Take-over time comparison by Demographics, Behavior, and Warning strength

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Automated Driving Research Office
Introduction

- **Objective**
  - Take-over time comparison according to the demographics, driver’s behavior, TOR warning strength
    - Demographics (Different participants)
    - Driver’s Behavior (Different task)
    - Take-over warning (Different strength)

- **Participants**
  - Recruiting condition = Driving experience * Age * Gender

- **Experiment Condition**
  - Driver’s Behavior (Oral/ Visual perception)
  - TOR Warning strength (Normal, Strong)

- **Measurements**
  - Steering wheel torque & angle, braking pressure
Well balanced 63 persons participated

- Driving experience: 1y ~ 39y
- Age: 20 ~ 79 years old
- Male: Female = 30:33

Screening Criteria:

- Driving on average more than twice a week
- Self-reported good health by participants
- No seriously medical problem
Driver’s Behavior

- In AD., the behavior of drivers is various and unpredictable.
- The possible actions depending on technical level are also different.
- The big difference of driver’s behavior between level 2 and 3 AD vehicles is the obligation to keep eye front.

To propose reasonable TOR times, it’s necessary to standardize driver’s behavior. So, two types of NDRT were designed to make driver pay attention to another task.

- The purpose of the NDRT is to force the driver to distract attention from driving task in AD

NDRT: Non-Driver Related Tasks (= Side task), A.D. : Automated Driving
Oral Task (auditory 1-back task)

- An auditory delayed digit recall task (e.g. the 1-back task requires the driver to memorize previous number and say out loudly the number when next number is spoken)
- Interval: 2 sec.
- The ratio of correct answer: 97%

The n-back task is a continuous performance task that is commonly used as an assessment in cognitive neuroscience to measure a part of working memory.

<table>
<thead>
<tr>
<th>Time(s)</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver listening</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct Answer by driver</td>
<td>-</td>
<td>X</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Visual perceptional Task (Arrow Task modified “Eriksen Flanker Task”)

- In cognitive psychology, the Eriksen Flanker Task\(^1\) is used to measure information processing and selective attention.

- Visual perceptional task intend to make eye-off from the front.
- Driver shell concentrated to percept an upward arrow in the monitor.
- Interval : 8 sec.
- The ration of correct answer : 93%

TOR Warning

- **Optical warning**
  - symbol + Text + Background color

  - Automated Driving Status symbol

  - Normal (Always on)
  - Strong (Blinking 5Hz)

- **Oral warning strength**
  - Normal (70db)
  - Strong (85db)
Take-over request process and Measurements

- **Take-over Request**
  - Automated Driving
  - ADS (Automated driving system) on
  - Alarm On

- **Take-over Preparation**
  - Sensory information of environment (Body balance, Vehicle movement, Road, Another vehicles, etc.) received
  - Environmental information processing
  - Sensory information of warning received
  - Warning information processing
  - stop or avoid?

- **Take-over Finish**
  - Manual Driving
  - Foot moves
  - Action by driver
  - Hands moves
  - Action by driver
  - Steering wheel torque, brake pedal pressure
  - Take-over Preparation time
  - Take-over Leading time
  - Take-over Finish time

**System (Measurements)**

**Human (Body)**

**Human (Brain)**

**Vehicle**
System Layout

TOR Warning

Arrow Task
Examples

- Visual perceptual and Oral task (video clip)
KATRI Driving Simulator

- 360° Dom screen, Medium size sedan, Motion platform
<table>
<thead>
<tr>
<th>Test</th>
<th>NDRTs</th>
<th>TOR Warning</th>
</tr>
</thead>
</table>
| 1~3  | Visual perceptual task  
      | Oral task      | No take-over request  
                        | No task          | *. To prevent guessing the TOR |
| 4~9  | Visual perceptual task  
      | Oral task      | Normal Warning   |
|      | No task          | Strong Warning |
Test set

- SET A, B (Training)
  - Training (MD)
    - 3min
  - Training (MD ↔ AD)
    - 4min
    - 10min
  - Training (MD)
    - 3min

- SET C~E (Tests)
  - MD
    - 1min
  - Test
    - 4min
  - Test
    - 4min
    - 13min
  - Test
    - 4min
  - MD
    - 1min

- Test
  - MD → AD
    - 10"
  - AD
  - Alarm
    - 3min
  - AD → MD
  - MD

NDRT (N/O/V)
Random start between
2m 10" ~ 2m 25"

TOR scenario

- Take-over request at automated driving
  - Traffic condition = LOS C (Avg. 80km/h, 12 vehicles (per 1 line, within 1km))
    - Set by actual traffic data of ROK’ highway
    - Simulated partial section of the Gyeongbu highway (13km)

**LOS C (Stable flow):** Ability to maneuver through lanes is noticeably restricted and lane changes require more driver awareness. Minimum vehicle spacing is about 220 ft (67 m). **LOS A is free flow. LOS F is brakedown flow.**
- Highway Capacity Manual (HCM), The publication of the Transportation Research Board of the United States.
## Results

### Take-over time distribution

<table>
<thead>
<tr>
<th></th>
<th>Take-over Preparation</th>
<th>Take-over Leading</th>
<th>Take-over Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>1.762</td>
<td>0.263</td>
<td>2.024</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>0.743</td>
<td>0.527</td>
<td>0.898</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>1.606</td>
<td>0.100</td>
<td>1.808</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>5.743</td>
<td>6.328</td>
<td>7.731</td>
</tr>
<tr>
<td><strong>95%ile</strong></td>
<td>3.111</td>
<td>1.061</td>
<td>3.763</td>
</tr>
</tbody>
</table>

* Take-over finish is the summation value of each take-over case
* Leading time is not always long in case of delayed preparation time

SD : Standard Deviation
Take-over method

- Brake pedal was mostly used to take-over (69%).
- Take-over methods didn’t related with the take over time.
- Drivers were hands on the steering wheel after brake.

Results

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<th>Time(s)</th>
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Take-over by break pedal: 69%
Take-over by steering wheel: 31%
• **Worst case by the demographics**
  - Resampling data over 95%ile (worst case) of each take-over Preparation, Leading, and Finish
  - In cases of gender and age
• Worst case by the demographics
  • Resampling data over 95%ile(worst case) of each take-over Preparation, Leading, and Finish
  • In case of driving experience
Worst case by behavior and warning.

- Resampling data over 95%ile (worst case) of each take-over Preparation and Leading
- In cases of NDRT and warning

Results
In terms of demographics

- Most participants were reacted (preparation) within 3.1s, and stable (leading) within 1s (95%tile).
- The 20s and the 60s had slower response in worst case.
  - In 20s, leading time was slower than others, because of short driving experience (<3y)
  - In 60s, preparation time was slower than others, because of lower cognitive ability.
- Participants less than 3 years, driving experience was take long time to react in worst case

In terms of Driver’s behavior

- Visual perception task: Leading time increase, because of blocked environment information.
- Auditory task: Memory processing disturb attention to transit to driving task (preparation time).
- (Stop or avoid?) Most participants (69%) were react using the brake.

In terms of Take-over warning (Request method)

- Strong warning can help to decrease the preparation time, but increasing the leading time.
- Normal warning make leading time shorter, but preparation time was increased.

Conclusion
Suggestion

- In terms of take-over warning (Request method)
  - In terms of intensity of acoustic warning, to start immediately with the highest intensity level are not recommended.
  - **Warning intensity suggest the escalation from normal intensity to strong intensity.**

- Take-over time
  - At least 6 seconds + α were required based on take-over preparation result.
  - **We suggest take-over time is not less than 8 seconds**
    - It’s a max value of take-over finish time.
    - The leading time may depend on scenario’s complexity and difficulty.