An empirical study on driving behaviour in a simulated T-intersection

- the effect of manipulation of instruction set and the variance in traffic velocity

Sanna Aronsson, Natalia González, Fredrik Köhler, Johanna Mercurio, Patrik Larsson, Maria Nyberg
University of Linköping, Linköping June 2007

This report intends to describe and explain what can affect driving behaviour in t-intersections. This is done by manipulating the instruction set and the variance in traffic velocity, with the use of a multi-user and fixed-base driving simulator. Both of these settings are believed to lead to a more demanding traffic environment that it in turn will lead to an increased risk of incidents in intersections. The empirical study was implemented in a controlled setting at Linköping University. A total of 56 persons participated in the study. They were divided into groups of four, all driving in the same simulated world. The participants answered a battery of self-report measures about their values and beliefs. To evaluate the driving behaviour of the participants a modified conflict indicator, the Post Encroachment Time (PET) algorithm, was applied. PET calculates the time between two meeting vehicles passing exactly the same point in an intersection. The PET values were then compared to the data that was a result of the manipulated settings. The results indicated that the PET value is held constant independent of our manipulations of each session.

Introduction

Traffic accidents can cause a lot of damage, not only personal injuries and casualties, but also financial and material damage to the vehicles and property. Many accidents can be attributed to human error. Therefore, traffic safety is one of the most important ongoing research areas, due to the high rate of fatality in traffic. Most traffic accidents in Sweden, and in other countries, occur in intersections (SIKA 2006). Statistics in the U.K. indicate that accidents occurring within 20 meters of intersections represent 61% (Ragland & Zabyshny, 2003) of all traffic accidents. This leads to an increase in demands on safety from drivers and society in general. Therefore, further research in this area is necessary. The study and examination of driving behaviour is a necessary step for understanding the causes of accidents in traffic.

Study background

The study is a part of the Intelligent Vehicle Safety Systems project (IVSS) and is driven by Autoliv Research. The IVSS goal is to improve the safety of vehicle-vehicle and vehicle-pedestrian interactions in intersections, in other words – to reduce accident risks and consequences in intersections. One of their goals are to contribute to the development of active safety systems that can prevent accidents before they take place. If so, this would maintain Sweden's position as the world's foremost developer and manufacturer of vehicular safety systems.

The 'Intersection Accidents' part of the IVSS project has chosen to focus its research on the Sävenäs T-intersection in Gothenburg because it is one of many intersections where the traffic safety is low, and where many accidents occur. The 'Intersection Accidents' project consists of three different parts; analysing the driving patterns of the Sävenäs intersection in Gothenburg by filming the intersections with several video cameras; having subjects drive in the Sävenäs intersection with a car equipped with a radar, a GPS and an eye-tracking device to see where the attention of the driver lies; and finally this simulator-based experimental research that currently is conducted at Linköping University (LiU), Department of Computer and Information Science (IDA).

Aim

Our research contributes to the IVSS in that we have used a simulator to test, refine, and assess alternative methods for manipulating the participants driving behaviour. By doing this we hope to give support to the current research in understanding the possibilities and the limitations of simulation-based research.

Simulator background

According to Reed and Green (1999) there are three primary justifications to why the usage of simulators in research is better than using real life cars. The first one is *safety*. Many studies that involve examination of behaviour prior to collisions or near accidents would simply be too hazardous to be applied to the real world. The *equipment cost* of studying driver responses in a simulator is often lower and it takes less time to implement. One does not have to construct an entire safety system with the features needed to study driver responses. The final advantage is *experimental control*. A greater range of conditions can be studied in a simulator than in a real car. The experiment leaders can hold such as weather, task and the course of events constant.

There are two types of simulators; moving-based and fixed-based. A moving-based simulator gives feedback from the steering wheel and the chair about the car movement in the simulated world, whilst a fixed-based does not. If the aim of the study is focused on secondary tasks and behaviour in a driving environment, then it might suffice with a fixed-based simulator to a smaller cost which is cheaper that a movement-based one (Santos, 2005).

Hancock and de Ridder (2003) studied behavioural accident avoidance in intersections, in a controlled simulator environment. This multi-user simulator study showed that situations with realistic avoidance response behaviour can be created and replicated in an interactive simulation environment.

Traffic behaviour background

Many traffic accidents can be attributed to stress (Hennessy and Weisenthal, 1999). Driver stress can also lead to aggressiveness, which in turn has a strong relationship with increased accident involvement. When a person is stressed, cognitive ability is impaired, which among other things causes difficulties in concentration, irrational thinking and a tendency to be easily distracted. The outcome of this is reduced performance in complex tasks such as driving, and can therefore lead to accidents (Howard and Joint, 1994).

Frith and Patterson (2001) refer to a study by Solomon (1964) that showed a strong relationship between speed variance and crash risk. Frith and Patterson states that *"the smaller the variation within the stream, the smoother and safer the traffic flow will be"*. According to Frith and Patterson, the accident risk at mean speeds below average could be an effect of the numbers of intersections and driveways that were located at the highways where the crashes occurred.

Conflict Indicators

A conflict indicator is defined as a measurement that indicates if an incident has occurred. Each conflict indicator is defined separately depending on what is essential to observe in each traffic safety situation. Previous studies assessing the severity of traffic safety has divided conflict indicators into two different methods of measurements. Objective methods rely on properties such as time, distance and speed while subjective methods rely on human observers to record the perceived risk at the moment of conflict (Lu, et al. 2004). Researchers claim that a combination of both subjective and objective methods to asses and evaluate safety in traffic is the most rewarding.

Indicators that might be interesting to look at, when studying behaviour in present traffic situations, are for example Time To Collision (TTC), Time to Accident (TA) and Post Encroachment Time (PET). A modification of the latter indicator was implemented in this study.

Jeffrey Archer (2005) describes Post Encroachment Time (PET) as an indicator that is used to measure situations in which two drivers with transversal driving directions, pass over a common spatial point or area with a temporal difference that is below a predetermined threshold (typically 1 to 1.5 seconds).

Klunder (et al. 2004) describes the PET event as a measurement that is calculated within the conflict zone. From the moment that the first car enters the conflict zone the distance in time between the conflict zone and the second vehicle is measured, divided by the velocity of this vehicle. If the first vehicle does not completely pass the area before the second vehicle enters, a negative PET value will be received. This indicates when an accident has occurred.

Self-Report Measures

Shalom Schwartz is a central figure in theoretically-grounded cross-cultural psychology and the creator of the Schwartz value survey, consisting of 57 human values that are formed into ten broader types:

- SD, Self Direction - *Independent thoughts and actions; autonomy and independence.*
- ST, Stimulation - *The organismic need for variety, excitement, novelty, and challenge.*
- HE, Hedonism - *Pleasure or sensuous gratification for oneself.*
- AC, Achievement - *Demonstrating competence to obtain social approval; the focus is social esteem*.
- PO, Power - *Attainment of social status and prestige, and control or dominance over people and resources; the focus is social esteem.*
- SE, Security - *Safety, harmony, and stability of society, of relationships, and of self.*
- CO, Conformity - *Self-restraint in everyday interaction, likely to violate social expectations or norms.*
- TR, Tradition - *Respect, commitment, and acceptance of the customs and ideas that one's culture or religion impose on the individual.*
- BE, Benevolence - *Concern for the welfare of close others*.
- UN, Universalism - *Understanding, appreciation, tolerance and protection of the welfare of all people and for nature.*

These reflect three universal human requirements: 1) biological needs, 2) needs for social coordination, and 3) need for group welfare and maintenance (Smith et al., 2006). Schwartz did dot only identify these values, but he also empirically found the dynamic relations amongst them.

The circular shape, seen in figure 1, shows that adjacent value types are compatible while values opposite of one another are in conflict. The boundaries should be seen as more continuous rather than discrete.

Figure 1 Model of relations of values

The Neo-FFI is a questionnaire designed to measure the Big Five model of personality treats, the five domains of adult personality, that is: extraversion, agreeableness, conscientiousness, emotional stability and openness. This is a widespread measure to see differences in personality between individuals and can be used together with the Schwartz value survey and other types of questionnaires.

Research Questions

Two hypotheses have been formulated in relation to the aims and goals of this study. The first research question is whether driving behaviour in intersections is a function of the variance in traffic velocity.

H_0: Driving behaviour in intersections is independent of the variance in traffic velocity.

H_{A1}: Increased variation in traffic velocity will lead to a higher rate of incidents in intersections.

H_{A2}: Increased variation in traffic velocity will lead to lower values of PET. (PET decreases as variance in velocity increases.)

The second research question is whether there is a difference in incident rate in intersections between sessions that emphasize on rule following and sessions that emphasize on competition.

H_0: There is no difference in incident rate in intersections between sessions with emphasis on rule following and sessions with competitive purpose.

H_{A1}: An emphasis on competition will lead to a higher rate of incidents in intersections.

H_{A2}: An emphasis on competition will lead to lower values of PET.

In addition, we also examined if there were any differences or correlations between the self-reported data (the questionnaires) and the main questions above. An evaluation of the participants' subjective opinion about the simulator and the simulated environment they drove in was done to see whether it may have had influence on the result.

Method

The study was conducted using a within-group design. A total of 56 participants were selected trough emails to student courses, electronic billboards and posters put up all over LiU. The participants attended the trials in 14 groups of four. A valid driver's licence was required for participation. The implementation of the project was utilized by four multi-user driving simulators that were located at IDA at LiU. This driving simulator was used to reproduce the driving characteristics of four people-driven vehicles. To test our hypothesis that different situations cause different individual behaviour among the participants, we created six different scenarios of which four were main scenarios. In each scenario there were 24 autonomous cars. All scenarios had the same road design, but slightly different landscaping. The autonomous cars were given a speed limit range according to a low velocity setting and a high velocity setting. Each of the four scenarios had either an emphasis on rule following or competition, and had a low or a high velocity setting. See figure 2.

	Rule following	*Competition*
Hi	Session A	Session B
Lo	Session C	Session D

Figure 2 Session conditions.

The scenarios were counterbalanced across the 14 experimental groups. This was to decrease the confounding variable of always driving one session before another. In each session the participants were given a task, this to create a purpose with their driving and to make them more eager to explore the world. The task was to find six different road signs with a word written on and use them to form a sentence. Once the participants had the sentence figured out, which was either a question or a request, the participants were then to answer the question or to accomplish the request. 11 different self-report questionnaires were used for collectiing the participants' subjective responses to questions concerning demographic variables, personality variables, value structure, risk attitudes and driving patterns.

Results

This section presents the collected questionnaire and simulator data. This results in qualitative and quantitative data that has been compared and evaluated. T-tests were conducted, and the results implied that our null hypothesis could not be rejected. Partial correlation tests were done between responses to the Schwartz Value Survey and to other questionnaires, and between the Schwartz Value Survey and PET. Establishment in correlation between PET and different types of personality traits were obtained.

All PET values above 10 seconds were considered irrelevant for the study and discarded. The t-test that assessed the first research question, which aimed to see if the speed variance affected the incident rate, failed to discard the null hypothesis. Therefore it has to be assumed that there is no difference in PET values that depend on velocity variance, neither for the high or low variance settings.

The second research question, which aimed to see whether there were any differences in incident rate in intersections depending on whether the session emphasized on rule following or competition was also answered with help of a paired t-test. The results showed that a difference between sessions, as a result of the emphasis on rule following or competition, could not be proved.

A rather strong correlation between PET and universalism (UN) was found. This correlation was independent of the given task or speed variance in the session. A conflicting and rather incomprehensible negative correlation was found between PET and security (SE). This particular correlation indicates that the more one values security the smaller a PET value one will get. A more understandable negative correlation was found between PET and power (PO). This indicates that people who values power (PO) high tend to get a lower PET value in intersections. A negative correlation between PET and benevolence (BE) was also found.

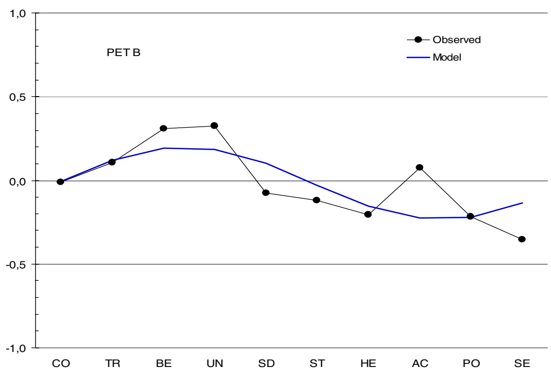

Figure 3 The correlation between PET value in B sessions, and Schwartz Value Survey

Analysis & Discussion

The negative correlation of PET with security (SE) and power (PO) on the one hand, and the positive correlation with universalism (UN) and benevolence (BE) on the other is surprising. But power (PO) and security (SE) are adjacent Schwartz values, as is universalism (UN) and benevolence (BE). The both value pairs are also located on opposing sides of the Schwartz-circle.

The main issue of the study has been to examine driving behaviour in intersections. Neither the manipulation of the instruction set nor variance in velocity seem to have had an affect on the participants in their driving behaviour.

PET values are constant and independent of our manipulation of the session. The results indicates that the drivers in the simulator tend to have a similar incident rate in an intersection, regardless of whether they are driving in a competitive session or driving in a session with emphasis on rule following. It is assumed that the drivers' speed limit is higher in a competitive session compared to a rule following session. Therefore, it might be implied that a higher speed does not necessarily cause low PET values.

This might actually indicate that the simulator has a high external validity. If the participants are equally aware of the risks involved in driving, regardless of the external influences affecting them, and take precautions to keep a higher safety distance when driving faster, this would correspond to the real world, where a potential crash is both dangerous and costly.

The claim that simulator drivers keep higher safety distance when driving faster could be verified by correlating the speeds of vehicles entering an intersection with the PET values generated by vehicles meeting in the same intersection. If the PET values are kept at a constant level despite higher entrance speeds, it can be concurred that the drivers keep a higher safety distance in the intersection.

Our study contributes to further research on traffic behaviour in intersections. Primarily it will contribute with our chosen experimental method and with the data that we have collected. IDA's part of the 'Intersection Accidents' project will continue with adding more participants to the study and also by looking at the velocity of the vehicles when they are at several different distances from the intersection.

References

Archer, J (2005) *Indicators for traffic safety assessment and prediction and their application in micro-simulation modeling: A study of urban and suburban intersections.* Stockholm: Kungliga Tekniska Högskolan. 05/013

Frith, W .J., Patterson, T. L. (2001) *Speed variation, absolute speed and their contribution to safety, with special reference to the work of Solomon,* IPENZ

Hancock, P.A., De Ridder, S.N. (2003) *Behavioural accident avoidance science: understanding response in collision incipient conditions,* University of Central Florida, Taylor & Francis Ltd. Transportation Group, Technical Conference Papers Hennessy, D.A., Weisenthal, D.L. (1999) *Traffic congestion, driver stress, and driver aggression,* Aggressive Behaviour, Volume 25, pp. 409-423.

Howard, A., Joint, M. (1994) *Fatigue and stress in driving*, Employee Counselling Today, Vol. 6 No. 6, pp 3-7.

Klunder, G., Abdoelbasier, A., Immers, B. (2004) *Development of a micro-simulation model to predict road traffic safety on intersections with surrogate safety measures,* TNO, Business Unit Mobility & Logistics.

Lu, J., Dissanayake , S., Castillo, N., Williams, K. (2001) *Safety evaluation of right turns followed by U-turns at signalized intersection as an alternative to direct left turns – conflict analysis,* Tampa, FL: University of South

Reed, M. P., Green, P. A., (1999) *Comparison of driving performance on-road and in a low-cost simulator using a concurrent telephone dialling task*, Ergonomics, 1999, vol. 42, nr 8, s. 1015-1037

Santos, J., Merat, N., Mouta, S., Brookhuis, K., De Waard, D. (2005) *The interaction between driving and in-vehicle information systems: Comparison of results from laboratory, simulator and realworld studies* Transportation Research Part F: Traffic Psychology and behaviour, 8(2), pp. 135-146

SIKA, Statens institut för kommunikations analys (2006) *Road traffic injuries 2005.* Stockholm; EO Grafiska AB. 2006:31

Smith, K., Lindgren, I., Granlund, R. (2007) *Bridging cultural barriers to collaborative decision making in on-site operations coordination centers.* Division of industrial ergonomics, Linköping Institute of Technology.