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Accident Risk when Resuming the Manual Control of an Automated Car: a Driving Simulator Study

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I. INTRODUCTION

Taking over control (TOC) will be a new process for drivers of future automated vehicles. With recent advances in automotive technology, systems will be able to take partial or total control of the vehicle. At the levels 2 and 3 of automation according to SAE [1], the driver has to take over the control of the vehicle from the Automated Driving (AD) when required. Furthermore, partial or conditional automated driving will probably be allowed first for traffic jam and then in a perspective of being used on highways. The complexity of TOC situations combined with the high speed of vehicles on highways [2], may lead to severe accidents. A better understanding of how accidents could occur and what would be the risk of accidents for future drivers is therefore necessary. Many studies focused on analysing the takeover performance in terms of time and quality, e.g., number of collisions, longitudinal and lateral acceleration [3]. The number of collisions is one of the measures of this quality, but the risk of the accidents and the postures of the drivers have not yet been studied. Using a driving simulator, this study aims thus to investigate the risk of accidents during takeover controls on highways, with a preliminary analysis on the postures of drivers at the onset of an accident.

II. METHODS

Participants and Experimental Apparatus

Twenty women and 20 men, between 20 and 43 years old (M = 26.9, SD = 5.1) participated in the experiment. A static driving simulator was used, composed of a steering wheel, three pedals, three mirrors, a control panel and five screens positioned in a semicircle. The vehicle automation was simulated by the V-HCD software environment [4]. To locate the driver's body position, a motion capture system (Optitrack) with 10 cameras was used. Eighteen markers were attached on the body, three on the steering wheel, four on the seat and three on the ground.

Simulator data, including vehicle control commands and environmental information such as collisions, lane position and vehicle speeds, and data from Optitrack were collected and synchronised using the RTMaps software environment. The Université Gustave Eiffel Committee (Champs-sur-Marne, France) approved the experimental protocol.

Experimental Conditions and Procedure

Each participant performed takeover controls from AD to manual driving (MD) in 16 different critical situations. The test scenarios took place on a two or three-lane highway with a cruising speed of 90 km/h. The duration of these scenarios ranged from 2 to 4.20 minutes and the takeover situation occurred at the end. The times available to takeover control and to avoid the crash were short in order to simulate an emergency situation (Mean Time Budget = 4.2 s). Within these 16 scenarios, four levels of engagement in driving were studied:

- (C1) Level 2 of automation without Take-Over Request (TOR), implying an initial posture of supervision, i.e,. a manual driving position but with the hands on the legs.
- (C2 Level 2 of automation with a TOR, implying an initial posture of supervision as in C1.
- (C3) Level 3 of automation with a TOR by performing a game on a tablet in the centre of the dashboard, implying an initial posture slightly tilted and shifted to the right.
- (C4) Level 3 of automation with a TOR in a reclined posture with closed eyes.

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Prior to the experiment, participants were informed about how the simulator should be operated. Then participants familiarised with the driving through a trial drive in both manual and automated modes. Finally, they performed 16 TOC situations.

III. INITIAL FINDINGS

Among 640 takeover scenarios performed by the 40 participants, 139 accidents occurred implying a crash. The highest number of accidents was observed in C1 (30%) and C4 (25%) conditions, followed by C3 condition (16.9%). C2 had the smallest number of accidents (15%). In terms of the speed of the vehicle at collision, Figure 1 shows the percentage of accidents by test condition and three categories of severity. In the C1 condition, the participants had to take over control by determining for themselves that the situation was critical, which may explain the high accident rate. In this condition, most of the accidents occurred over 80km/h, while this was not the case for any of the other levels of engagement. On the other hand, in C3 few accidents over 80km/h occurred. For the C4 condition with a reclined position, the high number of accidents suggests that requiring TOC from a reclined posture could be of higher risk than the conditions C2 and C3.

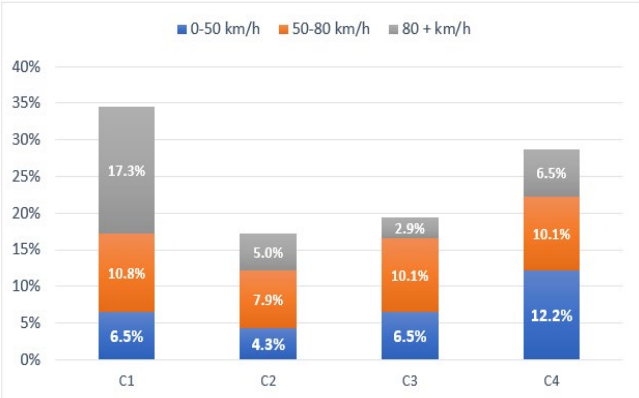

Fig. 1. Percentage of accidents by categories of severity. Low severity under 50km/h, medium severity between 50 and 80km/h and high severity over 80km/h.

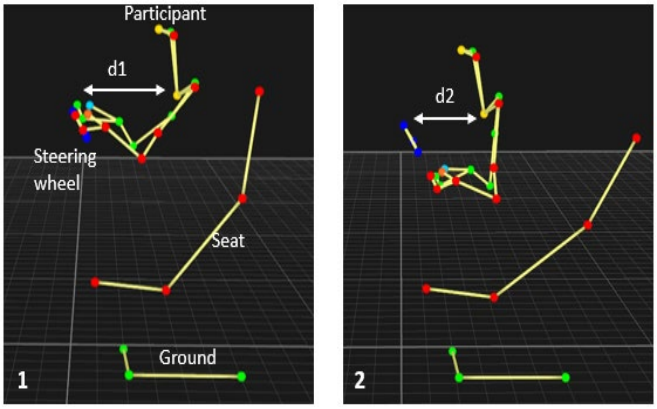

Fig. 2. Reference driving posture (1) and pre-crash posture when takeover after a reclined posture (2). The illustrations show the participant (head, torso, shoulder, arms and hands) markers and the seat, steering wheel and ground markers in the side view. d1 and d2 are the distances between the marker placed on the torso and a marker placed on the steering wheel.

Figure 2 shows preliminary analysis of the posture of one participant at the onset of an accident after a takeover control in C4 condition (2), compared to a normal driving posture (1). For this example, the pre-crash posture after a takeover was therefore different from a manual driving posture. The distance between the participant's torso and the steering wheel was 385 mm for the normal driving posture whereas it was 307 mm for C4. Analysis of captured motion data is in progress.

IV. DISCUSSION

In this study, we investigated the risk and severity of accidents that may occur during AD takeover. Preliminary results show a higher rate of accidents when the TOC was not requested or when the driver was in a reclined posture with TOC request. The body position at collision may be different from the normal driving posture. This is to be confirmed by further data analyses.

V. REFERENCES

[1] SAE, 2021.
[2] Aarts L et al., AAP, 2005.
[3] Bradley W et al., HFES, 2020.
[4] Bellet T et al., INCOSE, 2019.