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Design and analysis of semi-controlled studies

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ABSTRACT

Semi-controlled studies provide a hybrid approach in between controlled experiments and naturalistic driving studies. As in controlled experiments, the researcher can assign participants to groups, select the route and define the tasks, but the participants are given more freedom when it comes to *if, when, where* and *how* to perform the tasks. Increased flexibility makes it possible to investigate how drivers use tactical behaviour to accommodate task execution. The disadvantage is decreased control and more complicated analyses. The main objective of this paper is to discuss how to analyse data obtained in semi-controlled studies.

The analysis of data from a semi-controlled study include three types of variables: (i) variables that describe the experimental design, (ii) variables that describe the tactical choices of the participants and (iii), operational variables such as speed, lateral position or glance behaviour. To analyse the three types of variables a two-step procedure is suggested. First, the tactical indicators are analysed with regard to the experimental design. Second, the operational indicators are analysed and the tactical indicators are used to divide participants into sub-populations. The semi-controlled design does not need any new statistical procedures to be developed. It is more important that the analysis conditions on the initial properties and not on structures that happen to occur during the experiment, like where the participant chose to do a certain task.

We recommend to use the semi-controlled study method when investigating questions involving adaptive and compensatory behaviour on the tactical level. It is especially useful if causal relationships are of interest, if the data collection should be accelerated in comparison to naturalistic studies, and if certain geographical locations definitely should be included.

1. Introduction

A semi-controlled experimental design uses a number of aspects of a controlled design, for example to assign participants to conditions, choose the test route, choose tasks, etc., but the participants are given more freedom to execute the tasks as they would have done naturalistically. This enhances the external validity, but at the same time the loss of control has implications for the analysis. The objective of this paper is to discuss how to analyse data obtained in semi-controlled studies.

In driving behaviour research, just as in all research areas, the researcher chooses a suitable design to answer the question of interest. Two main categories of designs are experimental studies and observational studies, but there are also variants such as quasi-experimental designs and semi-controlled studies. The fundamental differences between the study types

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are whether and how the independent variables are manipulated, and whether and how the participants are assigned to the experimental conditions. The degree of control of external factors may also vary. In experimental studies, the participants are randomly assigned to conditions, and the experimenter has control over the independent variables to which the participants are exposed. In observational studies no such assignment is made, and external factors are not controlled. Quasi-experimental designs and semi-controlled studies both give up control in one of these two categories. Quasi-experimental designs control the factors of interest, but do not assign participants to the treatment conditions randomly, whereas semi-controlled designs assign participants randomly, but reduce the experimental control of the factors of interest. The advantages and disadvantages of different experimental designs have been discussed both in general (Campbell, 1957; Elmes, Kantowitz, & Roediger, 2011) and also within the realm of traffic research (Carsten, Kircher, & Jamson, 2013; van Schagen & Sagberg, 2012). Therefore we will not repeat them in detail in this paper.

In *controlled experiments*, the basic idea is to compare a certain treatment to either a baseline or another treatment. It is possible to draw causal conclusions about the effect the treatment has on behaviour, because the participants are assigned randomly to the different conditions. However, due to the imposed restrictions resulting from the stringent control, the participants often cannot choose when, where and how to execute the task they are asked to do, as most of those choices are already made by the experimenter. Michon (1985) described three levels of driver behaviour to be (i) strategical – high-level decisions like route choice or choice of mode of transport, (ii) tactical – contains choice of speed or whether to overtake, and (iii) operational – behaviour which is mostly automated, such as control of speed and lateral position. In controlled studies, the participants only have a limited range of action within a predetermined situation, therefore they can typically only vary their behaviour on the operational level. Furthermore, it is not known whether they would have chosen to get into this type of situation in the first place. Questions of prevalence and relevance for an applied setting can therefore not be answered in a controlled experiment. The analyses of controlled experiments are often straightforward, and typical statistical methods are *t*-tests, analysis of variance and various types of regression analyses.

In *observational studies* within the area of driver behaviour research, such as naturalistic driving studies, the independent variable is not controlled by the researcher. The participants themselves select when and where to go, and how to behave. Thus, they are free to make tactical choices to accommodate any additional tasks they might choose to perform – they are even free to make strategical choices that can for example include the avoidance of night-time driving or certain road types. This natural, adaptive and flexible behaviour differs substantially from the restricted conditions in a controlled experiment, and it constitutes an important aspect of human behaviour. The loss of experimental control has implications on the analysis, especially the fact that there is no obvious baseline for any given situation of interest. The analyses of naturalistic driving studies typically involve odds ratios using matched baselines (Hickman & Hanowski, 2012), or classical statistical methods such as analysis of variance and regression applied to uniform chunks of data (Dozza, Bärgman, & Lee, 2013).

Semi-controlled studies can be seen as a type of hybrid between controlled experiments and observational studies. Somewhat over-simplified, controlled experiments are suitable when investigating driver behaviour at an operational level, whereas naturalistic studies are suitable for questions of prevalence, when investigating driver behaviour on a tactical or strategical level. The main idea with the semi-controlled design is to allow participants to adapt on a tactical and possibly strategical level to accommodate the assigned task, while at the same time maintaining a certain degree of experimental control. Typically the researcher assigns participants to groups, selects the route and defines the tasks, but the participants are free to choose if, when, where and how to perform the tasks (Ahlstrom, Kircher, Thorslund, & Adell, 2015; Eriksson, Lindström, Seward, Seward, & Kircher, 2014; Kang, Lin, Green, Miller, & Comastro, 2014; Kircher, Ahlstrom, Palmqvist, & Adell, 2015). Given the described level of control, it is possible to make causal connections between manipulated variables and the resulting measurements. Also, the method is useful for investigating different tactics employed by the drivers to handle a given situation. Field operational tests (FOTs) can be categorised as semi-controlled studies with a very low level of control, as only the participant assignment to conditions and the conditions are specified, whereas when, where, how and why to drive is determined by the participant.

The semi-controlled design is useful when investigating how drivers adapt to facilitate dual task performance by using tactical choices. A difficulty when using semi-controlled designs is that the analyses become more complicated and need to be tailored to the study at hand. The aim of this paper is to show how data from semi-controlled designs can be analysed. Two case studies are included to exemplify how the suggested analysis procedure can be adapted to the particularities of each design.

2. Analytical approach in semi-controlled studies

Three levels or types of variables can be identified in semi-controlled studies (Table 1). Level 1 includes variables that describe the experimental design, just as in a controlled study. Examples of such variables are age, gender, time of day and the different treatments under investigation. Level 2 include variables that describe the tactical choices of the participants, for example whether a driver pulls over before making a phone call or writes a text message while standing still at a red traffic light. The outcomes of the Level 2 variables are thus decided by the tactical choices of the participants and not by the design of the experiment. These variables should therefore be treated differently from the Level 1 variables in the analyses. Finally, Level 3 includes operational indicators, such as speed, lateral position or glance behaviour.

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