MULTIMODAL REPRESENTATIONS OF TIME-TO-COLLISION ON LANE-CHANGING DECISION-MAKING

Yuanjing Sun
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Today’s Overview

History of vehicular Technology
- In-vehicle Information System (IVIS) & Advanced Driver Assistance System (ADAS)

Multisensory interface design & Situation Awareness (SA) model
- Information-processing model in Driving : SA, performance and environment complexity

The adventures of audio cue over perform visual display
- *Time threshold setting in alerting function should be correspondent with sensory threshold*

Hypothesis and experiment design
- Optimal decision-making bias by Signal detection Theory (SDT) and Receiver Operating characteristic plot
1990s: The Era of intelligent vehicles and IVIS

- Most interaction in IVIS Belong to parallel Visual-Manual tasks

*Figure 11: Early car navigation systems (Toyota 1987 (a) and BMW 1994 (b)).*
Test methods of mental workload

• Occlusion method with shutter goggles

AAM Guidelines (Alliance of Automobile Manufacturers, 2003)

2.1a Glance behavior, (Alternative A) Single glance durations should not be > 2s and total glance time <= 20 s

2.1b Reference task (Alternative B) # of lane exceedances should not exceed reference task, car following should not be worse
Self-report subjective workload measure: NASA-TLX

<table>
<thead>
<tr>
<th>Title</th>
<th>Endpoints</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>MENTAL DEMAND</td>
<td>Low/High</td>
<td>How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?</td>
</tr>
<tr>
<td>PHYSICAL DEMAND</td>
<td>Low/High</td>
<td>How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?</td>
</tr>
<tr>
<td>TEMPORAL DEMAND</td>
<td>Low/High</td>
<td>How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?</td>
</tr>
<tr>
<td>PERFORMANCE</td>
<td>good/poor</td>
<td>How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?</td>
</tr>
<tr>
<td>EFFORT</td>
<td>Low/High</td>
<td>How hard did you have to work (mentally and physically) to accomplish your level of performance?</td>
</tr>
<tr>
<td>FRUSTRATION LEVEL</td>
<td>Low/High</td>
<td>How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?</td>
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</table>
2000s: Semi-automatic Advanced Driver Assistance system
2010s: Multimodal Human Machine Interaction

- Automatic Speech Recognition and voice control interface
Metrics to evaluate IVIS - Situation Awareness

- System Capability
- Interface Design
- Stress & Workload
- Complexity
- Automation

Task/System Factors

Individual Factors

- Goals & Objectives
- Preconceptions (Expectations)

SITUATION AWARENESS

- Perception of Elements in Current Situation
- Comprehension of Current Situation
- Projection of Future Status

Level 1

Level 2

Level 3

Decision

Performance Of Actions

Information Processing Mechanisms

- Long Term Memory Stores
- Automaticity

- Abilities
- Experience

Feedback
Situation Awareness (SA) vs. Task Complexity

- SA (Uncertainty of environment) + Task Performance (Reaction pattern based on experience) * Task Complexity (The extent to understand the situation) = Attention Resource (differ from individual’s WM)

Figure 1. Cognitive resources and its relation to task performance (Riener, 2012).
**Definitions, maneuver sequence, and relevant parameters of the Lane Changing task**

**Goal:** compare different combinations of multimodal warning formats to efficiently convey more information and to enhance lane-changing decision making accuracy without distracting drivers’ attention resources.

<table>
<thead>
<tr>
<th>Car</th>
<th>SV,POV</th>
<th>Leading/Following</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane</td>
<td>Original/Destination Lane</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>Volecity</td>
<td>$\Delta V$</td>
</tr>
<tr>
<td>Distance</td>
<td>Range</td>
<td>$r=$Range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rate=$Range/\Delta V$</td>
</tr>
<tr>
<td>Time</td>
<td>TTC</td>
<td>TTA</td>
</tr>
</tbody>
</table>
Optimal Warning design

- Mapping context and environment evaluation with Representation modality
- Warning algorithm and threshold setting convey appropriate urgency perception
Auditory display design

• Event onset intuitively map to sound onset.
• Level of priority or urgency can be represented systematically with variety in rhythm, tempo, pitch and harmonic complexity
• Drawing attention to, or indexing, a specific location in space—a form of deixis (Ballas, 1994) accomplished with 3D audio-rendering techniques

Four heuristic evaluation factors for Distinction from each other (acoustic properties, ecological frequency causal uncertainty, sound typicality)
Auditory displays out-perform visual displays in representing dynamic distance

- The TTC assumes a constant speed and does not account for vehicle acceleration.
- Monitor the changing velocity and estimate motion trajectory for front, rear and side cars. Both normally means 2 things, not 3.
- Perceive distance by distorted 2D image in rear and side mirrors.
- Frequent eye glance (saccade and fixation) require high workload hurt SA.
- Doppler effect and Inter-aural Time difference (ITD) indicate human can sense azimuth of source to detect motion trajectory.
Time threshold setting in alerting function should be correspondent with sensory threshold

• The parameter selection and threshold setting should be modified iteratively based on performance outcome of results.

• The uncertainty in environment is the most difficult part.

• The threshold between executing and cancelling LC range from 6.17s~9.98s

• Duration time of Lane Changing

• $5.3 \pm 1.0$ s

Figure 6. Distribution of required time for lane change.
## Experiment-Stimuli group

<table>
<thead>
<tr>
<th>Group</th>
<th>Summary</th>
<th>Pros &amp; Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>a video simulating a six second scene in the rear and side mirrors will be displayed</td>
<td></td>
</tr>
<tr>
<td>Control+ Digital</td>
<td>changing numbers to represent the dynamic distance from POV</td>
<td>• Precise but abstract</td>
</tr>
<tr>
<td>Number in dial gauge</td>
<td></td>
<td>• Vision display contradict to scan</td>
</tr>
<tr>
<td>Control+ Audio</td>
<td>• 10 seconds and over : Unnecessary (no beep sound)</td>
<td>Interfere by environmental noise and head movement; Which direction?</td>
</tr>
<tr>
<td></td>
<td>• 5 to 10 seconds : Adjustable range (2000Hz 60dB, three impulse per second)</td>
<td>Hazard or Evasive Nuisance cause ignorance</td>
</tr>
<tr>
<td></td>
<td>• 3 to 5 seconds : Recommended (2000Hz,60dB,ten impulse per second)</td>
<td>Reliability vs. warning pollution</td>
</tr>
<tr>
<td></td>
<td>• TTC Under 3 seconds : Imperative (Continuous sound)</td>
<td></td>
</tr>
<tr>
<td>Omni</td>
<td>All</td>
<td></td>
</tr>
</tbody>
</table>
Signal Detection Theory &

Correct Rejection

Hit rate 76%

Miss

False Alarm rate 8%

sensory continuum

Criterion

“no” region

“yes” region

NOISE

SIGNAL+NOISE

d’
Conclusion

• The control of speed is solution to avoid collision in lane changing.
• System delay and driver’s reaction time should be considered in a high-fidelity experiment.
• The alert function to display TTC differ from vehicles attributes, driving type, driving style and traffic complexity.
• Spatial sound stimuli need customized setting depend on difference in head diameter.
REFERENCE:


