REQUIREMENTS AND CONDITIONS – Booth No. 07

CRITICAL SCENARIOS FOR HUMAN DRIVERS – SIMULATOR STUDIES –

PEGASUS

Driving simulator studies allow the assessment of thresholds of human performance in critical highway scenarios.

- Human performance serves as a benchmark against which highly automated driving functions can be compared [1].
- Human performance is a product of the driver's capabilities and the task demands of the driving scenario [2].
- Driving simulator studies can be used to study the thresholds of human performance in very critical situations.

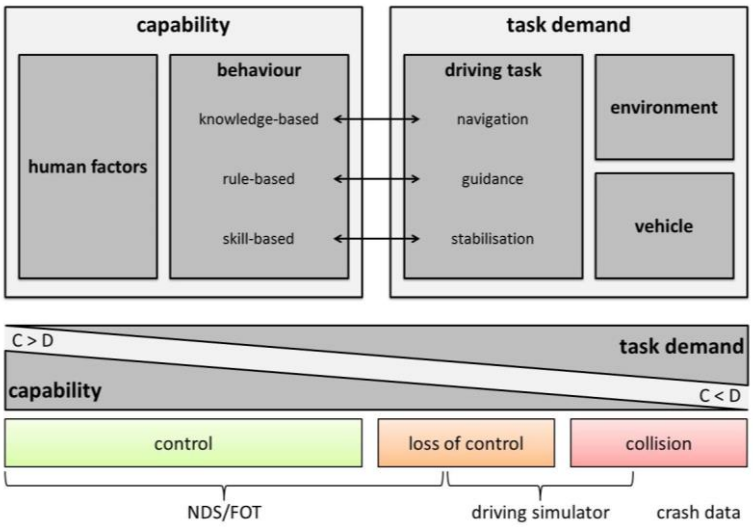

Figure 1. Simplified model of human performance in PEGASUS [3] based on the task-capability-interface model [2], three-level hierarchy of the driving task [4] and levels of human performance [5]. NDS = naturalistic driving study; FOT = field operational test.

Figure 2. Driving simulator used in the two studies. © DLR

- To quantify thresholds of human performance, a method from psychophysics, the method of constant stimuli [6], was used and adapted: A stimulus (e.g. a cutting-in vehicle) is presented repeatedly with randomly varying intensity (e.g. criticality of the scenario).
- Criticality was quantified by time to collision (TTC). Tested values were based on BMW's field operational test results [7]. In cut-in situations, for example, the most critical observed TTC was 1.7 s.
- The threshold of human performance is represented by the probability to collide at a certain criticality.

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Human performance is described by controllability and severity.

- In the first simulator study, participants were asked to keep on the left lane with a constant speed of 130 km/h. They encountered a cutting-in vehicle with a speed of 80 km/h (see Fig. 3).
- The TTC between two vehicles at the moment, when the cutting-in vehicle is just in the middle between two lanes, was manipulated in six levels: 0.5s, 0.7s, 0.9s, 1.1s, 1.3s and 1.5s.

Figure 3. Cut-in scenario: ego speed = 130 km/h; relative speed = 50 km/h. One case with a collision (top) and one case without collision (bottom).

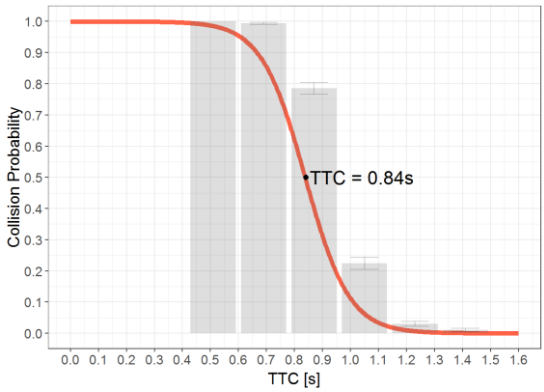

Figure 4. Relationship between collision probability and TTC.

- Controllability: The relationship between collision probability and TTC is presented in form of bar plot and logistic regression (see red line in Fig. 4).
- Threshold of human performance: The inflection point, where the collision probability is 50%. In this case, this threshold can be located at TTC = 0.84s.

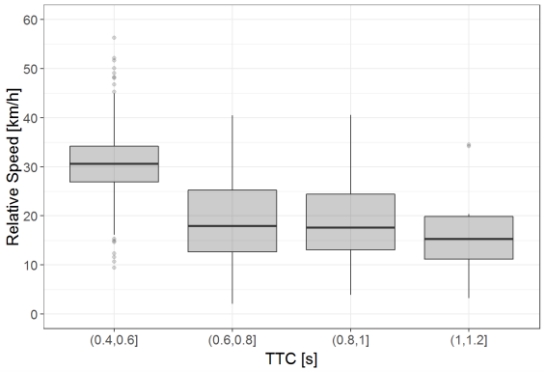

Figure 5. Distribution of relative speed per TTC.

- Severity: The box plot (see Fig. 5) presents the distribution of relative speed at the moment of a collision. A negative correlation between relative speed and TTC was revealed.

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Cut-in scenario

Figure 6. Cut-in scenario: ego speed = 100/130 km/h; relative speed = 50 km/h, aspired TTC = 0.6, 0.8, 1.0, 1.2 s; additional free lane in one quarter of trials (to provoke swerving).

- Replication of first study: TTC = 0.84 s (Fig. 4) vs. TTC = 0.82 s (red curve in Fig. 7)
- Values differ depending on the presence of a free lane (i.e., the likelihood of swerving) and driven speed

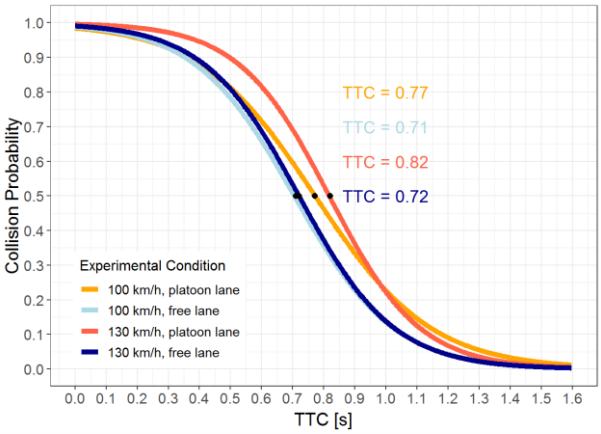

Figure 7. Relationship between collision probability and TTC in form of a logistic regression. The threshold of human performance in each scenario is defined as the inflection point (collision probability = 50%) of the curve.

Cut-out scenario

Figure 8. Cut-out scenario: ego speed = 100/130 km/h; relative speed = 100 km/h, aspired TTC = 1.4, 1.6, 1.8, 2.0 s; additional free lane in one quarter of trials (to provoke swerving).

- Values differ from cut-in scenario
- Values differ depending on potential driver reaction and (to a smaller extent) driven speed

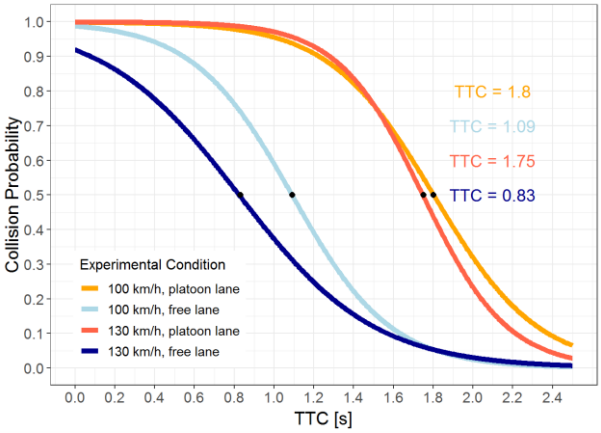

Figure 9. Relationship between collision probability and TTC in form of a logistic regression. The threshold of human performance in each scenario is defined as the inflection point (collision probability = 50%) of the curve.

- The replication of the Cut-in scenario indicates that the threshold of human performance is constant if the same scenario is tested.
- Factors influencing the choice of behavior as well as relative speed seem to shift the threshold of human performance. Therefore, differing scenarios should be tested separately.

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