Towards A Best Practice For Multi-Driver Simulator Studies

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Abstract
This paper illustrates the challenges related to multi-driver simulator studies and provides first steps towards a best practice. With the help of a multi-driver simulator, several participants are enabled to drive in the same virtual environment and thus driver-driver interaction can be examined. However, these studies constitute the need for a more tailored methodology of planning, conducting, and analysing. Based on recent experiences, these challenges will be outlined to create awareness for the new methodological challenges that need to be considered in order to ensure the validity of results from multi-driver simulator studies.

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Multi-Driver Simulator Studies; Driver-Driver Interaction; Cooperation; Intelligent Transport Systems (ITS)

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H.1.2. User/Machine Systems

Introduction
Communication in traffic is limited to mostly nonverbal communication and short time frames to interact. Thus misunderstandings, especially in cooperative interaction scenarios, can occur as communication is not correctly perceived or ambivalent [1,6]. Intelligent transport systems (ITS), such as in-vehicle information and communication systems (IVIS) or advanced driver assistance systems (ADAS), can support interactions via car-to-car-communication. To enable this, on the

one hand, the examination of driver-driver interaction is necessary to identify interaction scenarios in which drivers fail to communicate and thus can be supported by an ITS. On the other hand, the investigation of driver-driver interaction is necessary as ITS aims at supporting equipped drivers in a natural and thus most acceptable way. Thus, knowledge about how and when ITS support should be given to drivers is needed. Moreover, in regard to the relatively low penetration rate of ITS in nearer future, the examination of interaction scenarios with equipped and unequipped drivers is necessary: how do drivers equipped with ITS react to missing communication partners? How do unequipped drivers react to ITS-specific driving behaviour [5]?

These examples show that especially with further development of ITS, the need to study driver-driver interaction becomes more important. The greatest challenge, however, is to find an appropriate tool and a corresponding methodology to study driver-driver interaction. Naturalistic driving studies, traffic flow simulations or driver simulator studies can be used for this; however, they have methodological disadvantages [4]. A multi-driver simulator may be an appropriate tool: here several participants drive in the same virtual environment and thus driver-driver interaction can be studied. This concept was realized in the laboratory infrastructure MoSAIC (Modular and Scalable Application-Platform for ITS Components, **Figure 1**) at the Institute of Transportation Systems at the German Aerospace Center (DLR). First experiences show that multi-driver simulator studies constitute the need for a more tailored methodology [5]. These challenges will be discussed to pave the way to a best practice for multi-driver simulator studies.

Figure 1: The MoSAIC-laboratory.

Towards Best Practise

In the following, the so far existing findings towards a best practice for multi-driver simulator studies are summed up.

Planning & Conducting

A difficulty associated with multi-driver simulator studies is to ensure that participants will interact. If you let multiple participants drive, they might drift apart and never meet in the desired interaction scenario. For example, if you want to study how drivers cooperatively allow another driver in the neighbouring lane to merge, you will have to make sure that this interaction scenario actually takes place. Thus, one of the drivers wants to change the lane, while the others are nearby in the neighbouring lane. Smart restrictions that do not jeopardise the participants' feeling of free driving are necessary. Thus, it can be helpful to monitor, track, and plot participants' position within the scenario.

Further, we recommend the following for the realisation of the interaction scenario:

- Let a confederate trigger the interaction scenario.
- Use instructions, such as keeping certain headways to ensure that participants do not drift apart.
- Design the scenario in a way that participants can be easily reunited (e.g. traffic lights, stop signs) [4,5].

Another difficulty when studying interactions in a multi-driver simulator is that participants know they are monitored and thus might be more likely to show cooperative driving behaviour. Moreover, the willingness to cooperate might be influenced by social similarity and antipathy/sympathy between participants [3]. Additionally, gender effects might play a role [2]. Thus, future research needs to address the question whether physical separation of participants leads to more valid results and minimises the influence of confounding variables. Thus, we recommend the following:

- Use a cover story to disguise the true scope of the study. Otherwise participants may show behaviour that is social desirable, but not realistic.
- Keep in mind that confounding variables such as antipathy/sympathy, gender effects may interfere with results.
- When setting up a multi-driver simulator, discuss whether mock-ups should be in different rooms to physically separate participants.

Data analysis

Data analysis of a multi-driver simulator study is a challenge. Typically, in an experiment, a variable is manipulated, while all others are kept constant, to measure its effect on a response variable (i.e. whether a causal relationship exists between the manipulated and the response variable). For example, it can be of interest to find out under what circumstances a lane change request of a driver A (manipulated variable) leads to cooperative behaviour of driver B in the neighbouring lane (response variable). In a typical experiment, this causal relationship between the scenario (lane change request) and the number of cooperative lane changes can be analysed. However, in a multi-driver simulator study, driver A and driver B are participants and thus show uncontrollable driving behaviour. Driver A might show specific driving behaviour prior to the lane change request (e.g. drive aggressively next to driver B). This behaviour might affect the willingness of driver B to cooperatively allow a lane change. Thus, the response variable might not only be affected by the manipulated variable but also by the specific driving behaviour of the participants. This potential reciprocal effect of driving behaviour of several participants in a multi-driver simulator needs to be somehow handled. We recommend the following:

- Find parameters measuring the interaction of drivers. Parameters describing the interaction of drivers in a platoon have already been used. For example, the platoon's standard deviation of lateral position (SDLP) can be calculated taking into account each driver's mean lateral positon and the mean lateral positon of the platoon [4]. To quantify the longitudinal control of a platoon, the length of the platoon as the distance from the front bumper of the first vehicle to the rear bumper of the last vehicle in the platoon can be calculated [4,5].

- Think about using statistical methods such as multilevel analysis for the analysis of data of multi-driver simulator studies.

Conclusion

Driver-driver interaction can be studied when several participants are placed in a multi-driver simulator at the same time in the same environment. However, these types of studies are rather novel and need a best practice for planning, conducting, and analysing. Only then, multi-driver simulator studies can be considered a valid tool for measuring driver-driver-interaction.

References

1. Ahmed Benmimoun, Dirk M. Neunzig, and Christian Maag. 2004. *Effizienzsteigerung durch professionelles/ partnerschaftliches Verhalten im Straßenverkehr.* Forschungsvereinigung Automobiltechnik: FAT-Schriftenreihe ; Nr. 181.
2. Paul N. Blockey and Laurence R. Hartley. 1995. Aberrant driving behaviour: errors and violations. *Ergonomics* 38, 9, 1759–1771.
3. Eva Jaho, Merkouris Karaliopoulos, and Ioannis Stavrakakis. 2010. Social similarity as a driver for selfish, cooperative and altruistic behavior. In *2010 IEEE International Symposium on “A World of Wireless, Mobile and Multimedia Networks” (WoWMoM)*, IEEE, 1–6.
4. Dominik Mühlbacher, Jutta Zimmer, Florian Fischer, and Hans-Peter Krüger. 2011. The multi-driver simulator - A new concept of driving simulation for the analysis of interactions between several drivers. In *Human Centred Automation*, Dick de Waard, Linda Onnasch, Rebecca Wiczorek and Dietrich Manzey (Eds.). Shaker Publishing, Maastricht, the Netherlands, 147–158.
5. Katharina Oeltze and Caroline Schießl. 2015. Benefits and challenges of multi-driver-simulator studies. *IET Intell Transp Sy* 9, 6, 618-625.
6. Linda Renner and Björn Johansson. 2006. Driver Coordination in Complex Traffic Environments. In *Proceedings of the 13th European conference on Cognitive ergonomics: trust and control in complex socio-technical systems*, 35–40.