.*

Iverson, D. J., Gronseth, G. S., Reger, M. A., Classen, S., Dubinsky, R. M., & Rizzo, M. (2010). Practime Parameter update: Evaluation and management of driving risk in dementia. *Neurology, 74,* 1316-1324.

Kawano, N., Iwamoto, K., Ebe, K., Suzuki, Y., Hasegawa, J., Ukai, K., Umegaki, H., Iidaka, T., & Ozaki, N. (2012). Effects of mild cognitive impairment on driving performance in older drivers. *Journal of the American Geriatrics Society, 60,* 1379-1381.

References II

Lee, H. C., Lee, A. H., & Cameron, D. (2003). Validation of a driving simulator by measuring the visual attention skill of older adult drivers. *The American Journal of Occupational Therapy, 57,* 324–328.

Lundberg, C., Caneman, G., Samuelsson, S., Hakamies-Blomqvist, L., & Almkvist, O. (2003). The assessment of fitness to drive after a stroke: The Nordic Stroke Driver Screening Assessment. *Scandinavian Journal of Psychology, 44,* 23–30.

Lundqvist, A., Alinder, J., & Ronnberg, J. (2008). Factors influencing driving 10 years after brain injury. *Brain Injury, 22,* 295–304.

Massie, D. L., & Campbell, K. D. (1993). Accident involvement rates by age and gender. *UMTRI Research Review, 23,* 1-20.

Margolis, K. L., Kerani, R. P., McGovern, P., Songer, T., & Cauley, J. A, for the Study of Osteoporotic Fractures Research Group KEE. (2002). Risk factors for motor vehicle crashes in older women. *The Journal of Gerontology. Series A, Biological Sciences & Medical Sciences, 57,* M186–M191.

Mazer, B. L., Sofer, S., Korner-Bitensky, N., Gelinas, I., Hanley, J., & Wood-Dauphinee, S. (2003). Effectiveness of a visual attention retraining program on the driving performance of clients with stroke. *Archives of Physical Medicine & Rehabilitation, 84,* 541–550.

Meindorfner, C., Körner, Y., Möller, J. C., Stiasny-Kolster, K., Oertel, W. H., & Krüger, H. P. (2005). Driving in Parkinson's disease: mobility, accidents, and sudden onset of sleep at the wheel. *Movement Disorders, 20,* 832-42.

Ott, B. R., Heindel, W. C., Whelihan, W. M., Caron, M. D., Piatt, A. L., & DiCarlo, M. A. (2003). Maze Test performance and reported driving ability in early dementia. *Journal of Geriatric Psychiatry and Neurology, 16,* 151-155.

Ott B.R., Heindel W.C., Papandonatos G.D., Festa, E.K., Davis J.D., Daiello L.A., & Morris J.C. (2008). A longitudinal study of drivers with Alzheimer disease. *Neurology, 70,* 1171–1178.

Rizzo, M., Reinach, S., McGehee, D., & Dawson, J. (1997). Simulated car crashes and crash predictors in drivers with Alzheimer's disease. *Archives of Neurology, 54,* 545-551.

Söderström, S. T., Pettersson, R. P., & Leppert, J. (2006). Prediction of driving ability after stroke and the effect of behind-the-wheel training. *Scandinavian Journal of Psychology, 47,* 419-429.

Tuokko H., Tallman K., Beattie B. L., et al. (1995). An examination of driving records in a dementia clinic. *Journal of Gerontology Series B Psychological Sciences and Social Sciences, 50B,* S173-S181.

Sagberg F. (2006). Driver health and crash involvement: a case-control study. *Accident; Analysis & Prevention, 38,* 28–34.

Sims, R. V., McGwin, G. Jr., Allman, R. M., Ball, K., & Owsley, C. (2000). Exploratory study of incident vehicle crashes among older drivers. *The Journal of Gerontology. Series A, Biological Sciences & Medical Sciences, 55,* 22–27.

Uc E. Y., Rizzo M., Anderson S. W. et al. (2005). Driver landmark and traffic sign identification in early Alzheimer's disease. *Journal of Neurology, Neurosurgery and Psychiatry, 76, 764–768.*

Uc, E. Y., Rizzo, M., Anderson, S. W., Sparks, J., Rodnitzky, R. L., & Dawson, J. D. (2006). Impaired visual search in drivers with Parkinson's disease. *Annals of Neurology, 60,* 407-413.

Uc, E. Y., Rizzo, M., Johnson, A. M., Dastrup, E., Anderson, S. W., & Dawson, J. D. (2009). Road safety in drivers with Parkinson disease. *Neurology, 73,* 2112-2119.

Wadley, V. G., Okonkwo, O., Crowe, M., Vance, D. E., Elgin, J. M., Ball, K. K., & Owsley, C.(2009). Mild cognitive impairment and everyday function: an investigation of driving performance. *Journal of Geriatric Psychiatry and Neurology, 22,* 87-94.

Worringham, C. J., Wood, J. M., Kerr, G. K., & Silburn, P. A. (2006). Predictors of driving assessment outcome in Parkinson's disease. *Movement Disorders, 21,* 230-235.

Thank you for your attention!