Predicting behind-the-wheel driving behavior in Parkinson Disease through motor and cognitive testing in outpatient clinics

NEUROLOGICAL INSTITUTE OF ATHENS

National and Kapodistrian UNIVERSITY OF ATHENS

National Technical University of Athens

Nikolaos Andronas, MD[1,2], Elissaios Karageorgiou, MD, PhD[1], Ion N.Beratis, PhD[2], Stella Fragkiadaki, PhD[2], Dionysia Kontaxopoulou, PhD[2], George Yannis, PhD[3], Leonidas Stefanis, MD, PhD[2], and Sokratis Papageorgiou, MD, PhD[2]

(1) Neurological Institute of Athens, Athens, Greece, (2) National and Kapodistrian University of Athens, Medical School, Athens, Greece (3) National Technical University of Athens, Athens, Greece

Objective

The objective of this study was to investigate whether specific motor and cognitive tasks performed in clinic can predict behind the wheel driving performance in Parkinson's disease (PD) as represented through driving simulator behaviors.

Background

Driving Behavior (DB) is negatively affected in PD, with studies revealing increased risk for car accidents in drivers with PD. Studies have attributed these results to motor (rigidity and bradykinesia) and cognitive (executive and visuospatial) deficits, but with no robust associations. Additionally, studies to date have not found a consistent association between motor scores, as quantified by Hoehn & Yahr (H&Y) or UPDRS-III scale, to driving.

Methods

- **23 men with PD** (63.39 ± 10.39 yo),
- **23 matched controls** (58.30 ± 10.88 yo, one woman)
- Prospectively enrolled through the University of Athens outpatient clinic, satisfying the following criteria:
  - H&Y ≤ 3, CDR score ≤ 0.5 Valid driver's license, Regular car driving, No History of car accidents, No history of drugs with negative impact on driving.

All participants underwent:

(a) Neurological evaluation with administration of specific Motor tasks: Tandem Walking Test (TWT), TWT with Reverse Number counting (TWT-RC), Rapid Paced Walk Test (PRW), Head Rotation Task (HRT), Foot Tapping Test (FTT),

(b) Neuropsychological evaluation of all cognitive domains**,**

(c) Driving simulator test

Hypotheses tested:

1. Differences between PD and matched HC in motor and cognitive performance, as well as driving behavior (Student's t-test or Mann-Whitney U test depending on violation of normality assumptions)
2. Representation of motor, cognitive, and driving features into domains using principal component analysis (PCA)
3. Associations between cognitive and motor vs. driving domains using canonical correlation analysis (CCA).
4. Prediction of driving behavior from motor and cognitive domains, using regression and linear discriminant analysis (LDA)

Comparison of PD to HC

Patients with PD performed worse on **driving behavior**

- Tactical car control
- Operational safety
  - Lower average speed across traffic loads,
  - Worse average reaction times, and
  - Greater headway distance from the vehicle ahead.

Patients with PD performed worse on **cognition**:

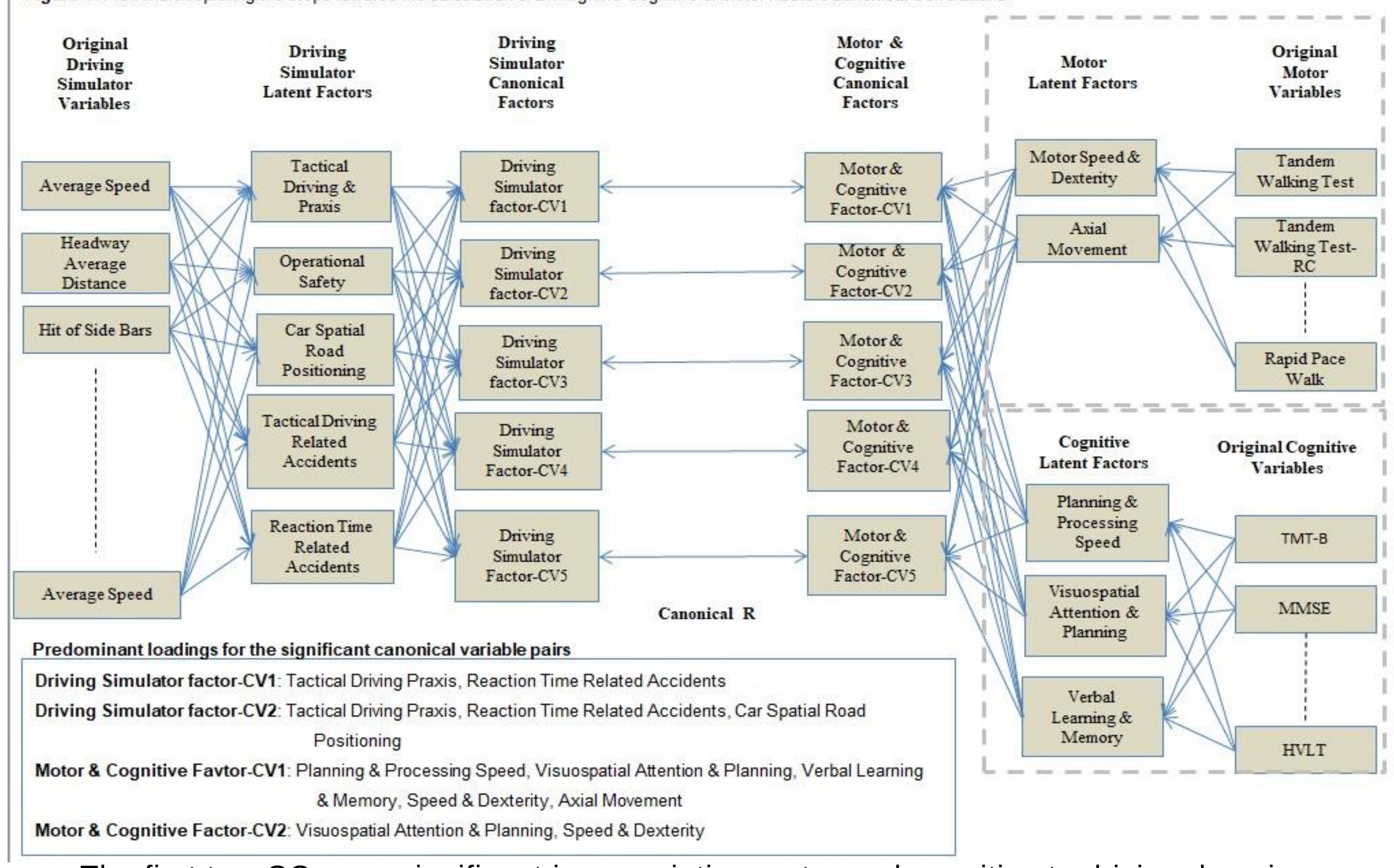
- Executive
- Visuospatial

Domain representation

- **Driving**: Tactical Driving Praxis, Operational Safety, Car Spatial Road Positioning, Tactical Driving related Accidents, Reaction Time Related Accidents;
- **Motor**: Motor Speed and Dexterity, Axial Movement;
- **Cognitive**: Planning and Processing Speed, Visuospatial Attention and Planning, Verbal Learning and Memory.

Motor & Cognitive to Driving Associations

Figure 1. Flowchart depicting the steps towards the calculation of Driving and Cognitive & Motor Factors canonical Correlations



The first two CC were significant in associating motor and cognitive to driving domains

Canonical Variate Pair	1	2	3	4	5
Canonical Correlation R	**0.848**	**0.741**	0.462	0.2	0.105
Factor Contributions (*L*)					
Driving - Tactical driving praxis	**-0.854**	**-0.354**	-0.301	-0.144	0.182
Driving - Operational Safety	-0.148	0.223	0.089	-0.948	0.147
Driving - Car spatial road positioning	0.159	**-0.605**	0.617	0.035	0.476
Driving - Tactical driving related accidents	-0.128	-0.094	0.5	-0.048	-0.85
Driving - Reaction time related accidents	**0.583**	**-0.541**	-0.524	-0.237	-0.191
Cognitive - Planning and processing speed	**-0.721**	-0.014	-0.685	0.106	0.011
Cognitive - Visuospatial attention and planning	**0.584**	**0.746**	0.209	0.119	0.212
Cognitive - Verbal learning and memory	**-0.581**	0.14	0.242	0.665	-0.376
Motor - Speed and dexterity	**0.538**	**0.552**	-0.177	-0.365	-0.491
Motor - Axial movement	**-0.753**	0.044	0.14	-0.637	-0.08

Driving Prediction from Cognitive and Motor Performance - Regression

Table 1. Prediction of Simulator Latent Factors by Motor and Cognitive latent factors

	Adjusted R^2	*F*	*P*
Tactical Driving Praxis	**0.6**	**14.4**	**5.3 x 10^{-6}**
Planning and Processing Speed	0.4 (0.1)		0.007
Speed and Dexterity	-0.3 (0.1)		0.009
Axial Movement	0.3 (0.1)		0.011
Car Spatial Road Position	**0.2**	**5.3**	**0.01**
Planning and Processing Speed	-0.6 (0.2)		0.005
Visuospatial Attention and Planning	-0.7 (0.3)		0.012
Reaction Time Related Accidents	**0.4**	**7.8**	**0.001**
Visuospatial Attention and Planning	-0.6 (0.2)		0.014
Learning and Memory	-0.5 (0.1)		0.003
Axial Movement	-0.5 (0.2)		0.001

Accident Prediction from Motor and Cognitive domains

- Cognitive factors alone allowed best prediction of accidents, whereas inclusion of motor domains led to slightly worse sensitivity, likely a result of overfitting with current sample size.

Table 2. Cross-validated prediction of accident probability in PD by motor & cognitive factors

		No accident	Accident	Total	Sensitivity	Specificity	LR+	LR-	DOR
H&Y and UPDRS-III	No accident	18 (85.7)	3 (14.3)	21	0.6	0.9	3.9	0.5	7.9
	Accident	3 (42.9)	4 (57.1)	7					
Motor Factors	No accident	8 (72.7)	3 (27.3)	11	0.4	0.7	1.5	0.8	1.8
	Accident	6 (60)	4 (40)	10					
Cognitive Factors	No accident	9 (81.8)	2 (18.2)	11	0.8	0.8	4.3	0.3	15.7
	Accident	2 (22.2)	7 (77.8)	9					
Motor & Cognitive Factors	No accident	8 (80)	2 (20)	10	0.6	0.8	2.8	0.6	5,0
	Accident	4 (44.4)	5 (55.6)	9					

CONCUSION

- Driving ability in early PD is related to cognitive abilities primarily, especially executive and visuospatial skills, and secondarily to motor performance
- Cognitive testing alone, or in combination with easy to administer motor tasks can be used by physicians at the bedside in predicting driving behavior and accident probability early in the disease course.

REFERENCES

- Classen S. (2014). Consensus statements on driving in people with Parkinson's disease. Occup Ther Health Care, 28, 140-147
- Crizzle AM, Classen S, Uc EY (2012). Parkinson disease and driving: an evidence-based review. Neurology, 79, 2067-2074
- Uc EY, Rizzo M, Johnson AM (2009). Road safety in drivers with Parkinson disease. Neurology, 73, 2112-2119
- Dubinsky RM, Gray C, Husted D, Busenbark K, Vetere-Overfield B, Wiltfong D, et al. Driving in Parkinson's disease. Neurology. 1991;41:517-20.

Funding: DriverBrain Action «ARISTEIA» Greek General Secretariat for Research and Technology, European Social Fund and the Greek State. MES-CoBraD Project H2020-EU.3.1.5 (ID: 965422) grant to the Neurological Institute of Athens.