Same-Direction-Pattern of Drivers' Avoidance Behaviour in Critical Intersection Situations – Field Accident Data Analysis and Driving Simulation Study

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I. INTRODUCTION

An enhanced understanding of driving behaviour – particularly manoeuvres performed prior to accidents – benefits the development of Advanced Driver Assistance Systems (ADAS). Accident analysis and driving simulation are two possible approaches to this issue: the former for statistical data-mining; the latter for parametric analysis. In China, side-impact accidents are the most prevalent accident type (30.03%), and 22.6% of accidents occur at intersections [1]. Apart from widespread ignorance of stop signs, right-of-way or even traffic lights, a significant and dangerous swerving tendency, which is described in this study, could prove to be a key factor in causing such accidents. It appears that drivers swerve towards the same direction as the oncoming obstacle. In this study, field intersection accident data analysis was carried out to demonstrate this Same-Direction-Pattern (SDP). Following this, a driving simulation experiment was carried out to verify this pattern.

II. METHODS

Field Accident Data Analysis

The data sets used in this accident study came from the field in-depth data collection compiled by the Traffic Accident Reconstruction & Traffic Safety Laboratory (TARTSL) at Tsinghua University. The database is comprehensive, and includes data from field investigation, from police and hospital reports, from vehicle damage measuring and from accident reconstructions. Based on the data collection, the swerving avoidance manoeuvre described – either same-direction-swerving (SDS) or opposite-direction-swerving (ODS) – could be confirmed by skidmarks, surveillance video, vehicle deformation, or drivers' statements. In order not to confuse the swerving avoidance manoeuvre with the driver's original turning intention, accidents were selected for this study only if both vehicles intended to travel straight through the intersection.

Driving Simulation Experiment

The driving simulation experiment on critical intersection situations was carried out on a six-degree-of-freedom driving simulator (DS) in Tsinghua University (Fig. 1), and was performed as a 2 (incursion direction, "left" vs. "right") $\times$ 2 (Time-To-Collision, TTC, "1.5 s" vs. "3.5 s") within-subject design. Participants were instructed to drive on an urban road containing 13 intersections and with a speed limit of 50 km/h. Four of the intersections were selected as conflict scenarios, while the others were decoys. Different trigger points were set up based on TTC designing. When a conflict was triggered, the obstacle was approached from either the left or right side of the crossing road at 50 km/h (Fig. 2). A total of 30 experienced drivers (26 males and 4 females, aged from 21 to 48 years) were recruited, and their reaction behaviour data was recorded by DS at a rate of 60 Hz.

Fig. 1. Driving simulator in Tsinghua University.

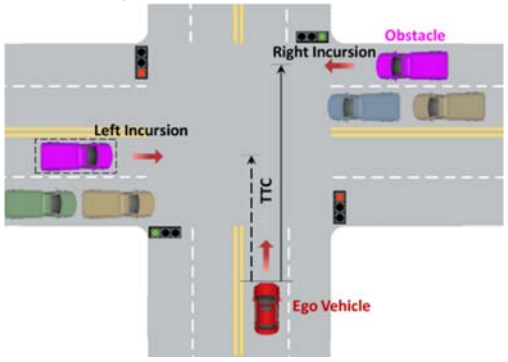

Fig. 2. Critical intersection scenarios.

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III. INITIAL FINDINGS

Altogether, 178 intersection accident cases were collected in this study, all of which occurred between 2009 and 2012. Of the 356 drivers involved in these accidents, 62 (17.4%) were confirmed to have exhibited a steering reaction. Figure 3 shows the proportion of swerving manoeuvres, indicating that SDP is a significant feature in these cases (91.9%). There were "uncertain incursion" situations because in some cases the steering behaviour was confirmed only by vehicle deformation analysis, which makes it impossible to judge which of the two vehicles performed the swerving reaction. The results suggest SDP is a significant phenomenon in both left and right incursion cases. All of the five attempted ODS seemed close to success, resulting in collision only with the tails of the obstacles. Furthermore, accident reconstruction analysis indicates that 87.1% of those SDP accidents could have been avoided if the drivers simply swerved in the opposite direction, which suggests that SDP could be one of the most important causes of side-impact intersection accidents. Another major cause is breaking red lights: 46 of the 62 intersection cases had correctly functioning traffic lights, which were clearly ignored by one of the drivers.

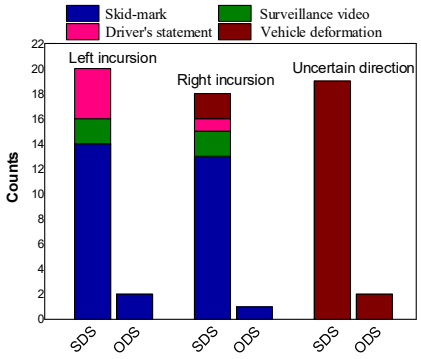

Fig. 3. Proportion of SDS and ODS in swerving behaviour.

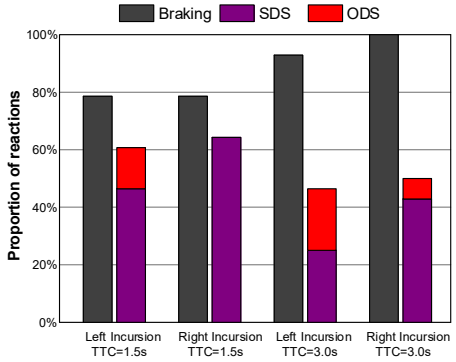

Fig. 4. Reactions per critical situation in driving simulation.

The number of reaction manoeuvres per critical situation in the driving simulation tests is shown in Fig. 4. It could be observed that braking was mostly applied, and that more drivers attempted a swerving reaction when TTC decreased. Among all the swerving manoeuvres, SDP accounts for 66.7% in left incursion situations and 90.9% in right incursion situations, and the difference between them is significant ($\chi^2(1) = 5.64, p = 0.018$). The influence of urgency is also apparent: 88.6% of drivers chose an SDP manoeuvre when TTC=1.5 s, while the proportion decreases to 67.9% when TTC=3.0 s. The difference between the two urgency levels is significant ($\chi^2(1) = 4.08, p = 0.044$). The collision rate analysis shows that 92.9% of conflicts resulted in crashes when TTC=1.5 s, and almost all of the successful evasion manoeuvres came from ODS drivers. When TTC rose to 3.0 s, collision rate decreased to 39.3%, while SDP accounted for 16 (72.7%) of all 22 collisions. Reconstruction studies showed that if the drivers had simply altered their SDS to ODS, 85.4% of the SDP collisions would have been avoided, which is in line with the result from accident study above.

IV. DISCUSSION

Both the accident case study and the driving simulation show that SDP is widely adopted by drivers and that it leads to a greater possibility of collision. It should be noted that SDP still existed in the left incursion with 3.0 s TTC situation, in which the proportion of SDS seemed to be as low as 54.5%. Because SDS always has less chance of bypassing the obstacle compared to ODS in the same situation, especially when a braking reaction is made at the same time. So even a proportion of 54.5% of SDS is much higher than it supposed to be.

The proportion of SDP is significantly higher in right incursion situations because of the manner of the driving simulation, which makes the pattern easier for investigators to observe [2]. China's left-hand drive (LHD) policy could be a reasonable explanation for this, either because a different reaction time [3] or an instinctive self-protection response resulting from LHD led to the difference on SDP. The significant influence of TTC on the incidence of SDP suggests that the drivers' SDP is more likely to be an instinctive reaction. A minor TTC provides less time for perception/decision-making and greater mental pressure, both of which could induce the drivers to rely on their primary reflexes [4].

V. REFERENCES

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[4] Malaterre, G., *et al*., *Ergonomics*, 1988.