

A HUMAN FACTOR-BASED APPROACH FOR THE EFFECTIVE USE OF DRIVING SIMULATORS AND E-LEARNING TOOLS IN DRIVER TRAINING AND EDUCATION

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ABSTRACT: The present state of driving simulator technology makes it possible to implement driver training applications with a growing level of complexity and fidelity to real driving conditions. However, driving simulators only become an effective tool in driver training if they are effectively included as an integral part of the training curriculum. Such integration requires a methodical approach as well as a detailed analysis of the training curriculum, the learning goals and training needs. This paper presents the results of Humanist Task Force G regarding a definition of a human factor-based approach for the effective use of technology in training taking into account cognitive aspects, as well the special needs and requirements of the training process for different target groups: novice drivers, professional drivers, elderly drivers, and disabled drivers. Methodological conditions for enhancing the acquisition of different levels of driving abilities and for using new technologies as a tool of performance measurement are discussed,

1 General framework for driver training

It is generally accepted that driver training must include a theoretical and a practical component, which ideally should enable the student to acquire the required abilities to master the driving task by means of an abstract approach and through practical training by driving in a real vehicle in real traffic.

Driver training curricula are based on theoretical assumptions about driver behaviour and the driving task. A common premise is that driver behaviour is organised in three hierarchical levels –strategic, tactical and operational – as described by Keskinen [2], building on previous work by Michon [2,3]. Based on this work, the European project GADGET described the issues relevant for driver training and in particular training of novice drivers in order to provide a theoretical framework to define and cover the areas of competences that driver training and education need to address [4]. This project provided the basis for developing the Goals for Driver Education (GDE) framework.

The GDE-framework comprises two dimensions. The first dimension includes the three hierarchical levels mentioned above. A fourth level concerning “goals for life and skills for living” was added. It refers to personal motives and tendencies in a broader perspective than simply conducting the driving task. This level is based on the assumption that lifestyle, social background, gender, age, income, etc. have an influence on attitudes, driving behaviour and accident involvement.

In addition to the four levels of driver behaviour, the GDE-framework operates with another dimension constituted by three goals for training: knowledge and skill, risk-increasing factors, and skills for self-assessment. These dimensions all relate to behaviour at the different levels thus influencing both driving preconditions as well as the accomplishment and execution of the driving task.

The knowledge and skill level refers to the skills a driver needs for driving under different circumstances.

Risk-increasing factors deal with aspects of driving or traffic that may increase the risk, such as perception of the traffic situation, speed adjustment, and risk acceptance.

The skills for self-assessment refer to the driver's capability to assess his performance on the four behavioural levels. It really points to critical self-adjustments of everything from skills in vehicle handling to a reflection of individual risk attitudes.

Ideally, driver training curriculum should cover all the areas of the framework and address the appropriate driving behaviour associated with them [5]. However, traditional driver training typically only covers the last two levels of behaviour (vehicle manoeuvring and mastery of traffic situations). Similarly, at the goal dimension level only the first level of knowledge and skills is included and risk increasing factors are covered to a lesser extent in existing training programs. The third level is rarely encountered during driver training.

2 Target groups

2.1 Novice drivers

Novice drivers need to acquire both theoretical and practical skills as well as knowledge at all levels of the GDE-framework.

Novice drivers are the group with the highest accident risk. Fatality rates for 18 to 24-year old drivers (number of driver fatalities per million age group) in industrialised countries are about the double of those of experienced drivers (aged 25 to 54). During the first years after having passed the driving test, the accident risk declines sharply. Several studies have found that the accident risk decreases rapidly during the first years of driving experience. However, it takes about 7 years of driving experience before the accident risk reaches an acceptable, low level [6].

In-depth accident analysis of crashes involving young novice drivers has revealed that it is not so much a lack of basic driving skills that has caused the accident, but a lack of so-called higher order skills. These skills deal with risk perception, risk acceptance, self-assessment, the motivation to drive safely, etc. Young drivers tend to misinterpret traffic situations and show an inefficient visual search. Furthermore, they have difficulties in adapting their speed and driving distance to the driving conditions [7]. They also tend to underestimate the risk of a hazard resulting in an accident and overestimate their ability to deal with hazards [8].

There are indications that simulator training helps to speed up the learning process, although at present the knowledge on transfer and retention of the skills acquired during simulator training is insufficient to assess its effects on the performance of the drivers after the training period [9].

2.2 Professional drivers

Professional drivers typically undergo training in handling difficult driving manoeuvres and driving special vehicles or goods. Simulators have been developed for both research and training of professional drivers. Already in 1958 the Iowa State driving simulator linked a vehicle cabin mock-up to a scaled physical terrain model allowing the driver to control actions in a rudimentary road layout. Since then there have been many different technical innovations including videos of real scenes and, more recently, computer generated environments. At present, several European countries employ truck driving simulators as part of in-service training.

Brock et al. studied the effects of training with three types of simulators that are often used in the US to retrain experienced drivers: an open-loop video simulator, a low-end simulator, and a mid-range simulator [10]. The use of simulation decreased trainee drop-out rates by 35% for an agency using the midlevel simulator, decreased student failure rates by 50% in an agency using the open-loop and the low-end simulators, and decreased the collision rate by 10% in an agency using a combination of open-loop and low-end simulators. In addition, the use of simulation reduced training time in one agency from 19 days to 17 days by replacing classroom bus training with simulator training. In another agency using only the open-loop system, training time was reduced by 5 days when simulation was employed.

Strayer and Drews conducted an experiment with professional drivers who spent 2 hours in a simulator learning shifting strategies in order to maximise fuel efficiency [11]. The participants' fuel consumption performance when driving their normal route in their own vehicles was monitored for 6 months. Training increased fuel efficiency by an average of 2.8% over the six-month interval. Drivers who drove not specifically simulated vehicles in the training sessions were also found to improve their performance after training.

In the UK, Parkes and Reed conducted a longitudinal cohort study that sought to provide an analysis of the benefits of synthetic training in the area of fuel efficiency improvement [12]. 36 drivers received training designed to improve their driving style in a range of traffic situations in a truck simulator

During each simulator visit, apparent fuel consumption figures were recorded and compared to real-world fuel consumption records for the same drivers. In addition and over the same period, fuel consumption data were obtained for a matched cohort of drivers who did not attend the training. The mean change in fuel efficiency observed of the drivers in the simulator group showed an improvement of 15.7 % in their on-road performance.

These results suggest that simulators can be effectively used to improve specific driving skills in experienced drivers.

2.3 Elderly and disabled drivers

Similarly, training groups of elderly or disabled drivers would have to implement different approaches such as focusing on the functional awareness of their abilities and limitations and adapting their driving behaviour accordingly without exposing them to the risks of real traffic.

Roemaker et al. (2003) designed a study to examine if a speed-of-processing training can improve at-risk older adults' driving performance. Training transfer and retention were assessed in an on-road driving evaluation immediately after training and 18 months after training. Simulator training resulted in an improvement in the specific driving manoeuvre skills that were expressively practiced during training. However, those effects were mostly temporary, and dissipated at the 18-month follow-up [13].

Disabled drivers are typically trained in order to identify functional weaknesses, i.e., not for the purposes of training per se but rather to be able to identify the driving conditions in which they would encounter difficulties. In this context simulators can be of great use in helping the subjects to gain functional awareness of their abilities and to adapt their driving behaviour to them without being exposed to the risks of real traffic [14].

Akinwuntan et al. designed a study to test the effectiveness of simulator training in heart stroke patients [15]. Eighty-three first-ever subacute stroke patients entered a 5-week 15-hour training program in which they were randomly allocated to either an experimental (simulator-based training) group or a control (driving-related cognitive tasks) group. Simulator-based driving training improved driving ability, especially for well educated and less disabled stroke patients. However, the findings of the study may have been modified as a result of the large number of dropouts and the possibility of some neurological recovery unrelated to training.

Simulation can also be a useful tool for assessing drivers with disabilities. Driving aids could be simulated so that drivers could test them together with the assessor in a safe artificial environment.

3 Including simulators in the training curriculum

Driving simulator technology makes it possible to implement driver training applications with a growing level of complexity and fidelity to real driving conditions. Driving simulators only become an effective tool in drivers' training if they are effectively incorporated as an integral part of the training curriculum. Such integration requires a methodical approach and a detailed analysis of the training curriculum, the learning goals and training needs [16]

A simulator is an abstraction of reality, and many aspects cannot be reproduced with sufficient detail or realism. The term fidelity refers to how closely the simulation imitates reality. From an educational point of view the learning goals determine the required level of fidelity. Limited fidelity restricts the range of tasks or task aspects that can be trained in the simulator.

Slick et al. found that transfer of training from simulated environments to the real world was maximized when training is characterized by a high degree of

both physical and psychological fidelity [17]. Nevertheless, some research results indicate that higher fidelity does not always improve the training results [18]. Beginning trainees could be overwhelmed by the complexity of the real system and environment and may, therefore, sometimes be better served by a simplified, lower fidelity simulation [19]. More experienced trainees, however, would learn more from a high-fidelity simulation [20].

3.1 Basic vehicle handling skills

Simulators can be used for training in the first steps of vehicle handling. The advantages are related to safety - trainees would be able to learn these skills without endangering themselves or other road users - and to environmental preservation since the use of simulators instead of practice on a motor vehicle eliminates the pollutant emissions created by the latter.

Trainees should learn to recognise or experience closely the risk-increasing aspects of the tasks, especially underestimation of speed. By enabling trainees to evaluate their skills in a realistic way, they will learn to compare their estimates with the real outcome.

3.2 Cognitive aspects and decision process

Novice drivers lack perceptual skills and anticipation in traffic. On the one hand they do not use peripheral vision, and on the other hand they underestimate the time needed for many manoeuvring tasks such as overtaking, merging, lane changing, reaching an intersection, stopping, and turning. They have problems estimating the behaviour of other road users as well, i.e. how much time these drivers need to perform the tasks mentioned above. When an unexpected and unusual situation does occur, they do not know how to react adequately.

Recent developments in software make it possible that drivers in a simulator can learn to behave in very realistic way. Automatic Traffic Generation and Autonomous Driver models reproduce the circumstances in real traffic and enable users to repeat and therefore train certain tasks in changing environments, with varying risk, and different road users, with variable behaviour. These devices facilitates training of anticipatory skills, like risk or hazard perception, which are highlighted by recent research as very important for safe driving [21].

The main advantages of simulators compared with real driving are that trainees can experience scenarios which are too dangerous to create on the road, and that they can train cognitive skills without fully automated manoeuvring skills.

In order to increase driving skills without increasing excessively the self-confidence of the trainees, the manoeuvring component should not be overemphasised. It is preferable that the training process includes demonstrations and exercises in which novice drivers may fail in order to develop a realistic self-evaluation of their capabilities. Additionally, trainees should be given comprehensive feedback on their attitudes, risk perception and personal tendencies during training. Self-assessment tools like questionnaires and scales, discussions with other trainees about personal experiences and

evaluations made by instructors or examiners seem to be appropriate educational methods.

In a simulator trainees will better experience the harmful influence of factors such as stress and mood on driving behaviour, and how drivers can cope with these risk-increasing aspects.

3.3 Training of higher order skills

Training of higher order skills included in the GDE-matrix would mean that the present driver training should extend the theoretical and practical training curriculum to areas including confrontation with difficult or risky situations or with situations where the drivers' attitudes (motivations, representations and emotions) are challenged.

However, the sequencing for the acquisition of higher order skills is important. Higher order skills are primarily integrated through experience and not solely obtained through education or training. They should be introduced in training after the trainee completes the skill-and-knowledge based levels.

Groeger casts some doubts on the usefulness of driver simulators for the acquisition of higher order skills [22]. Simulators make it possible to structure driver training and to introduce mass repetition of skill drills. Laboratory experiments have shown that mass repetition of partial tasks helps speeding up the learning process; but retention is lower. This is in particular the case when subjects have to conclude from the context what skills have to be applied. Therefore, in Groeger's opinion, associative learning during many hours behind the wheel under varying conditions with an experienced driver next to the learner driver is a better way of acquiring higher order skills than structured simulator training in a reduced environment.

Falkmer and Gregersen [23] conducted an experiment to assess the effectiveness of hazard perception training with simulators in Sweden. Driving school learners received multimedia training on PC's and subsequently simulator training focused on hazard perception and risk acceptance in addition to their driving lessons. A limited positive effect was observed when using a simulator with a 120° screen view angle and simple movement feedback. When a very simple simulator (40° view angle and no feedback) was used, the simulator training had absolutely no effect on the hazard perception and risk acceptance by these driving school learners.

These results indicate that the potential of driver simulators for the acquisition of higher order skills is limited.

4 Conditions for an effective use of simulators in driver education

Training effectiveness depends on the degree to which trainees are able to apply the knowledge, skills, and attitudes gained in a training context to the real context. This means that training is effective when transfer of training is achieved, and the value of a training device is determined by the degree of

learning and transfer that occurs. Barnard et al. [24] defined the following forms of transfer:

- Positive transfer: Extent to which trainees have acquired knowledge, skills and attitudes, which can be applied effectively in work practice.
- Negative transfer: Extent to which an undesired effect occurs after following a course.
- Far transfer: Transfer when the initial learning task and the subsequent tasks to be learned differ substantially.
- Near transfer: Transfer when the initial learning task and the subsequent tasks to be learned differ only slightly or not at all.
- General transfer: The trainee acquired certain working methods, knowledge and skills, which can be used in tasks other than the original learning task.
- Specific transfer: The learning task is so specific that no transfer can be expected to other tasks, but only to the same task.

The main goal of driver training is to achieve positive transfer: the things learned in the simulator should be transferred to the real-life driving task. At the same time it is important to avoid negative transfer. With simulators this is a possible risk, as the technical driving task is certainly not the same as in a real car, especially with relatively simple simulators. Perceptive tasks are also different. For example, the perception of speed and distance is different compared with real driving.

Although specific transfer is not a problem in itself - the trainee only needs to transfer the learned driving task to a driving task in the real environment - general transfer is desired when it concerns traffic insight. The traffic situations encountered in the simulator should be generalised to other traffic situations [25].

Despite their prevalent use, there still exists a lack of evaluation studies to provide evidence on the effectiveness of driving simulators in driver training. Humanist Task Force G has synthesised the existing experience on the effectiveness of simulators as an educational tool [26]. It was found that at present there is not enough knowledge on transfer and retention of the skills that are acquired during simulator training to assess its effects on the performance of the drivers after the training period. Nevertheless, existing research provides indications of the potential efficiency of simulators and e-learning with respect to improving some aspects of driver training [27].

The following recommendations for effective use of simulators in driver training and education were formulated as a conclusion of Humanist TFG work.

4.1 Novice drivers

Simulator-based training scenarios and instruction program should provide:

- A valid environment for practicing the necessary skills.
- Clear goals and contents for training.

- Enough feedback to improve behaviour and to learn.
- A possibility to gain enough experience.
- A learning period long enough to commit the skills and knowledge learned to memory, and a learning climate favourable to safety.

It is recommended to extend the curricula in order to cover all the levels of the GDE-framework. Trainees should learn to know or better experience the risk-increasing aspects of the tasks, especially underestimation of speed. In order to enable trainees to evaluate their skills in a realistic way, it should be possible for them to compare their estimates with the real outcome.

In order to increase driving skills without excessively increasing the trainees' self-confidence, the manoeuvring component should not be overemphasised. It is preferable that the training process should include demonstrations and exercises in which novice drivers may fail so that they may develop a realistic self-evaluation of their capabilities.

Training of novice drivers should include instruction on the proper and safe use of ITS devices. Discussion and work groups combined with simulator and multimedia training might be appropriate methods to make novice drivers aware of specific problems in connection with the use of ITS.

4.2 Professional drivers

Training safe driving strategies can only be successful if driver training covers motivational and self-evaluative aspects. Trainees should be given comprehensive feedback on their attitudes, risk perception and personal tendencies during training.

Physical fidelity is not a sufficient precondition for optimal training effects. For the training of certain skills (e.g. hazard perception) simulations with lower fidelity (e.g. video scenes) can be efficient training tools.

4.3 Elderly and disabled drivers

Retraining of disabled older drivers requires the development of specific scenarios based on their particular needs.

Simulation can also be a useful tool for the assessment of drivers with disabilities. Driving aids could be simulated so that drivers could test them together with the assessor in a safe artificial environment.

5 Further research

As a conclusion of the analytical review of driver training and education process conducted by Humanist Task Force G, research needs were identified in the following areas [28]:

- a) Pedagogical and didactical components
 - Development of effective training curricula (activities, sequence of activities, scenarios etc) including simulator-based training particularly

designed for the needs of specific target groups including novice, experienced, professional, elderly and impaired drivers.

- Guidelines for the role of the trainer and his task in the simulator training process.
- Criteria for the selection of training media (classroom, slide show, mechanical devices, computer, e-learning, simulation, real driving, etc.) for different training activities.
- Assessment of the effectiveness of using simulators for the acquisition of higher order skills such as risk perception, and the retention of skills acquired through simulator training.

b) Technological aspects

- Technical specifications defining the minimum conditions required for a simulator in order to be suitable for use at the different levels of driver training applications.
- Development of a framework for converting vehicle performance data into usable training feedback for the driver.
- Development of a driver performance monitoring tool to assess the driver's decisions and actions in specific driving situations in real time.
- Development of an advanced traffic model to produce a realistic traffic environment around the learner.
- Techniques to avoid simulator induced sickness.

6 References

- [1] Keskinen, E.: Why do young drivers have more accidents? Referate der Esten Interdisziplinären Fachkonferenz 12-14. Berichte der Bundesanstalt für Strassenwesen. Mensch und Sicherheit, Heft M 52, 1996
- [2] Michon, J.A.: A critical view of driver behavior models: what do we know, what should we do? In: Evans, L. and Schwing, R. (Eds.) Human Behavior and Traffic Safety. Plenum Press, New York, 1985
- [3] Michon, J. A.: Explanatory Pitfalls and Rule-Based Driver Models. Accident Analysis and Prevention, Vol 21,1989, pp. 341-353.
- [4] Hattaka, M., et al. : Results of EU- Project GADGET, WP3, 1999.
- [5] Gregersen, N.P. et al.: Driving simulator scenarios and requirements – Deliverable D4.1 GRD1-1999-10024 – UE TRAINER Project System for driver Training and Assessment using Interactive Evaluation tools and Reliable methodologies, 2001
- [6] Turetschek, C.: Potentials and Risks of New Technologies in the Training of young drivers. Proceedings of the Conference on European guidelines for the application of new technologies for driver training and education. Humanist NoE, Madrid, 2006

- [7] Clarke, D. et al: Voluntary Risk Taking and Skill Deficits in Young Driver Accidents in the UK. 37:3 Accident Analysis and Prevention, 2005, pp. 523-529.
- [8] Deery, H.: Hazard and Risk Perception Among Young Novice Drivers, Journal of Safety Research, Vol 30, No 4, 1999
- [9] Vlakveld, W.: What does educational psychology tells us and what are the implications for simulator training?. Proceedings of the Conference on European guidelines for the application of new technologies for driver training and education. Humanist NoE, Madrid, 2006
- [10] Brock, J., Jacobs, C., and McCauley, M.: Simulators and Bus Safety: Guidelines for Acquiring and Using Transit Bus Operator Driving Simulators. TCRP Report 72, TRB, The National Academies, Washington, D.C., 2001.
- [11] Strayer, D. and Drews, F.: Simulator Training Improves Driver Efficiency: Transfer from the Simulator to the Real World. Proc., Second International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Aspen, CO, 2005, pp. 190–193.
- [12] Parkes, A. and Reed, N.: Fuel Efficiency training in a full-mission simulator. Behavioural Research in Road Safety Fifteenth Seminar, Department for Transport, London, 2005.
- [13] Roenker, D. et al.: Speed-of-processing and driving simulator training result in improved driving performance. Human Factors, 45(2), 218- 233, 2003.
- [14] Rizzo, M., et al.: An abstract virtual environment tool to assess decision-making in impaired drivers. In J. D. Lee, M. Rizzo & D. V. McGehee (Eds.), Proceedings of the Second International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design. University of Iowa, Iowa City, 2002.
- [15] Akinwuntan ,A. et al.: Effect of simulator training on driving after stroke: A randomized controlled trial. Neurology , 2005, vol. 65, pp. 843—850.
- [16] Pardillo J.M. et al.: Guidelines for the development of a European driver training and education tool. GUPM-061030T1-AB Humanist deliverable G4 Humanist NoE, Lyon, 2006
- [17] Slick, R. et al.: Using Simulators to Train Novice Teen Drivers : Assessing Psychological Fidelity as a Precursor to Transfer of Training - DSC Asia/Pacific, 2006 – Tsukuba.
- [18] Alessi, S. M.: Fidelity in the design of instructional simulations. Journal of Computer-Based Instruction, 15(2), 1988, pp. 40-47.
- [19] Alessi, S. and Trollip, S.: Multimedia for learning: Methods and development. Needham Heights, MA, 2001.
- [20] Verstegen, D.: Iteration in instructional design: An empirical study on the specification of training simulators. Doctoral dissertation, Utrecht University, the Netherlands, 2003.
- [21] Espié, S.: Training novice driver: toward cognitive training. Proceedings of the Conference on European guidelines for the application of new technologies for driver training and education. Humanist NoE, Madrid, 2006

- [22] Groeger, J.A.: Understanding Driving-Applying cognitive psychology to a complex everyday task. Psychology Press Ltd. Hove, 2000
- [23] Falkmer, T. and Gregersen, N.P.: The TRAINER Project- The Evaluation of a New Simulator-Based Driver Training Methodology. In: Dorn, L. (red.), Driver Behaviour and Training, proceedings of the 1st international conference on driver behaviour and training, Stratford-upon-Avon, England, 2003, pp. 317-330.
- [24] Barnard, Y., Veldhuis, G., and Rooij, J.: Evaluation in practice: identifying factors for improving transfer of training in technical domains. *Studies in Educational Evaluation*, 27 (3), 2001, pp.269-290.
- [25] Shea, J. and Morgan, R.: Contextual interference effects on acquisition, retention, and transfer of a motor skill. In: *Journal of Experimental Psychology; Human learning and memory*, vol. 5, nr. 2, p. 179-187, 1979
- [26] Pardillo, J.M. et al.: Report on the effectiveness of simulators as educational tool. GUPM-071015T1-DA. Humanist deliverable G5 Humanist NoE, Lyon, 2007
- [27] Dolan, D.M., et al.: Simulator training improves driver efficiency: transfer from simulator to real world. Proceedings of Second International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle design, Park City, Utah, USA, 2003.
- [28] Pardillo, J.M. et al.: Functional requirements of driver training and education tools, identification of research needs and potential applications of e-learning. GUPM-051220T1-DA (2). Humanist deliverable G3 Humanist NoE, Lyon, 2005