PDT: Several examples of on-line measurement of driver cognitive workload

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The problem: workload and distraction

ITS the solution?
Behavioral Research by:

Accident analysis
Real-world observations/
Field Operational Tests
Instrumented vehicles
Driving simulators
Laboratory experiments
Mathematical modelling

+ ↔ valid
- ↔ effects interpretable
TNO driving simulator facilities
Behavioural measures

- Performance indicators:
  - speed, speed variance, headway, TTC
  - lateral placement, SDlat, TLC

- Visual attention/distraction
  - Glance duration, number of glances

- Workload
  - PDT, Tocc, physiological measures, subjective ratings

- Comfort
  - vertical accelerations, subjective ratings

- Acceptance
  - questionnaires, surveys
Car driving

- Continuous task (lane keeping)
- Planned actions (overtaking, turning)
- Sudden actions (braking lead vehicle)
- Changes in road environment (work zone)
- Use of in-vehicle system (navigation)

- How to measure workload while conducting these tasks?
Workload

- **Secondary task**
  - CMT (Continuous Memory Task) *(mental workload)*
  - Numerical ‘99’ task *(visual)*
  - Peripheral Detection Task (PDT)

- **Physiological measures**
  - Heart rate frequency *(overall level of activation)*
  - Heart rate variability *(cognitive or mental workload)*
  - EEG (Electro Encephalo Gram) *(P300 measure for attention)*

- **RSME (Rating Scale Mental Effort)**
  One-dimensional. For driving as sensitive as multi-dimensional scales *(e.g. NASA-TLX)*
Workload measures

• Disadvantage of several measures:
  • Measurement for longer periods of time/whole run

• Need for a measure:
  • Suitable for short periods of time (peak loads)
  • Able to measure variations in workload
  • Objective
  • Is not distracting attention
  • Suitable for different workload conditions, due to:
    • road environment
    • traffic situation
    • in-vehicle system
    • etc.
Secondary tasks

- Secondary task performance depends on workload level primary task
  - Verwey and Veltman (1995): secondary visual task sensitive to variations in task demand
Functional field of view decreases with increasing workload

Miura (1986):
• with increasing traffic density, detection times for light spots on the windscreen increased.
• Visual field of view reduces with higher driving task complexity

• higher reaction times to more peripheral stimuli with increasing workload

Visual tunneling or cognitive tunneling?

Van Winsum, Martens & Herland (1999):
• Peripheral Detection Task PDT
Peripheral Detection Task PDT

- First used in European project IN-ARTE
  - A small red square presented on simulator screen for 1 s (not of relevance for primary task, easy to neglect)
  - On average, each 4 s (random between 3-5 s)
  - In an area 11-23 degrees left and 2-4 degrees above horizon
  - Response via finger switch (< 2s)

- Low-level easy-to-automate process that needs little conscious attention
- Sensitive to short lasting peaks in workload
Examples of PDT/workload studies

Driving simulator studies
- IN-ARTE
- Roadwise WoW
- Road environment complexity

On-the-road studies (instrumented vehicles)
- Type of display control
- Safety effects of navigation systems
Example 1: IN-ARTE study: Rural road

- Reaction time
- Fraction of missed signals
Example 1: IN-ARTE study: Motorway

Reaction time  Fraction of missed signals
Example 1: IN-ARTE study: type of support
Example 1: IN-ARTE study: visual or cognitive tunneling?

- Difference high/low workload
- No difference in horizontal angle

-> cognitive tunneling
Example 2: WoW Driving simulator study

- Dutch DOT pilot FOT ‘Wijzer op Weg’: ‘Roadwise’
  - Which information is suitable for direct presentation in the car?
  - Possibilities for traffic management?
  - Implications for traffic safety?
- Main Question for driving simulator study:
  - Safe to do so on public road?
  - Standing still:
    - points of interest
    - menu

audio:
- news headlines
- speed warning
Example 2: WoW

- Driving behaviour
  - speed
  - headway
  - Steering behaviour
  - Lane keeping
  - Time-To-Collision

- Workload
  - questionnaire (RSME)
  - Peripheral Detection Task (PDT)

- Acceptance
  - Standard questionnaire
  - open question

Scenarios:
- normal driving
  - DRIP-info
- Sharp curve
- Rural roads
- City driving
- Work Zone
- Traffic jam by incident
Example 2: WoW

Results PDT

RSME: from 34.9 \(\rightarrow\) 42.8 from just below to just above ‘some effort’
Example 3: Complexity of road environment and workload

How to measure effects of motorway environments?

A10 Beltway Amsterdam
Example 3: Complexity of road environment and workload
Example 3: Road environment complexity and workload
Example 4: Display Control
Dashboard versus steering column

Steering column: blind operation (after practice)
Dashboard: buttons ask for eye-hand coordination

Execution of task needs check on display

Differences between dashboard and steering column with respect to visual attention and workload?
Example 4: Display control and workload

- **Peripheral Detection Task (PDT)**
  - Secondary task
  - Functional visual field of view reduces with increasing workload of driving task -> decreasing performance

- **Rating Scale Mental Effort (RSME, BSMI in Dutch)**
  - Subjective measure
  - Scale between 0 – 150
Example 4: Display control
Results workload PDT (1)
Example 4: Display control and workload (2)

RSME
Example 5: Safety effects of navigation systems

- Are navigation systems reducing workload?
Example 5: Are navigation systems reducing workload?

<table>
<thead>
<tr>
<th></th>
<th>free</th>
<th>waypoint</th>
<th>navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDT reaction time</td>
<td>1.14</td>
<td>1.22</td>
<td>1.00</td>
</tr>
<tr>
<td>PDT %missed signals</td>
<td>53.8</td>
<td>68.7</td>
<td>27.8</td>
</tr>
</tbody>
</table>

subjective RSME

Diagram showing RSME levels for free, waypoints, and navigation conditions.

Considerable effort
Rather much effort
Some effort
A little effort
Conclusions PDT examples (1)

IN-ARTE study
- PDT sensitive for variations in workload
- PDT makes distinction in workload:
  - by task complexity (type of road, other traffic)
  - By in-vehicle support modality

Wow study
- Overall, workload increased (both RSME and PDT)
- But PDT could identify that:
  - Workload increased for normal scenarios (free + car-following)
  - For more critical scenarios increase in workload due to system diminished
Conclusions PDT examples (2)

Road environment complexity simulator study:
- Subjective workload higher in the maximum version (including work zone), but around the level ‘some effort’ (RSME)
- Experienced workload was larger for numerical task than for the PDT
- Overall, secondary tasks showed no workload effects (subjects are able to neglect distraction by the visual complex environment)
- Both secondary tasks sensitive to identify small workload effects for specific road sections (sharp curve and work zone)

Display control on-the-road study:
- Both steering column and dashboard control resulted in a substantial increase of workload (both RSME and PDT)
- No effects on workload between type of control based on PDT
- Reduction of subjective workload (minus 20%)

Navigation system on-the-road study:
- RSME: With navigation system workload rated much lower than with conventional aids
- PDT: % missed stimuli 20% lower; reaction time decreased with 12%
Overall conclusions PDT

- PDT is a visual secondary task but measuring cognitive workload based on cognitive tunneling paradigm
- PDT low-level easy-to-automate process that needs little conscious attention
- PDT suitable for measuring short-lasting peaks in workload
- PDT sensitive for variations in workload
- PDT makes distinction in workload:
  - by task complexity (type of road, other traffic, critical scenarios)
  - By in-vehicle support modality
- Head-mounted LED better than ‘dashboard related’
- Reaction time and % missed signals give similar results, but last one a bit more sensitive
- Criterion values can be derived based on normal and safety-critical scenarios (both relatively and absolutely)
- Ready for standardization
Literature


