A multimodal model for the prediction of driving behavior

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Driving Behavior

- Driving is an integral part of everyday life in modern societies
- Various endogenous and exogenous factors may influence driving behavior and fitness
- Endogenous factors: personality traits, cognitive functioning, depressive mood, sleeping abnormalities, advanced age
- Exogenous factors: traffic load, distraction, driving environment, time of day

Older individuals & Driving

- The number of drivers in Europe that are older than 65 is constantly increasing (Yannis et al., 2011)
- Elderly individuals keep their driving license longer and drive larger distances
- The percentage of older drivers that are at risk due to cognitive or physical impairments remains unknown

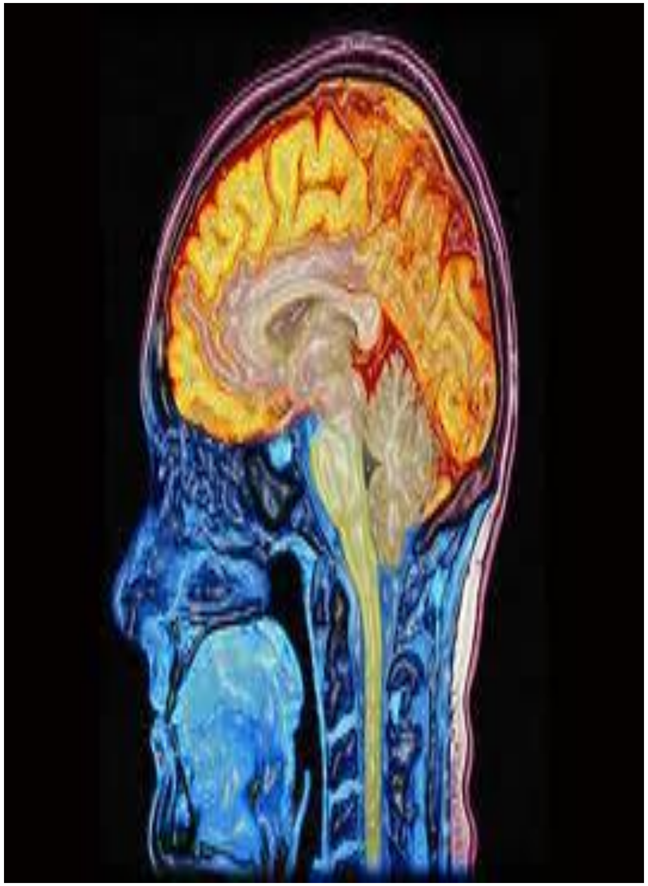
Cognitive functions & driving

- **Attention**
- quick perception of the environment

- **Executive functions**
- process multiple simultaneous environmental cues
- make rapid, accurate and safe decisions

- **Visuo-spatial skills**
- position the car accurately on the road
- manoeuvre the vehicle correctly
- judging distances and predicting the development of traffic situations

- **Memory**
- journey planning
- adapting behaviour



(Reger et al., 2004)

Alzheimer's disease (AD) and driving

•Patients with dementia at a moderate or severe stage are incapable of driving

•Significant risk to public road safety - increased possibilities of causing car accidents

•However, not all patients are incapable of driving, especially in the earlier stages of the disease (Carr et al., 2000; Perkinson et al., 2005)

(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)

Parkinson’s disease (PD) and driving

- Epidemiological data indicate increased risk for driving accidents in patients with PD

- On-road driving evaluations and driving simulator assessments have observed increased driving difficulties in patients with PD

- Drivers with PD need more time to initiate deceleration, have greater difficulty to stop at the proper position, have lower speed during driving around curves, and have greater lateral position variation

(Classen, 2014; Crizzle et al., 2012; Meindorfner et al., 2005; Ranchet et al., 2011; Stolwyk et al., 20050

Mild Cognitive Impairment & Driving

- MCI population is at risk for driving difficulties, although their performance on on-road or on simulator testing is not consistently worse than that of controls (Fritteli et al., 2009; Kawano et al., 2012; Wadley et al., 2009)

- Measures of mental flexibility, inhibitory control and visual attention appear to be associated with driving performance in patients with MCI, but this issue needs further investigation (Kawano et al., 2012)

Objective of Study

- **Development of a multimodal model for predicting indexes of driving behavior**

- Predictors: Cognitive Functioning, Motor Skills, Advanced Age, Medical Disorders (AD, PD, MCI), traffic load, driving environment (urban/rural), distractors (conversation/mobile phone use)

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

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.

Participants and Driving Simulator Assessment

<u>Sample of the study:</u>

239 Participants

- 114 controls
- 28 AD patients
- 65 MCI patients
- 32 PD patients

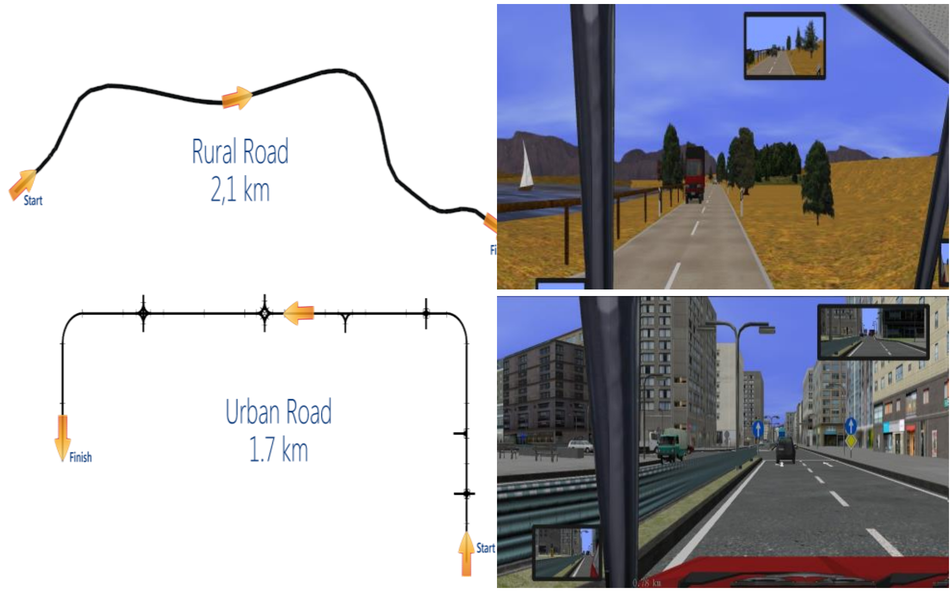


Figure 1. The two plans of the driving routes (rural and urban) and two screenshots for each driving environment

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

Latent Variable: Driving Performance

- Average Speed
- Variation of Lateral Position
- Gear Average
- TTL Average

Latent Variable: Driving Errors

Outside Road Lines

Hits of Side Bars

High Rounds per Minute

Latent Variable: Cognitive Fitness

- Letter Number Sequencing (Working Memory)
- Driving Scenes (Visual Attention)
- Symbol Digit Modalities Test (Information Processing Speed)

Latent Variable: Motor Skills

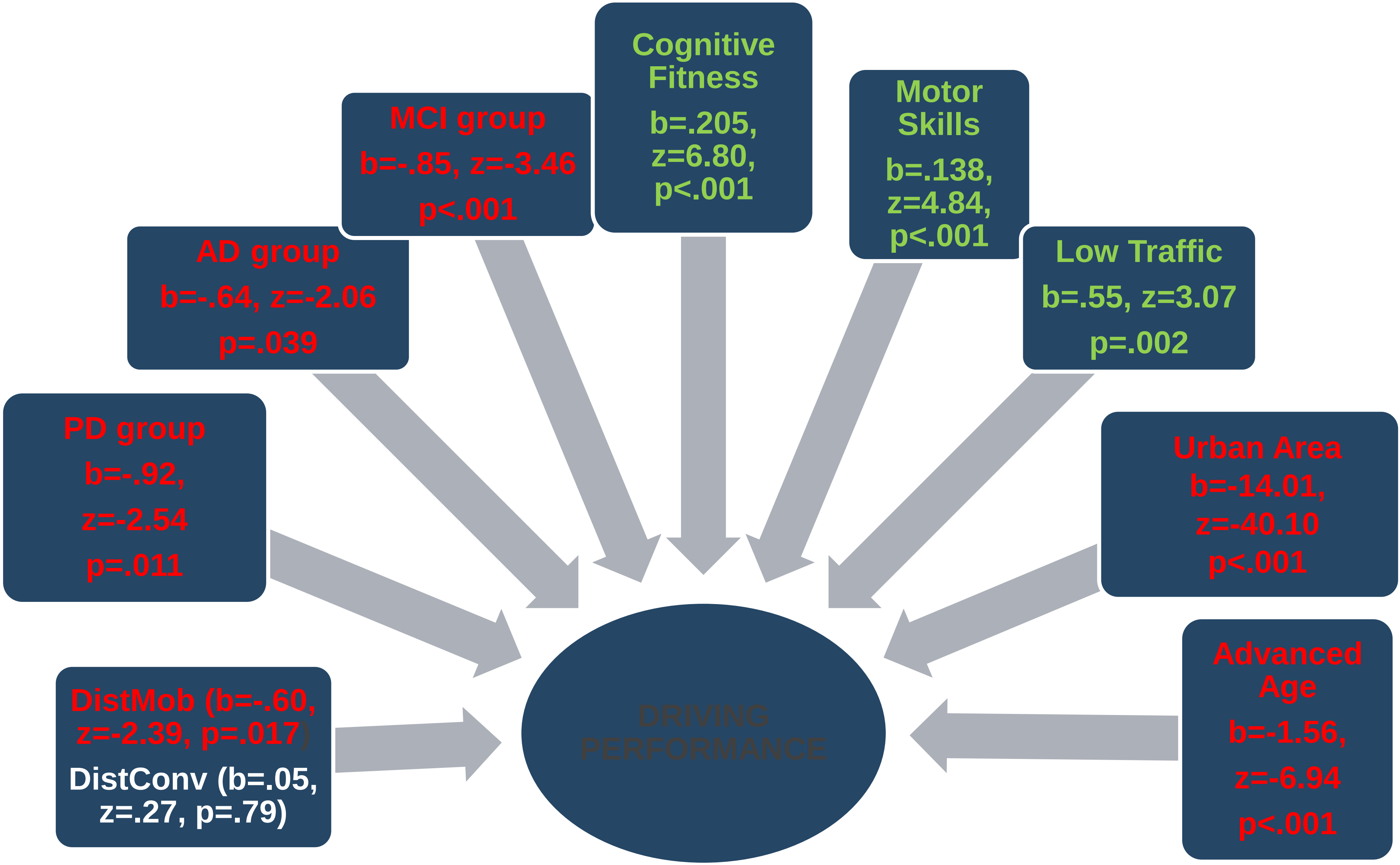
- Tandem Walking: Completion Time
- Tandem Walking: Errors
- Tandem Walking with RNC: Completion Time
- Tandem Walking with RNC: Errors

Outcome Measures

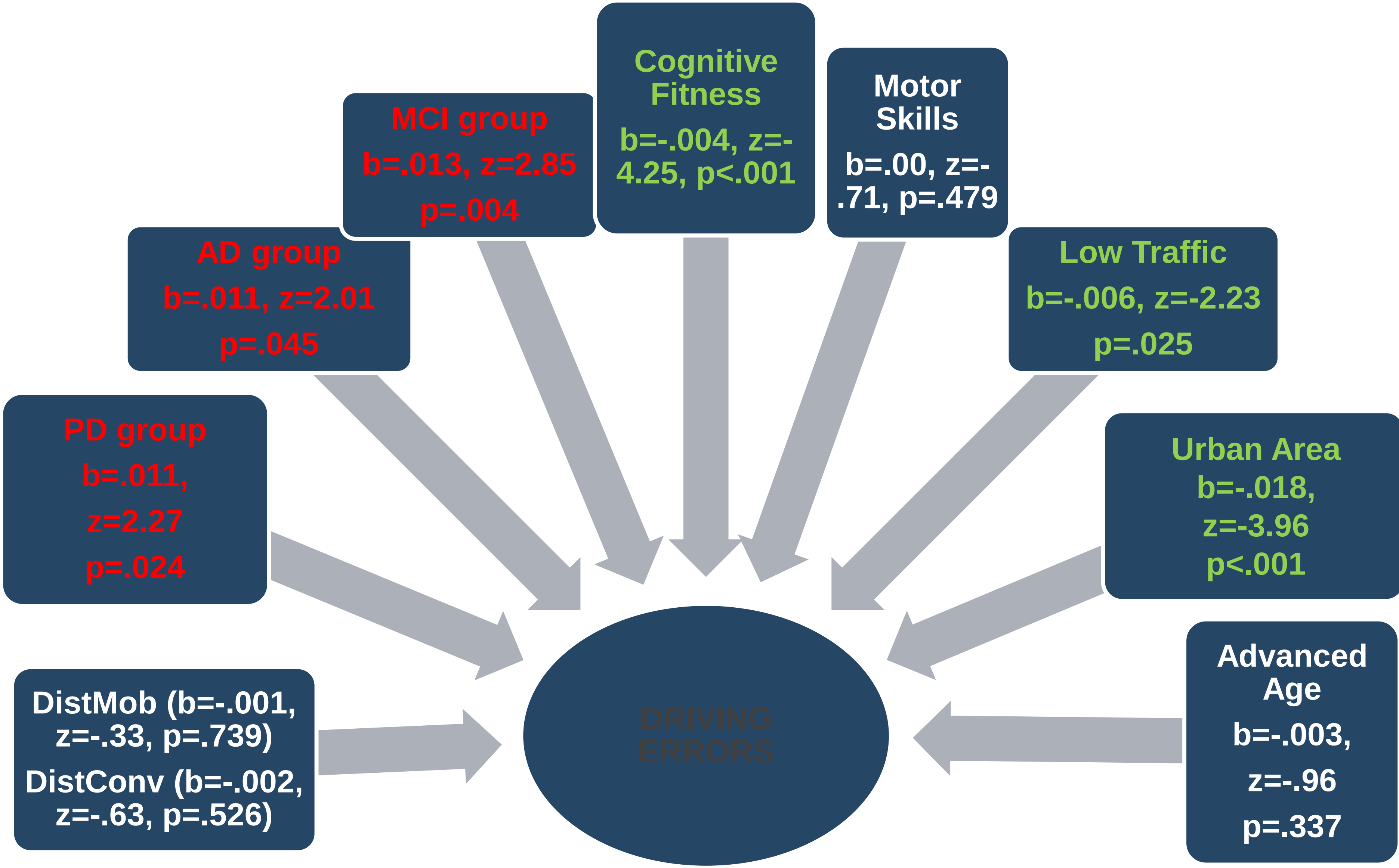
- Driving Performance
- Driving Errors
- Accident Risk
- Reaction Time

RESULTS

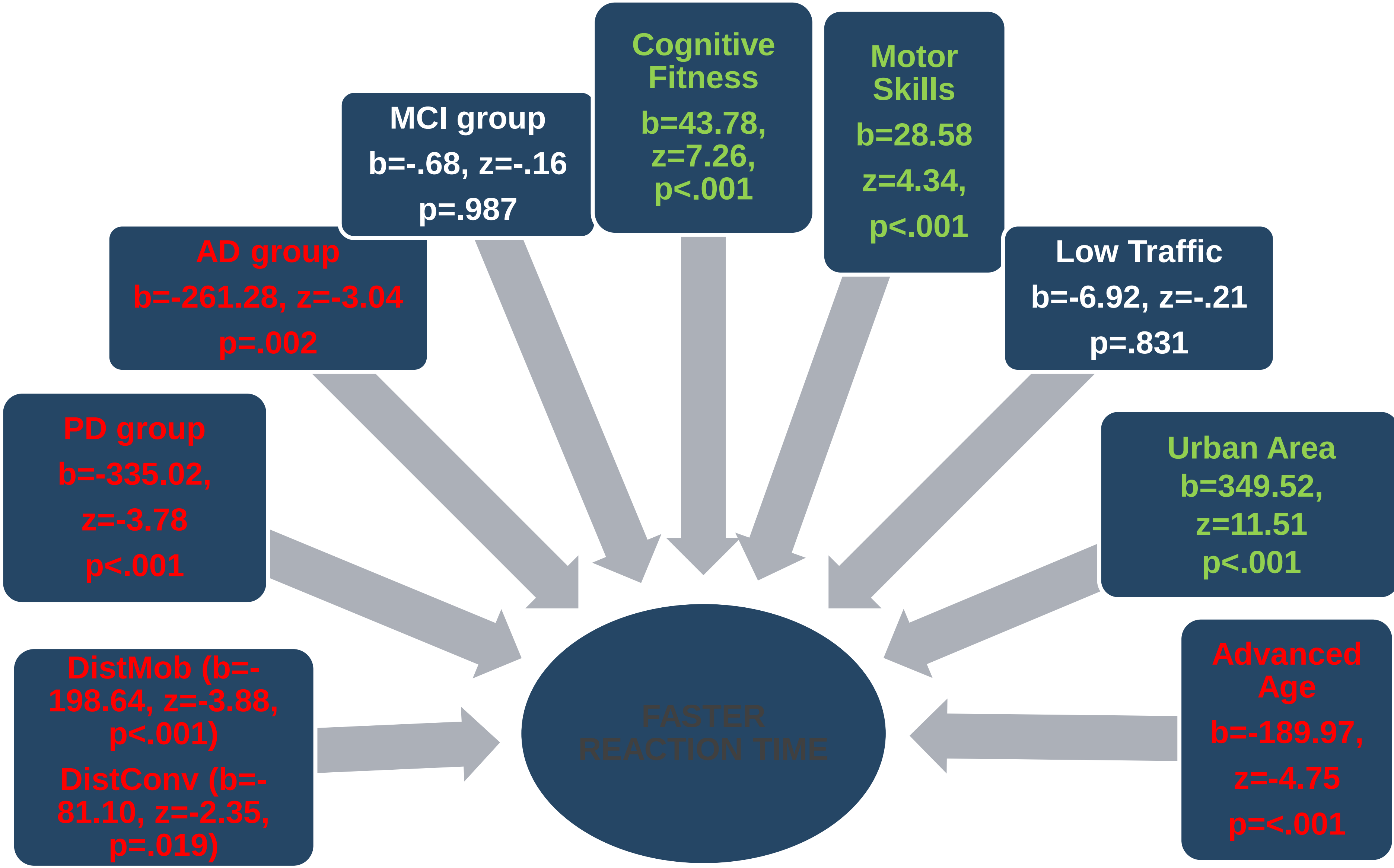
Multivariate Model for Driving Performance



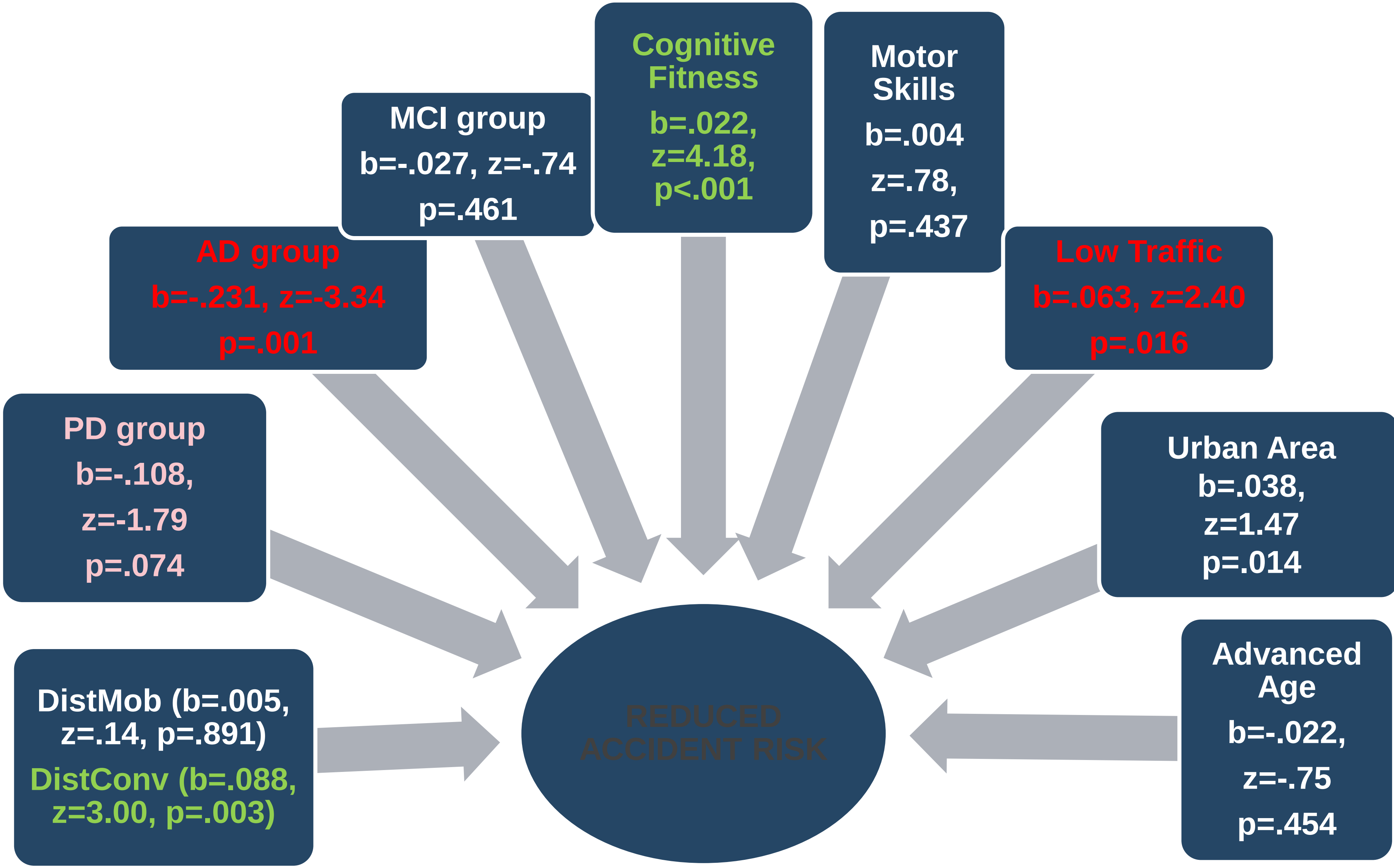
Multivariate Model for Driving Errors



Multivariate Model for Reaction Time



Multivariate Model for Accident Risk



Summary I

- MCI, AD and PD patients have altered driving behavior as indicated by the lower levels of overall driving performance and the increased number of driving errors. Moreover, AD and PD patients have larger reaction time.

- AD patients have a significantly increased risk for driving accidents, whereas in the drivers with PD the specific association marginally failed to achieve statistical significance

- Cognitive fitness was associated with better driving performance, fewer driving errors, smaller reaction time and lower accident risk

Summary II

- Motor skills are associated with better driving performance and smaller reaction time

- The use of mobile phone but not conversation was associated with lower levels of driving performance

- Both mobile phone use and conversation were associated with larger reaction time

- Advanced age was associated with lower levels of driving performance and larger reaction time. On the other hand, no significant association of advanced age was observed with driving errors and accident risk

Summary III

- Driving in an urban region was associated with lower levels of driving performance, whereas a low traffic load was beneficial for driving performance

- Driving in an urban region was associated with less driving errors and smaller reaction time

- Possibly, the more complex environment of the urban region increased the levels of awareness, thus leading to less driving errors and smaller reaction time

Future research

- Exploration of the predictive capacity of the aforementioned predictors under on-road driving conditions

- Development of multimodal models aiming at predicting driving behavior separately for various age groups

- Development of multimodal models aiming at predicting driving behavior separately for the various clinical conditions

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