Visual and Cognitive Distraction Effects on Drivers Situation Awareness

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Based on Yu Zhang’s Dissertation completed in 2011 at the Department of Industrial & System Engineering, North Carolina State University

Cycle of Driver Behaviour and Distraction Mechanism

- Behavior and Performance change
- Cognitive process & Situation Awareness
- Distraction
- Reflect
- Dictate
- Mediate
Visual and Cognitive Distraction Effects on Drivers Situation Awareness

[Adapted from Rasmussen, 1983]
Note: components highlighted by yellow require working memory
Levels of Driving Control & Operational Modes

Operational

Implementing basic vehicle control actions:
- Lane control,
- Speed control...

Skill-based

Tactical

Developing strategies to realize local goals:
- Passing,
- Merging...

Rule-based

Strategic

Planning an itinerary under general constraints:
- Trip plan
- Route Congestion
- Accidents...

Knowledge-based

(Driving levels by Michon, 1995)
Degree of Driving Task dependence on Driver SA

Operational  Tactical  Strategic

L1 SA  L1 SA  L1 SA
L2 SA  L2 SA  L2 SA
L3 SA  L3 SA  L3 SA

Skill-based  Rule-based  Knowledge-based

(Driving levels by Michon, 1995)
Distractions interfere with cognitive process, cause deficiency in SA, and lead to errors in decision making and action selecting.

Two forms of visual distraction: Visual distraction and Cognitive distraction

Note: Shaded components are cognitive elements required by driving; V indicates components are influenced by visual distraction; C indicates components are influenced by cognitive distraction

Adapted from Wickens, 1984
Hypotheses

Visual and Cognitive Distraction Effects on Drivers Situation Awareness
## Hypotheses

<table>
<thead>
<tr>
<th>Work load</th>
<th>Operational driving control</th>
<th>Tactical driving control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Visual</td>
<td>Cognitive</td>
</tr>
<tr>
<td>Level 1 SA</td>
<td>Degradation</td>
<td>N/A</td>
</tr>
<tr>
<td>Level 2 SA</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Level 3 SA</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Work load</td>
<td>Increased</td>
<td>Increased</td>
</tr>
</tbody>
</table>
Apparatus & Participants

- Participants: 20 young driver
  - Age: 16~21 yrs. (M= 2.45 yrs)
  - Driving experience: 0.5~4 yrs. (M= 2.45 yrs.)

- Apparatus:
  - Fixed-based STISIM Drive M400 driving simulator (135 degree field of view)
  - Visual distraction: 12-inch HP tablet
  - Cognitive distraction: Hi-fi speakers
  - ASL EYE-TRAC® head-mounted eye tracker

- Experiment Design
  2x2x2 factorial design
  - Tactical (Passing) and operational (following)
  - With/without visual distraction
  - With/without cognitive distraction
Primary Tasks Details

<table>
<thead>
<tr>
<th>Required activities</th>
<th>Following</th>
<th>Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead vehicle changes lane</td>
<td>Lane maintenance &amp; Lane changing</td>
<td>Lead vehicle decelerate (10mph below speed limit)</td>
</tr>
<tr>
<td>Interval</td>
<td>20~40s (Mean 30s)</td>
<td>45~65s (Mean 60s)</td>
</tr>
<tr>
<td></td>
<td>12 times of lane changing</td>
<td>6 times of passing</td>
</tr>
<tr>
<td>Required levels of driving control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring phase</td>
<td>Operational</td>
<td>Operational</td>
</tr>
<tr>
<td>Maneuvering phase</td>
<td>Operational</td>
<td>Operational; Tactical</td>
</tr>
<tr>
<td>Required levels SA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring phase</td>
<td>Level 1</td>
<td>Level 1 &amp; Level 2</td>
</tr>
<tr>
<td>Maneuvering phase</td>
<td>Level 1 &amp; Level 2</td>
<td>Level 1, Level 2 &amp; Level 3</td>
</tr>
</tbody>
</table>
Secondary Tasks Details

Visual Distraction: 
Refreshed every 10 s

Cognitive Distraction: 
Delivered every 20 s

Q: “Start from North, go clockwise, and pass one exit”
A: “East”
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Experiment Procedure

**Introduction**
- Consent form
- Simulation sickness questionnaire (SSQ)
- Adjusting of simulator

**Training**
- Primary driving tasks
- SA probe questions
- Distraction tasks
- Simultaneous tasks
- NASA TLX ranking

**Formal test**
- Eye tracking calibration
- Test
- Post SSQ
- NASA-TLX Rating
Dependent Variables

- **Perceived Workload (NASA-TLX)**
- **Real-time SA probes**
  - Probe questions are task-related questions based on a goal-direct task analysis (GDTA).
  - Probes were categorized according to the 3 levels of SA, including perception, comprehension and projection.
    - Level 1: Are the brake lights of lead vehicle on?
    - Level 2: Is the closest vehicle in the adjacent lane moving faster/slower than us?
    - Level 3: How long will it take for us to pass them?
  - Probes are delivered by a confederate operator as part of a natural conversation (every 26 s; 18 probe questions in one trial)
  - Measured by response latency & accuracy
  - Measure may only reflect quality of explicit awareness and not implicit awareness.
Data Analysis

- **Screening data for outliers due to unanticipated events**
  - Equipment problems or possible failure of subjects to follow instructions can lead to outliers that may introduce spurious variance in responses.

- **Validation of data set for parametric analysis**
  - Normality test (Shapiro-Wilks test)
  - Constant variance test (Bartlett statistic)

- **MANOVA** - conducted within each type of response to account for potential intercorrelations among responses measures in identifying significant effects of independent variables.

- **ANOVA on individual response measures** (revealed to be sensitive by MANOVA)
  - Tukey’s Honestly Significant Difference HSD test for post-hoc comparison of condition means
### Results:

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<thead>
<tr>
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<th>Tactical driving control</th>
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<tbody>
<tr>
<td></td>
<td>Visual</td>
<td>Cognitive</td>
</tr>
<tr>
<td>Level 1 SA</td>
<td>Improved accuracy</td>
<td>Improved accuracy</td>
</tr>
<tr>
<td>Level 2 SA</td>
<td>Increased latency</td>
<td>Increased latency</td>
</tr>
<tr>
<td>Level 3 SA</td>
<td>Decreased latency, increased accuracy</td>
<td>Decreased accuracy</td>
</tr>
</tbody>
</table>

**Possible reason for improved SA**

- Operational control is primarily supported by implicit awareness
- The presence of distractions make explicit awareness emerge and driver maintain more SA explicitly

**Workload**

- Increased
- Increased
- Increased
- Increased
- Increased
- Increased
Correlation Analyses (among SA measures)

► In following task [Operational control]
  ▪ Significant but weak dependence of higher levels (comprehension and projection) on perception.
  ▪ The relation among levels of SA did not appear to be sequential in nature.

► In passing tasks [Tactical control & operational control]
  ▪ The latency of Level 2 SA was strongly correlated with the latency of Level 1 SA;
  ▪ the latency of Level 3 was strongly correlated with the latency of Level 2 SA.

When tactical control is required, drivers need explicit SA to support to address cognitive task demands, which may work in a sequential manner.
Correlation Analyses (SA & Workload)

► Following task
  ▪ Workload was correlated with Level 3 SA
  ▪ However, Level 3 SA was not necessarily required by concurrent driving tasks.

► Passing task:
  ▪ Workload was also correlated with Level 1 and Level 2 SA, which actually addressed concurrent driving task needs.

- When primary driving tasks are supported by implicit SA, some elements of SA measure may simply serve as indicators of workload.
- SA probes assess different aspects of cognitive process from workload measures when explicit SA is used.
Conclusion

Drivers were affected by both distraction modalities and behavior outcomes were mediated by control modes required by concurrent driving tasks.

SA response measures derived from technique reflected influence of distraction tasks on explicit SA.

Demonstrated value of internal process index for driver distraction state classification and developed two potential approaches for detecting cognitive and visual distraction simultaneously.
Thank you for your attention!!

Questions are welcomed!