Driving simulator experiment design for the effects of driver distraction and the assessment of driver skills

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‘Vehicle User Characteristics Committee’
Background

- **The DISTRACT research project**
  - “Analysis of causes and impacts of driver distraction”
  - Causes: endogenous & exogenous, Impacts: driver behaviour & safety
  - Drivers from the general population, as well as drivers with altered cognition due to cerebral diseases with high prevalence: e.g. Mild Cognitive Impairment (MCI), mild Alzheimer’s Disease, Cerebrovascular disease (stroke).

- **The DriverBrain research project**
  - “Analysis of the performance of drivers with cerebral diseases” altering cognition
  - Alzheimer’s Disease, Parkinson’s disease, Cerebrovascular disease - both in their MCI (pre-dementia) stages, but also in their mild dementia stages.

- **An interdisciplinary research team**
  - Dpt. of Transportation Planning and Engineering of the NTUA
  - Dpt. of Neurology of the University of Athens (NKUA) Medical School, ATTIKON General University Hospital, Athens
  - Dpt. of Psychology, UoA School of Philosophy, Pedagogy and Psychology

- **A common simulator experiment**
Objectives

- To present our approach for the design of a driving simulator experiment which:
  
  - Has a twofold objective
    - impacts of driver distraction
    - assessment of driver performance and skills
  
  - Targets two groups of drivers
    - Drivers from the general population
    - Drivers with a mild pathological condition
Key research variables

- **Diseases & conditions targeted**
  - Parkinson’s (PD), Alzheimer’s (AD), Cerebrovascular (CVD) in their Pre-Dementia or the very Mild Dementia Stages
  - MCI due to various causes (mainly pre-dementia stage of AD)
  - In terms of driving performance, but also as ‘endogenous’ causes of distraction

- **Exogenous distraction causes**
  - Use of mobile phone (hand-held)
  - Conversation with passenger

- **Road and traffic variables**
  - Area type (urban / rural)
  - Traffic volume (low, moderate, high)
Overview of the experiment

- Sample design & characteristics:
  - Healthy drivers & impaired drivers: oversampling of ages >55 years

<table>
<thead>
<tr>
<th>Age</th>
<th>Impaired</th>
<th>Healthy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 55</td>
<td>125</td>
<td>75</td>
<td>200</td>
</tr>
<tr>
<td>&lt; 55</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>175</td>
<td>125</td>
<td>300</td>
</tr>
</tbody>
</table>

- Duration: 2 years
- Questionnaire on driving habits
- Medical, clinical & neurological evaluation
- Neuropsychological assessment
- Driving simulation experiment
  - Familiarisation with the simulator
  - Phase 1: Distracted driving experiment
  - Phase 2: Assessment of driver skills at operational level
Medical 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 acuity, 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

- **Comprehensive Neuropsychological Evaluation**
  - Tests covering a large spectrum of Cognitive Functions:
    - visuo-spatial, verbal episodic and working memory
    - general, selective and divided attention
    - reaction time
    - Processing speed, psychomotor speed

- Associated with fitness to drive:
  - MMSE: General Gognitive State
  - Clock Drawing Test
  - Hopkins Verbal Learning Test
  - Trail Making Test
  - Useful Field of View
Simulator experiment phase 1

- **Distracted driving and performance assessment experiment**
- Full factorial within-subject design
- 3 distraction conditions: none / cell-phone / conversation with passenger
- 2 road environments: divided urban arterial / undivided two-lane rural road
- 2 traffic scenarios
  - $Q_M$: moderate traffic conditions
    (vehicle arrivals drawn from a Gamma distribution with $m=12$ sec, $\sigma^2=6$ sec ~ $Q=300$ veh/h)
  - $Q_H$: high traffic conditions
    (vehicle arrivals drawn from a Gamma distribution with $m=6$ sec, $\sigma^2=3$ sec ~ $Q=600$ veh/h)

<table>
<thead>
<tr>
<th>Distraction sources</th>
<th>Road and traffic conditions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban area</td>
<td>Rural area</td>
</tr>
<tr>
<td></td>
<td>$Q_M$</td>
<td>$Q_H$</td>
</tr>
<tr>
<td>No distraction</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Cell phone</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Conversation with passenger</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>
Simulator experiment phase 1

- Distracted driving and performance assessment experiment
- Summary of participant trials
  - 2 blocks with 6 trials each
  - Randomized between and within block-trials
  - Incidents at fixed points

<table>
<thead>
<tr>
<th>Block</th>
<th>Trial</th>
<th>Area type</th>
<th>Time</th>
<th>Traffic</th>
<th>Distractor</th>
<th>~Length (Km)</th>
<th>~Duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Urban</td>
<td>Day</td>
<td>Moderate</td>
<td>None</td>
<td>1.7</td>
<td>3.0</td>
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<tr>
<td>1</td>
<td>2</td>
<td>Urban</td>
<td>Day</td>
<td>High</td>
<td>None</td>
<td>1.7</td>
<td>3.0</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>Urban</td>
<td>Day</td>
<td>Moderate</td>
<td>Cell phone</td>
<td>1.7</td>
<td>3.0</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>Urban</td>
<td>Day</td>
<td>High</td>
<td>Cell phone</td>
<td>1.7</td>
<td>3.0</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>Urban</td>
<td>Day</td>
<td>Moderate</td>
<td>Passenger conversation</td>
<td>1.7</td>
<td>3.0</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>Urban</td>
<td>Day</td>
<td>High</td>
<td>Passenger conversation</td>
<td>1.7</td>
<td>3.0</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>Rural</td>
<td>Day</td>
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<td>3.0</td>
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<td>8</td>
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<td>Day</td>
<td>High</td>
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<td>3.0</td>
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<td>9</td>
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<td>Day</td>
<td>Moderate</td>
<td>Cell phone</td>
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<td>3.0</td>
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<td>2</td>
<td>10</td>
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<td>Day</td>
<td>High</td>
<td>Cell phone</td>
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<td>3.0</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>Rural</td>
<td>Day</td>
<td>Moderate</td>
<td>Passenger conversation</td>
<td>2.0</td>
<td>3.0</td>
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<tr>
<td>2</td>
<td>12</td>
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<td>Day</td>
<td>High</td>
<td>Passenger conversation</td>
<td>2.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Total 22.2 36
Simulator experiment phase 1

- **Distracted driving and performance assessment experiment**

- Traffic scenarios
  - **Input**: Vehicle headways drawn from a Gamma distribution with a given mean and variance
  - **Output**: The specific traffic volume experienced per trial for each participant

- Quantitative indicators - Trial specific (automatically recorded)
  - Reaction time
  - Speed (& difference from mean)
  - Lateral position (& difference from mean)
  - Steering angle (& difference from mean)
  - Accident probability at specific incident
    - Urban: parked car door opening, sudden appearance of child
    - Rural: sudden appearance of animal
Simulator experiment phase 2

- **Assessment of driver skills at operational level**
- Control tasks and a working memory task that involves information presented on road signs
- Scenarios enabling assessment of drivers’ performance on control tasks and a working memory task
- 3 drives
  - Duration of experiment (phase2): ~ 12 minutes
  - Conditions of varying level of task demand:
    - Low demand
    - Moderate demand
    - High demand
Simulator experiment phase 2

- **Assessment of driver skills at operational level**
  - Driving tasks
    - Car following
    - Lane changes (driving between traffic cones)
    - Decision task
  - Quantitative indicators
    - Speed
    - Lateral position
    - Collisions
  - Qualitative indicators
    - Recall of safety information
    - Compliance to instructions
Discussion

- Contribution of the research
  - Interdisciplinary approach
  - Large sample size
  - Focus on impaired drivers
  - Endogenous and exogenous effects on driver performance
  - Detailed effects of traffic

- Challenges in the experiment design
  - Combine and balance the objectives & targets
  - Selection of key variables (medical, neuropsychological, traffic)
  - Individual assessment and population analysis
  - Efficiency: rigorous design yet manageable size
  - Effects of simulator sickness and unfamiliar technological environment
  - Need for extensive pilot-testing (in progress)
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