Driving Characteristics and Development of Anticipation of Experienced and Inexperienced Drivers When Learning a Route in a Driving Simulator

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Abstract – *The driving behaviour is clearly different when the driving route is unfamiliar in comparison to the situation in which the driving route is known. However, the details of the critical behavioural and physiological parameters during the development of the mastering of the driving are not well known. It is possible that the development of the anticipation in different phases of the driving plays a critical role in the learning of the driving skills. It is as well possible that the critical differences between experienced and inexperienced drivers will be found in their anticipatory processes. In the present study, we examine driving characteristics and development of anticipation in inexperienced and experienced drivers when learning a new driving route through an unknown city in the driving simulator. The present paper presents preliminary results from nine subjects. The results show that significant differences were found in braking activity and driving speed when comparing the groups of different driving experience levels. Also, the development of anticipation was more pronounced with the experienced drivers as indicated by the driving parameters.*

Key words: *Anticipation, driving simulator, driving behaviour, simulator data, learning task*

1. Introduction

It is obvious that the driving behaviour is different when the driving route is unfamiliar in comparison to the situation in which the driving route is known, i.e. when the route is well-mastered. However, the details of the critical behavioural and physiological parameters during the development of the mastering of the driving are not well known. It is possible that the development of the anticipation in different phases of the driving plays a critical role in the learning of the driving skills (see e.g., [Jar3]). It is as well possible that the critical differences between experienced and inexperienced drivers will be found in their anticipatory processes. Such differences could be seen in the temporal activation of muscles (EMG) in relation to the phases of driving, in the indicators of the activation of the autonomic nervous system (heart rate, heart rate variability and galvanic skin response), in changes in perception and attention (e.g., eye movements, see [Gar1] and [You7]), in the amount of driving errors (failed attention to traffic signs, breaking the traffic rules, over-speeding, breaking the lane borders, etc.) and in changes of driving controls (movements of the steering wheel, throttle, brake, etc.).

Anticipatory driving is considered essential in successful and quick acting in sudden occurrences. It is also related to economical driving, which reduces the harmful CO_2 emissions. But how to explicate what anticipation is in the driving behaviour? We approach this question with a psychophysiological perspective. The theoretical approach of our research is based on a systemic anticipation model of the theory of the organism-environment system [Jar2]. According to the model, anticipation is not a process for waiting for stimuli, but an active process of preparation for results of action, which develops during learning. The anticipatory process proceeds towards the result of action, and it is this process that determines which parts of the environment can be used as “stimuli”, i.e. as necessary constituents in the realization of actions. In the present study, we examine, by recording changes in driving behaviour and in electrophysiological indices of performance, how anticipation develops in inexperienced and experienced drivers when learning a new driving route through an unknown city in the driving simulator. The present paper presents preliminary analysis of changes in driving controls (simulator data) from nine subjects when learning a new route in a simulated city.

2. Methods

The experiments were carried out in a low-cost driving simulator. The task of the subject was to navigate and learn a shortest route through an unknown virtual city.

The base for the simulator and the driving control system are manufactured by Frex GP (Osaka, Japan). The system consisted of two degrees of freedom motion platform, high quality steering wheel and pedals. Blinkers as well as a middle console with a gear shifter and a hand brake from a Volvo S60 were added to the simulator in order to increase the realistic driving feeling. Also a high impact speaker was installed inside the driver's seat in order to add a feeling of vibration while driving. Logitech Z-5500 high quality speaker system was used for creating the driving sounds. Two high performance desktop computers were used to run the driving simulator. An in-house designed 220 degree curved display with radius of 2.5 meters was constructed (10 x 1.9 meters; 3840 x 720 pixels). For combining the image from three different projectors and making the view look seamless, a program called Nthusim was used. rFactor was selected as the main simulator software for several reasons. It is inexpensive, but also highly modifiable, and it supports custom-made driving scenarios and enables recording telemetry data with an in-house programmed plug-in. Lastly, the control program for the actuators was a program called X-Sim which was also used to show gauge values (speed, RPM, etc.) in a small display and to send a trigger pulse to other research equipment to start recordings. [Kos5] The simulator is presented in Figure 1.

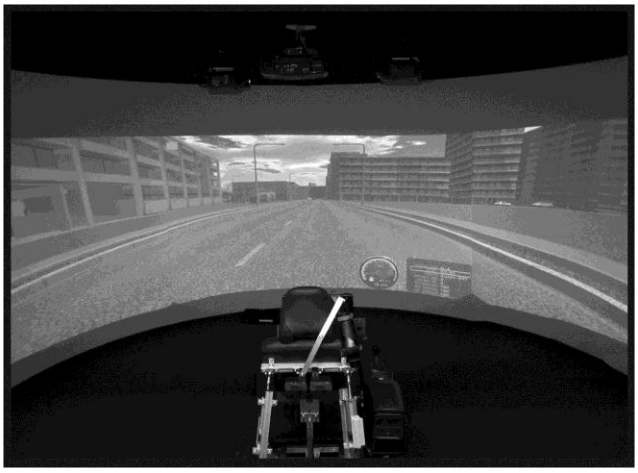

Figure 1 The driving simulator

The research equipment included a number or measurement devices, including NeurOne (EMG), EyeLink II (eye tracker), Polar S810i heart rate monitor (RR-interval), and a simulator data capturing system.

22 male subjects (Ss) participated in the experiments. 17 of the subjects were policemen and five were university students.

In this paper, we present preliminary results of the study that consist of the data from nine Ss. The nine Ss were divided into three groups (N=3 in each): 1) inexperienced drivers (university students, age 21–34 years, driving license max three years, mileage 0-4000 km/year), 2) experienced drivers (policemen, age 23–33 years, driving license 6–16 years, mileage 10000–55000 km/year), and 3) very experienced drivers (policemen, age 47–51 years, driving license 29–32 years, mileage 15000–30000 km/year).

Before the experiments, the Ss were interviewed to collect the background information, as well as information of the driving experience and driving behaviour. Driving experience was classified according to the time the S had received their driver's license and on the basis of driven km per year. In addition, questions related to simulator and motion sickness were asked. The Ss filled in the SSQ form [Ken4] before and after the experiments. The experiment was part of a larger study, in which we also explored simulator sickness by using SSQ and TMSS-methods [Nur6], and how drivers performed in unexpected driving tasks. The present analysis is based on the temporal changes of driving controls (steering wheel, pedals). During the experiments, also electrophysiological data were recorded for deeper analysis.

The navigation task in the virtual city started from a parking place at one side of the city. The task of the S was to find the shortest driving route through the city to a skyscraper that could be seen at the other side of the city from the starting place. The S had a limit of five minutes in trying to find the route, after which the trial was stopped. After each trial, the S got feedback of his driving task (e.g., "after the bridge there is a shorter route"), and another trial began. When the S had found the shortest route, he was asked to drive twice the same route. The average amount of trials to find the route was 3.8 (minimum 2 and maximum 6 trials).

The data from each S was divided for the examination of the development of the anticipatory processes in two sections: 1) driving the unfamiliar route (the first and the second trial) and 2) driving the known route (the last two drives).

The changes in driving behaviour were explored by looking at changes in driving parameters in relation to a fixed point on the road (time control point), which was static and could be precisely detected in each trial (e.g., the front part of the vertical white line on the road before the zebra crossing, see Fig. 2). The changes in driving behaviour were examined by looking at temporal changes between the trials in driving speed, the starting moment of braking and loosening the throttle, and the starting moment of steering movement. The subjects were advised to obey the traffic rules, e.g., comply with speed limits.

The five situations, in which the driver had to make decisions concerning the route selection, were chosen to explore the possible changes in driving activity. These situations were

1) the first intersection when arriving to the city centre (turning right prohibited),
2) an intersection with a yield-sign (left, right or straight),
3) an intersection with a STOP-sign that could easily be detected rather early (turning left or right),
4) an intersection (left or straight), and
5) an intersection with a yield-sign (left or right).

Figure 2 Situation 5: the time control point is the front part of the vertical white line on the road in front of the zebra crossing

The changes in the use of throttle, braking, steering and speed were studied from the simulator data. The time interval between starting to press the brake pedal and crossing the time control point is referred as braking delay. Similarly, the time interval between starting to steer and crossing the time control point is referred as steering delay. The use of the throttle is detected from the moment the S starts to loosen the throttle or alternatively pressing the throttle pedal in comparison with passing the time control point. Finally, the data was analysed with SPSS 20.0 statistical analysis software (IBM) by using t-test and one-way ANOVA.

3. Results

The results are based on the preliminary analysis of nine subjects (inexperienced, experienced and very experienced). Changes in driving behaviour are approached from three points of view. First, we examine the dependence of driving parameters on driving experience by concentrating on the differences related to experience in situations in where the route is known. Second, we examine the dependence of driving parameters on the development of anticipation during the route learning task. Finally, we explore the dependence of the development of anticipation in relation to driving experience in order to find what differences can be detected between the groups during learning.

3.1 Dependence of driving parameters on driving experience

We examined the dependence of driving parameters on driving experience when the driving route was learned (the last two trials). Experienced drivers started braking significantly later (see Fig. 3) than less experienced and inexperienced drivers (One-way ANOVA; p<.001; F=11,871; df=2,40). Parameters related to steering and the use of throttle did not show any significant differences.

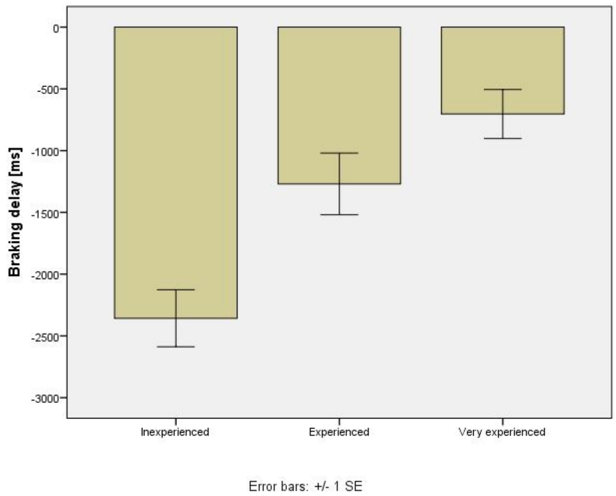

Figure 3 Braking delay of the subjects with different driving experience when the driving route was known

Significant differences were also found in the driving speed. The driving speed was higher with very experienced drivers (48,9 km/h) in comparison to inexperienced drivers (38,6 km/h) (One-way ANOVA;p<.01; F=4,612; df=2,82).

3.2 Dependence of driving parameters on the development of anticipation during the route learning

We explored how anticipation develops during the learning of the route through the city. The changes in driving parameters were analysed when the route was unknown (first two trials) as well as when it was known (last two trials). The analysis shows that the beginning of braking starts later (avg. 1,3 s. later) when the route has been learned (t-test, p<.001; t=-3,697; df=52,458). Additionally, as the route became familiar, the driving speed increased significantly (t-test, p<.05; t =-2,099; df =162). No significant differences were seen in loosening the throttle pedal.

For more detailed analysis, we studied situations 4 and 5. In these situations the subject had to turn the steering wheel in order to drive the car correctly in an intersection. The results show a significant effect of learning in the steering delay (t-test, p <.05; t=2,335; df=59) when the driving route became known. The steering started earlier in the last two trials i.e. when the route was known. The change in the steering delay is presented in Figure 4.

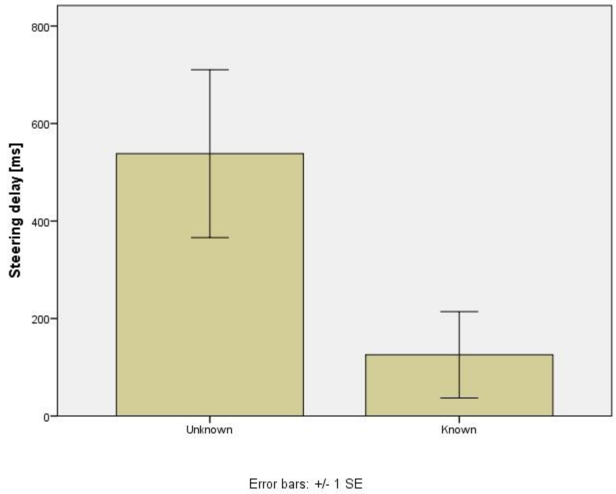

Figure 4 Comparison of steering delay with unknown and known driving route, situations 4 and 5

3.3 Dependence of development of anticipation in relation to the driving experience

Finally, the dependence of development of anticipation was examined in relation to driving experience between the groups (inexperienced, experienced and very experienced drivers) as indicated by the driving parameters.

The braking delay showed significant differences in experienced and very experienced drivers during the learning of the driving route (see Fig. 5). The beginning of braking moved 1.7 s. later in experienced drivers (t-test, p<.01; t=-3,156; df =31), and 1.5 s. later in very experienced drivers (t-test p<.05; t=-2,453; df=9,881). No significant difference was found in inexperienced drivers.

Driving speed increased in every group when the route became known, significant difference was found in very experienced drivers (t-test, p<.05; t=-2,305; df=55).

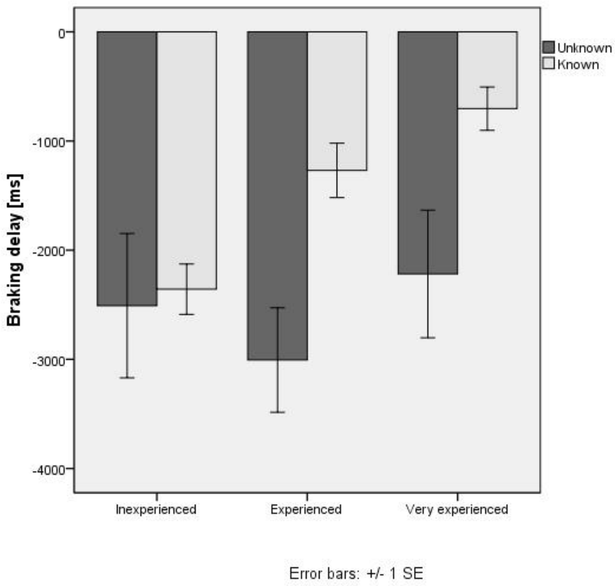

Figure 5 The difference in braking delay with unknown and known driving route for the subjects with different driving experience.

4. Conclusions and future work

The preliminary results on the analysis of driving parameters of experienced and inexperienced drivers show that in a driving simulator some interesting features can be seen during learning of a shortest driving route through an unfamiliar simulated city. The results show how anticipation develops with familiarisation of the route. The driving experience was reflected in some driving parameters, the indications of the development of anticipation during learning were seen, and this development was more pronounced with more experienced drivers.

In general, with the learning of the driving route, the driver performance became more goal-oriented and smooth. The Ss reduced the amount of unnecessary use of brakes, controlled better the speeding but also drove faster.

In the present analysis only several driving parameters were examined, but the analysis of bioelectrical data (EMG and heart-rate) may help to determine in more detail how anticipation develops during learning. Exploring how anticipation develops in certain driving situations enables us to understand driving behaviour better. The findings from our study may provide information that can be utilised in developing driver's training for novice drivers, as well as training of, for instance, economical driving.

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