The “Human” Problem: Reactions to Disengagements

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How do drivers respond to AVs off-nominal conditions?

Let’s start by looking at what happened during the reported accidents:

- 62% in Autonomous mode
- 15% in Conventional mode
- 19% in Manual disengagement before collision
- 4% in Manual disengagement after collision

- Indicative of the fact that the human driver is still a “weak link” when driving manually
- Indicative of potential discomfort and/or lack of trust in the vehicle
- Indicative of drivers taking control of the situation too late
- Indicative of rear-end collisions which are hard to predict for both humans and autonomous technology

But how does a driver react to a car that disengages from the autonomous mode?
Trends for Different Automakers

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**Waymo Average Reaction Time as a Function of Miles Driven**

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**Mercedes Reaction Time as Function of Autonomous Miles**

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This can help understand an average, but does not help determining factors like driver’s training, confidence in driving the car, and the trend is oscillating and inconclusive → What can we look at?
Drivers Training and the importance of Performance

- Look at how reaction times change each month → increasing or decreasing?
- Look at how many miles are driven each month → more or less miles?
- Compare these two derivatives (normalized) and obtain 4 sectors: ++, +-, -+, --

**Waymo data**

**Sparse testing effect:** as less miles are driven (testing not frequently enough) the reaction time to disengagements increases

**Fast response effect:** least likely type of occurrence. Drivers have faster response (decreasing reaction time) while driving (and thus training) less. Short trips can have higher attention span and explain this

**Experience effect:** decrease in reaction time as more miles are driven and more experience is acquired → can cause bias in the results if drivers are trained to react to disengagements (not typical driver situation)

**Trust and distraction effect:** reaction times are increasing as mileage driven increases. It is easier to ”get comfortable” and improve your trust in the vehicle as more miles are driven
Comparison of the reported Data

- Just like for disengagement causes, there are many inconsistencies in the reported reaction times.
- There is no agreed upon definition set forward by the CA DMV.
- This leads to inconsistent methods for measuring the reaction time (e.g., hands on steering wheel? braking input?)
- Manufacturers do not have to report how the reaction time is computed.

<table>
<thead>
<tr>
<th>Metric</th>
<th>BMW</th>
<th>Delphi</th>
<th>Waymo</th>
<th>Nissan</th>
<th>Mercedes-Benz</th>
<th>Volkswagen</th>
<th>GM Cruise</th>
<th>Ford</th>
<th>Tesla</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average reported reaction time</td>
<td>$&lt; 2 \text{ s}$</td>
<td>$&lt; 1 \text{ s}$</td>
<td>$0.87$</td>
<td>$&lt; 1 \text{ s}$</td>
<td>$&lt; 1 \text{ s}$</td>
<td>$3.17 \text{ s}$</td>
<td>$&lt; 1 \text{ s}$</td>
<td>$&lt; 3 \text{ s}$</td>
<td>$1.03 \text{ s}$</td>
</tr>
</tbody>
</table>

Why is this important?

- We need to assess whether a driver can respond effectively to an AV disengagement.
- If not, we need to change regulations accordingly on who is using such technology.
Understanding Disengagements

- On average, manufacturers are reporting a reaction time of 0.83s
  
  \textit{Is this a reasonable number?}

- Mean reaction time shown in current studies with prior warning of participants $\geq 2$ s

Not all disengagements are the same. We can identify two main categories:

1. **Structured Disengagements**: these are disengagements where prior warning is issued to the driver. The warning can also be generalized to a visible cue of an external threat or hazard

2. **Unstructured Disengagement**: these represent worst-case scenario and a more realistic situation to test and assess, as no prior warning is given to the driver of an upcoming failure of the autonomous technology

\textit{When comparing mean reaction times we need to understand whether we are talking about structured or unstructured scenarios! To assess safety, we need to ensure reasonable performance of drivers within unstructured disengagement occurrences!}
Our next steps: Human-in-the-loop

• The only way of gathering insight into the problem is understanding the reactions to the worst-case scenario of unstructured disengagements

Experimental setup:

• Integrated real-car simulator, with 270° screen
• BMW series 6 with Ipad interface
• 40 test drivers to measure reaction times
• Aural and visual “retake control” message issued with no prior warning
• Gather regulatory insight on age, speed limits, timed usage (e.g., no more than 2 hr?)

We need rules to guarantee the safety of the system for the driver and the public
We analyzed trends in the data provided by manufacturers about the reaction times to disengagements.

**Issues** with current reported data:
- Not indicative of factors like drivers’ training, confidence in the car or other factors in driver performance.
- Not indicative of whether disengagement was structured/unstructured.
- Some manufacturers have reported ranges instead of actual reaction time.

What we believe needs to be done:
- Specific regulations should be set by the DMV for the method of measuring reaction time that all manufacturers adhere to.
- Regulations are required that set safety thresholds the drivers needs to follow/match so they can rely on the software.