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Functional requirements of driver training and education tools, identification of research needs and potential applications of e-learning

Deliverable G3 of Task Force G:
Use of ITS to train and to educate drivers

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EXECUTIVE SUMMARY

This document reports the results of Humanist Task Force G work assess the present state of the art in the application of driver simulators to driver training, and to identify what additional R&D effort is needed to achieve the potential effectiveness in using simulators to improve the driver training process. The results of a workshop on the Application of new technologies to driver training held in Brno (Czech Republic) on January 2005, provided the base to synthesise the existing knowledge on the general framework of driver training, and the application of simulators and e-learning tools in the process.

As a conclusion, research needs to fill the gaps in existing simulator and multimedia tools to achieve the potential effectiveness in using simulators to improve the driver training process at a European level with harmonized procedures have been identified in the following fields:

- Pedagogical and didactical components
- Technological aspects
- E-learning applications

1 INTRODUCTION

Driving simulators and e-learning communication technologies hold considerable promise for enhancing driver training, testing, and licensing and in consequence for improving driver performance and highway safety. Present state of the technology makes it possible to implement different driver training applications with a growing level of complexity and fidelity to real driving conditions.

In general little scientifically validated knowledge exists on the transfer effects of e-learning in regards to driving behaviour, situation awareness or anticipatory behaviour. Elderly drivers, impaired drivers or drivers with special needs are not targeted in any of these applications though many of these driver groups could potentially benefit from certain elements of these applications. There is also a lack of common technical specifications both at national level and at European level that define the minimum conditions that driving simulators should have to be suitable for use in the different levels of driver training applications.

The validation of simulators is also an area were there is still a need for further advance. There have been some efforts in this field, but without a systematic approach that enables to compare results or to derive general conclusions. A methodological approach to driver simulator validation for driver training is required as a key step towards extended use of simulators as standard tools in the driver training process in Europe.

Finally, e-learning techniques should be regarded as an alternative or supplement to traditional theoretical training as it holds great illustrative value. On the other hand it is unlikely that e-learning could replace real driving. As most e-learning applications are not yet used as compulsory training tools little knowledge exists on the learning potential compared to traditional driver training (both theoretical and real driving).

This report presents the results of Humanist TFG work to assess the present state of the art in the application of driver simulators to driver training, and to identify what additional R&D effort is needed to achieve the potential effectiveness in using simulators to improve the driver training process at a European level with harmonised procedures.

2 METHODS

A workshop on the Application of new technologies to driver training was organised by Humanist TFG at the CDV facilities in Brno (Czech Republic) on January 25-26 2005, covering the following topics:

- State of the art in driving simulators.
- State of the art on e-learning applications. .
- Driver simulators: Perspective of stakeholders.
- Framework for the application of simulators to driver training
- Curriculum for driver training based in simulators and e-learning
- Validation techniques: state of the art and research needs
- Initial approach for the preparation of guidelines on the application of new technologies to driver education.

During the workshop 20 papers were presented, and 30 researchers from Humanist partners discussed the requirements and research needs in the field of driver training. The minutes of the Workshop including the papers that were presented are available through the Humanist Web Site (www.noehumanist.org/documents/Download%20documents/Delivrables/TFG).

Based on the conclusions of the Workshop, and the materials that were presented in it, the Task Force worked on two areas:

1. Study of functional requirements of driver education tools and identification of research needs to fill the gaps in existing simulator and multimedia tools.
2. Analytical review of driver training and education process and identification of potential applications of e-learning.

These two studies provided the base for the preparation of the report on functional requirements of driver training and education tools, identification of research needs and potential applications of e-learning.

As few TFG partners had been involved in either development or use of e-learning applications, the studies were complemented in this are with results from the project TRAINER, which addressed issues relevant for driver training and specifically put them within a context of multimedia or simulator use relevant for driver training

3 GENERAL FRAMEWORK OF DRIVER TRAINING

It is generally accepted that driver training needs to encompass a theoretical and a practical component, which ideally should enable the student to both acquire 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.

3.1 Theoretical background for driver training

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 described by Keskinen [1996], building on previous work by Michon [1985 and 1989]. Based on this work the European project GADGET addressed issues relevant for driver training and particularly training of novice drivers in order to provide a theoretical framework to define and comprehend the areas of competences that driver training and education need to address (Hattaka et al., 1999). From this project the GDE-framework (Goals for Driver Education) was developed (fig.1). The GDE-framework compromises two dimensions. The first dimension includes the three hierarchical levels mentioned above – the strategic, tactical and operational level, but a fourth level is also added concerning "goals for life and skills for living". (the highest levels ranked first). In:

- Goals for life (personal motives and beliefs): this level is based the assumption that lifestyle, social background, gender, age, income etc., has an influence on driving behaviour and attitudes towards driving. As such this level refers to personal motives and tendencies in a broader perspective than simply conducting the driving task. The assumptions behind this level is based on knowledge that lifestyle, social background, gender, age and other individual preconditions have an influence on attitudes, driving behaviour and accident involvement.

- Goals and context of driving: This level focuses on the context in which driving is performed, particularly, on choice and planning of trips, travel-mode, time of day, road situations or driving under influence of deteriorating conditions or substances.

- Mastering of traffic situations: The conditions applied to this level refers to the mastering of adaptation to specific traffic situations, such as overtaking, speed choice, perception of hazards.

- Vehicle manoeuvring. The lowest level refers to vehicle control such as shifting gears or steering manoeuvres. On this level is also included evasive manoeuvres, control in different weather conditions and use of passive safety measures such as seatbelts and airbags.

This hierarchical approach assumes that abilities and preconditions on a higher level influence the demands and preconditions on lower levels.

- In addition to the four levels of driver behaviour the GDE-framework also operates with another dimension, which is formed by three goals for training;

knowledge/skill, risk increasing factors and skills for self-assessment. These dimensions all relate to behaviour at the different levels thus influencing both the preconditions of driving as well as the accomplishment and execution of the driving task: Knowledge and skills: this level refers to the skills a driver needs for driving under different circumstances.

- Risk-increasing factors: this level deals with aspects of driving or traffic that can increase the risk, such as worn out tyres, perception of the traffic situation, speed adjustment, risk acceptance.

- Self-evaluation: this level emphasises how the driver is capable of assessing the performance on the four behavioural levels. It really points to critical self-adjustments of everything from skills in vehicle handling to reflection of individual risk attitudes.

Hierarchical level of behaviour	Essential contents (examples) Knowledge and skills	Risk-increasing factors	Self evaluation
Goals for life and skills for living (general)	Knowledge about/control over how life-goals and personal tendencies affect driving behaviour • lifestyle / life situation • group norms • motives • self-control, other characteristics • personal values etc	Risky tendencies • acceptance of risks • self-enhancement through driving • high level of sensation seeking • complying to social pressure • use of alcohol/drugs • values, attitudes towards society etc	Self-evaluation/ awareness of • personal skills for impulse control • risky tendencies • safety-negative motives • personal risky habits etc
Goals and context of driving (trip related)	Knowledge and skills concerning • effects of trip goals on driving • planning and choosing routes • evaluation of requested driving time • effects of social pressure in car • evaluation of necessity of trip etc	Risks connected with: • driver's condition (mood, BAC etc) • purpose of driving • driving environment (rural/urban) • social context and company • extra motives (competing etc) etc	Self-evaluation / awareness of • personal planning skills • typical goals of driving • typical risky driving motives etc
Mastery of traffic situations	Knowledge and skills concerning • traffic rules • observation/selection of signals • anticipation of course of situations • speed adjustment • communication • driving path • driving order • distance to others / safety margins etc	Risks caused by • wrong expectations • risk-increasing driving style (e.g. aggressive) • unsuitable speed adjustment • vulnerable road-users • not obeying rules / unpredictable behaviour • information overload • difficult conditions (darkness etc.) • insufficient automatism/skills etc	Self-evaluation / awareness of • strong and weak points of basic traffic skills • personal driving style • personal safety margins • strong and weak points for hazard situations • realistic self-evaluation etc
Vehicle manoeuvring	Knowledge and skills concerning • control of direction and position • tyre grip and friction • vehicle properties • physical phenomena etc	Risks connected with • insufficient automatism/skills • unsuitable speed adjustment • difficult conditions (low friction etc) etc	Awareness of • strong and weak points of basic manoeuvring skills • strong and weak points of skills for hazard situations • realistic self-evaluation etc

Figure1: GADGET-MATRIX

One of the conclusions from the GADGET project was that the driver training curriculum should address safety relevant issues in accordance with four levels of driver behaviour:

3.2 Basic vehicle handling skills

Training the basic vehicle handling skills is a natural feature of driver training. But in order to enable trainees to cope with new technical devices, like ACC or ABS, it is necessary to implement lessons that take these new developments into account. The simulator can be used for training the very first steps of vehicle handling. The advantages are not safety related – trainees could learn these skills without endangering themselves or other road users (like learning with a real car in a fenced off driving-instruction range), and ecological related: fuel is not consumed; the use of a simulator is absolutely exhaust-free.

Trainees should learn to know or better experience the risk increasing aspects of the tasks, especially underestimation of speed. To enable trainees to evaluate their skills in a realistic way they should have the possibility to compare their estimates with the real outcome. Especially the connection between reaction, braking and total stopping distance should be understood.

3.3 Cognitive aspects and decision process

Insufficient skills and incomplete automation of manoeuvring skills lead to a greater involvement of novice drivers in accidents. Furthermore, novice drivers (and for some tasks drivers in general) 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, like overtaking, merging, lane changing, reaching an intersection, stopping, and turning off. They have problems to estimate 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.

To train these cognitive skills it is suggested to use filmed clips, videos or digital media, where the trainee has to detect certain cues, to predict, what could happen and what he/she would do. Trainees should also be given comprehensive feedback whether the task is an estimate or a performance prediction. It is also possible to train this with simulators. The main advantages of simulators compared with real cars are that trainees can experience scenarios, which are too dangerous to create on the road, and that trainees can train cognitive skills without fully automated manoeuvring skills.

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

Through the combination of opportunity to practice and obtaining feedback on those skills trainees can come to their own understandings of how cues in traffic and outcome are related. Moreover, trainees can experience the results of their own risky choices. However, risky driving behaviour results not only from poor perception, but also from overestimation of own skills. In order to increase driving skills without increasing the confidence in these skills the manoeuvring component should not be overemphasised. It is better to use more demonstrations and exercises in which novice drivers fail in order to develop a realistic self-evaluation of their capabilities.

3.4 Strategic tasks

Demonstrations should also be used to convince trainees on following safety instructions (e.g. use of seat belt). Trainees should know or better experience (in a simulator) which harmful influences on driving behaviour factors like stress and mood could have and how drivers can cope with these risk increasing aspects.

Techniques like mental practice and group decision could influence the behaviour of novice drivers due to the fact that trainees are forced to make known their own attitudes and reflect them. So trainees are aware of their own conditions and can discuss the influence of their and other road-users´ conditions on the interactive task of driving. They should know that certain motives for driving, like competing or showing off have serious effects on driving performance.

3.5 Motivational and self-evaluative aspects

Knowing the relations between driving style on the one hand and personal tendencies, social pressure and lifestyle on the other hand, could enhance the trainees´ awareness of their higher risk in accident involvement. Feedback during training, self-assessment tools like questionnaires and scales, discussions with other youngsters about personal experiences and evaluations made by instructors or examiners seem to be appropriate educational methods.

It should be born in mind that every training of manoeuvring skills (and probably this is as well relevant for cognitive skills like e.g. hazard perception) may result in overconfidence of young drivers. Therefore, training safe driving strategies can only be successful, if driver training covers the whole range of contents, and consequently it should also include motivational and self-evaluative aspects.

Ideally, driver training curriculum should cover all these areas of the framework and address the appropriate driving behaviour associated. However, one of the conclusions from the GAGDET-project was that, traditional driver training typically only covers the first two levels of behaviour (vehicle manoeuvring and mastery of traffic situations). Similarly, at the goals dimension level only the first level of knowledge and skills is included and to a lesser extent risk increasing factors is covered in existing training schemes. The third level is rarely encountered during driver training. (Hattaka, 1999).

4 THE USE OF SIMULATORS AND E-LEARNING TOOLS IN DRIVER TRAINING

Following the ideas of the previous sections two dimensions seems of particularly relevance when conducting discussions of driver training in the context of driving simulators and e-learning.

Firstly, from the conclusions drawn from previous works on driver training it is obvious that existing driving training schemes do not encompass all aspects of the driving task and the context in which it is embedded. From the perspective of the GDE-framework an extension of the curricula would be suggested.

However, on a second level with the introduction of new learning tools and training technologies it is important to consider how the different levels and dimensions of the GDE framework is most appropriately incorporated. This requires that when considering elaborations of existing training schemes in relation to simulators and e-learning, it should not only be regarded as an extension or improvement of current curriculum but also as a possibility to reconsider the pedagogical tools and didactical approaches of the applications. It could be argued that the advent of new instructional tools makes it possible to consider the usefulness of the traditional distinction between abstract and practical learning which are presently employed. Similarly, it needs to be considered that the range of new technologies varies substantially in format offering a variety of different approaches to the training process giving opportunities to consider which tools are most relevant and cost-efficient according to the learning tasks and processes involved.

However, a distinction is often made between e-learning (and multimedia) and driving simulators as distinctive entities. It is likely that this stems from the traditional division between theoretical learning or curriculum based training (the abstract understanding of the traffic systems and the rules which applies) and the practical application of these into real world driving (vehicle control, navigation and interaction with the traffic environment).

From a training perspective one of the important questions is how transfer of training occurs between the theoretical training into real world driving. Though this distinction is analytically useful it easily blurs the potential possibilities of fusion between the use of e-learning of the abstract and practical aspects of driver training and the use of simulators for the acquisition of practical driving competences. E.g. it is technically possible to combine the abstract (e-learning) and practical aspects (simulator) of training within the same sessions, eg. as.virtual learning environment.

This report will however operate with the analytical distinction between e-learning and driving simulators in order to of give the reader a thorough overview of the two training technologies and the considerations which needs to be taken into account when applying them into the different spheres of driver training.

4.1 Driving simulators

Ever since the development of the first driving simulator, driving simulators have been considered as training devices. The advantages of using simulators in driver training are numerous: lack of risk, reproducibility of the situations, control of the parameters, time savings, cost reductions, etc.

The Directive 2003/59/EC of the European Parliament and of the Council of 15 July 2003 on the initial qualification and periodic training of drivers of certain road vehicles for the carriage of goods or passengers prescribes the following conditions for the use of simulators in driver training:

- *Each driver may drive for a maximum of eight hours of the 20 hours of individual driving on special terrain or on a top-of-the-range simulator so as to assess training in rational driving based on safety regulations, in particular with regard to vehicle handling in different road conditions and the way they change with different atmospheric conditions and the time of day or night.*

- *The practical test may be supplemented by a third test taking place on special terrain or on a top-of-the-range simulator so as to assess training in rational driving based on safety regulations, in particular with regard to vehicle handling in different road conditions and the way they change with different atmospheric conditions and the time of day or night.*

- *When driving individually, an instructor, employed by an approved training centre, must accompany the trainee driver. Each driver may drive for a maximum of four hours of the 10 hours of individual driving on special terrain or on a top-of-the-range simulator so as to assess training in rational driving based on safety regulations, in particular with regard to vehicle handling in different road conditions and the way they change with different atmospheric conditions and the time of day or night.*

- *Compulsory periodic training courses must be organised by an approved training centre. Their duration must be of 35 hours every five years, given in periods of at least seven hours. Such periodic training may be provided, in part, on top-of-the-range simulators.*

Unfortunately, the safety performance of drivers trained in this way compared to that of traditionally trained drivers has not been assessed yet. What is known, though, is that the passing rate for the driving test of this short but intensive training programme with the use of modern technology (multimedia training, simulator training) is slightly above average. It would be very revealing to determine whether there is a difference in crash rate in the period just after having passed the driving test, between traditionally trained novice drivers and drivers that have attended this new training programme with the aid of driver simulators.

4.2 E-learning

E-learning or multimedia[1] learning can be defined as the combination of text, graphics, animations, pictures, video or sound to present information (Najjar, 1995). Since these media can readily be integrated by means of computers, e-learning is becoming a more and more widespread tool for training and education within many spheres of society. It has been stated that the future of e-learning is not whether it should be deployed or not but rather how, when and to what end (Littig, 2003). In accordance with this the European Commission has commissioned several projects on e-learning within the Leonardo da Vinci project (Littig et al, 2003).

Within the domain of driver training e-learning denotes all kinds of techniques using electronic means or multimedia to enhance traffic safety through improvement of drivers' skills and knowledge. E-learning techniques can employ strategies, which range from theoretical knowledge of traffic rules and regulation to training of certain skills or techniques or improvements in awareness of special subjects. Finally e-learning might be integrated as tools for influencing the attitudes of drivers and as tools for self-assessment.

As such e-learning applications can be considered as a cost effective training tool to use, both for development and running, for any purpose such as increase specific knowledge, raise awareness or simply illustrate certain traffic situations thus making it an attractive product for commercial developers of driver training. E-learning applications can be used in conjunction to other training courses or as activities in simulator courses.

In relation to the GDE-framework, the TRAINER project found that the content of the training through e-learning are primarily aimed at the control and manoeuvring tasks, and do not address the strategic level of driver training to an extent desirable and thus utilising one of the potential benefits of the interactive multimedia [Hoeschen et al, 2001]. Recently e-learning applications have also attempted to address the higher order skills like hazard perception, situational awareness and self assessment. and it is likely that a substantial amount of applications already exists on topics related to driver training or safety e.g. defensive driving, hazard perception or driving fuel efficiently. However no comprehensive overview of the extent of usage is available.

4.3 Target groups for driver training

When discussing issues of driver training it is beneficial to distinguish between the target groups e.g. training of novice drivers from retraining of professional drivers or experienced drivers. Though an overlap occurs between the different groups, as they have to abide the same rules and regulations, training typically rest on different

[1] In this paper e-learning and multimedia will be used inter-changeably. Though it could be stipulated that e-learning denotes the use of electronic means whereas multimedia denotes the use of several media. For instance this would mean that e-learning occurs when a book text is presented through a computer screen (the text is simply presented in a different media. However in order to qualify as multimedia the text would have to be supplemented by other media (e.g. graphics or videos etc.).

approaches to the driver. The novice driver needs to acquire both theoretical and practical skills and knowledge at all levels of the GDE-framework, whereas training of experienced or professional drivers typically is directed at more specific areas of the driving task. Similarly, training groups of elderly or disabled drivers would implement different approaches such as the obtainment of functional awareness of their abilities and limitations and to adapt their driving behaviour accordingly without being exposed to the risks of real traffic.

4.3.1 Novice drivers training

In many European countries, driving simulators are being used for initial driver training. Novice drivers need to learn basic skills, like vehicle operation, steering, manoeuvring and interaction with other traffic. These skills may be learnt in a virtual environment in which the complexity of real driving environment can be simplified. The current generation of low-cost driving simulators can offer such an environment, with traffic in a detailed road environment, providing virtual instruction and feedback on errors. These simulators focus on the didactical aspects of the simulator, and are integrated with the normal driver training. Nevertheless, without motion or with limited motion base it is difficult to train the control tasks (breaking, lateral guidance...), although its is possible to train “psycho-motricity” (e.g. to change gear without turning the steering wheel).

For example, ANWB, one of the largest driver training schools in the Netherlands, has integrated simulator training and multi media training in their entire basic driver-training programme. At first the driver simulator with a projected environment (with the aid of beamers) and a mock-up of a real car (but without a moving base) is used for an assessment of the learning capabilities of the applicant driver. This is a special test scenario. If these capabilities are rated as good, the applicant driver is offered a training programme of 10 days. During working days (8 days) the learner driver trains the whole day long [Vlakveld, 2005].

The training programme is structured in modules. The degree of complexity increases after each module, and for each module, training objectives are stated. Each module starts with multi media based training. The intention of this training is to show the learner driver (on film or animation) the skills that he has to acquire in the module, and to let him comprehend why the skills are executed that way. After this multi media session on a PC, the simulator training starts. A driver instructor is not directly involved during the simulator training, but an operator/instructor that operates more simulators simultaneously, might provide some additional instruction or feedback. As soon as the learner driver is behind the wheel of the simulator, a voice on tape tells him/her what to do. This 'virtual' driving instructor also automatically provides feedback during the training. The aim of the simulator training is to train the core of the skills in a reduced environment. What is not essential to the skill training is left out. Directly after the simulator training of about 20 minutes, the learner driver starts to drive with a driving instructor in real traffic (for about one hour). The aim is only to improve those skills of which the core was learned during the simulator lesson just before. After this driving lesson in real traffic, the learner driver has to observe another learner driver (from the rear seat) that is doing the same driving lesson he/she has just had. The intention is to learn from each other's mistakes. After this, the cycle (multi media training, simulator training, driver training in real traffic, observation of one's other driver training) starts all over again with the next module.

The majority of e-learning applications in both the TRAINER and HUMANIST surveys were targeting novice drivers. Most of the applications in the HUMANIST-survey were only developed and used as supplement to existing training courses. For the majority of applications the purpose was to give the driver additional possibilities of learning existing curriculum and were based on existing training programmes (though not interactive programs). The applications had an emphasis on training the trainee in traffic rules and regulations. Some of the applications stated to include a test section, which were based on the existing curriculum and developed as supplement e.g. through focus on traffic situations at intersections.

From the TRAINER survey it was found that only five out of sixteen multimedia tools provided content on both the control, manoeuvring and strategic level of driving, whereas the rest covered various aspects of the three levels but not comprehensively. In general however it was found that these three levels were covered unevenly with a emphasis on the manoeuvring level: Particularly circumstances (e.g. night driving, having an accident, driving in narrow streets), non-moving traffic (parking, towing), observing traffic (when starting, stopping overtaking), keeping safe distances, driving at appropriate speeds. In contrast risks related to specific driver groups, human characteristics or personal conditions were only were only sparsely covered, reflecting that most of the applications primarily covered the manoeuvring level whereas the strategic level was only explored to a lesser degree.

4.3.2 Professional drivers training

These groups of drivers typically have several years of experience. However the application or motivations of driver training for these driver groups typically differ quite substantially. Experienced driver undergoing post-license training typically have had a conviction of serious traffic offence (e.g. driving under influence of alcohol) or the offence might have led to a temporarily loss of driver license. In countries like France and the Netherlands, a retraining program is mandatory.

Professional drivers typically undergo training in handling difficult driving manoeuvres, driving special vehicles or goods. Disabled drivers are typically trained for the purposes of identifying functional weaknesses thus not for the purposes of training per se but rather to identify which conditions of driving they would encounter difficulties with.

The Gadget project did not cover professional drivers, experienced drivers or disabled drivers. However as most of the hierarchical levels of the Gadget matrix, especially level three and four should be included as part of the general mastering of the driver task it would be reasonable to propose that these skills also applies for these groups.

Simulators have been developed both for research and training for road vehicle 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 video of real scenes and more recently, computer generated environments. A report of the Federal Highway Administration [FHWA, 1999] detailed a scoping study on commercial motor vehicle driving simulator technology. The intervening period since the FHWA study has seen continued technological development in simulators, particularly in visual database rendering, but very patchy uptake and development of simulation facilities for commercial truck driver training.

From a world-wide perspective a clear lead has been taken by France and the Netherlands [Grognet, 2004], but even in those countries there is neither the capacity to introduce simulation components to all drivers undergoing current training, nor to satisfy any potential increase in demand.

There appear to be four fundamental reasons for the relatively slow adoption of simulation as a key component of professional truck driver training:

- A lack of documented evidence showing a clear benefit of simulation training over traditional on-road and test track methods.

- A concern over the economics of providing high technology facilities and the attendant high costs of entry to the area.

- A concern from the drivers that such training will be additional to, rather than replace parts of, the current requirements.

- Some people get ill in simulators.

There has been a general assumption that simulators (or more correctly, *synthetic or part-task trainers*) will probably eventually become widespread as computer costs come down and power increases, but the freight industry and the driver training industry is so fragmented in Europe, there is little to encourage early adopters of the technology.

The picture, in Europe at least, may soon change. The European Commission Directive on Training for Professional Drivers (EU Commission 2001, and adopted by European Parliament in April 2003) stipulates that all persons wishing to drive Large Goods Vehicles (LGV) in excess of 7.5 tonnes in a professional capacity, will have to undergo training for, and obtain, a vocational Certificate of Professional Competence (CPC) further to the LGV licence. The directive provides a framework for licence acquisition, testing and further skills development.

The total length of *full basic training* in the proposal is 420 hours (12 weeks of 35 hours each). For *minimum basic training* this will be 280 hours. Each trainee driver must drive for at least 20 hours individually in a vehicle of the category concerned.

Each driver may drive for a maximum of eight hours of the 20 hours of individual training:

"…on special terrain or on top-of-the-range simulators so as to assess training in rational driving based on safety regulations, in particular with regard to vehicle

handling in different road conditions and the way they change with different atmospheric conditions and the time of day or night." (European Parliament 2003, p24).

According to the Directive, basic vocational training is divided into three areas:

- Advanced training in rational driving based on safety rules
- Compliance with regulations
- Health, safety, service and logistics

In addition there are other areas of direct relevance to possible simulator training. These relate to:

- Road traffic regulations
- Ergonomic principles
- Behaviour in an emergency situation:

This shows where simulation, and synthetic training in general, could provide a valuable role, but it does not *prescribe* exactly which elements may be suitable, nor *proscribe* those that are unsuitable [Parkes, 2005].

The introduction of compulsory basic, and continuous training, will require a large increase in capacity in the training industry. As the industry expands there is a general expectation that simulation will become more common, and could eventually be a core component of the curricula. However, it could be a mistake to assume that simply because simulators are widespread, successful, and necessary in aviation or military ground vehicle applications, that they will be similarly well accepted and suitable for truck driver training.

The possible benefits of simulation are clear. There is potential for: control of the training environment, repeatability of specific combinations of features, objective performance scoring, cost reduction and consistent on-line tutorial delivery. The training environment can be prepared to focus the exercises in especific situations due to the ability to remove unessential elements from any particular scenario; and safer, due to the lack of physical risk, no matter how catastrophic the performance failure. On the other hands there are also limits to what training in a driving simulator can achieve, an there is a need of scientifically proved assessement of its benefits, and of the retention of the skills that are acquired through it.

A smaller amount of the e-learning applications were targeted at professional drivers compared to the number of applications targeting novice drivers. However, most of these used existing driving curriculum as the basis for the content. Similarly, it was found that the applications were operating on the control and manoeuvring level, though a few of the applications also targeted hazard detection strategies.

4.3.3 Older and disabled people training

In addition to the application of ITS to train novice and professional drivers, other field that is being explored is the training of elderly and disabled people. 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. A problem that requires further investigation is the causes of simulator induced sickness, which can affect users of all ages, but to a larger extent to older persons.

In 50 years time, the number of citizens 65+ will increase by 100%, to represent 30% of the total population in 2050. Within the 65+ cohort, the prevalence and the incidence of disabilities are larger than for any other cohort [Falkmer, 2005].

Re-training of disabled older drivers requires the development of specific scenarios based on their particular needs. A first attempt in this direction, based on the GDE matrix, was conducted within the AGILE project [Wildroither et al, 2003].

Facing approximately 10-20% of the entire future driving population being disabled requires assessments of their fitness to drive, prior to any training or re-training. Driving assessment is, however, a complicated issue. In order to do it scientifically sound, we need to know what driving really is, i.e. we need a commonly accepted normative model of driving. Despite the fact that driving has been an everyday activity for almost 100 years for many people, there is, however, no such general model. Not even the driving test itself is a valid and reliable predictor of who will drive safely and who will not. Different driving assessment screening tools are tested and used in several clinics on a regular basis. None of them has a sensitivity and specificity of 100%, respectively. This means that in a driving assessment situation, we will face the trade off problem of either reducing capable but wrongly categorized safe drivers' mobility or reducing the traffic safety for all road users by wrongly categorize unsafe drivers as safe.

5 EMBEDDING SIMULATORS IN THE TRAINING CURRICULUM

5.1 Driving simulators

Driving simulators only become an effective tool in drivers training if they are effectively embedded as an integral part of the training curriculum. A student should progress logically through the training. For this purpose, books, computer based training, simulator and driving in the real world should be integrated. Such integration requires methodical approach, and detailed analysis of the training curriculum, the learning goals and training needs analysis. Ideally, it is performed prior to the acquisition of a simulator system.

A simulator is an abstraction of reality, and many aspects cannot be reproduced with sufficient detail or realism. For instance, things like having eye contact with drivers or pedestrians, and other subtle cues that allow the inference of their intentions are impossible to simulate. The human instructor will focus on tuning the acquired skills, and on the subtler, higher order, cognitive aspects of the driving task. Even for the tasks that are trained by the virtual instructor.

A virtual driving instructor allows an instructor to teach multiple students at the same time, and it allows the instructional process to be standardised. However, automated driving instruction is a complex process, requiring an extensive analysis on the selection, timing and form of instruction and feedback. It also requires insight in the state and the mental processes of a student. Human instructors are able to evaluate such processes while virtual driving instructors are currently not.

The current set of driving simulator lessons is linear: all students go through an identical training curriculum. This ensures that all students have had an explanation of the same basic procedures. This suits well in a highly structured driving course, but it does not fit well to courses that are more flexible. Methods to generate tailor-made simulator lessons are required for this purpose. In theory, an adaptive curriculum would allow each student to be trained at his or her optimal learning curve [Kappe et al, 2005].

5.2 E-learning applications

E-learning basically has the potential to move the learning process from the classroom or traditional written curricula into the learners' world, providing access to learning anytime or anywhere without geographical or time barriers. In addition it is technically possible, e.g. through the internet, to provide immediate access to learning materials and interaction with experts or/and fellow learners. Finally the advancement of computers' capacities makes it possible to illustrate real life driving situations and animated scenarios thus making the experience quite realistic.

This gives e-learning the potential to become a useful tool to develop the learning processes, but essentially it has to be borne in mind that the learning outcome to a large degree will depend on the technical and pedagogical approach to the whole learning process in driver training.

It has been suggested that e-learning compared to traditional class room teaching or instructions from text-books, offers several learning advantages on several levels of the learning process (Najjar, 1995):

- Instructional methods: Multimedia instruction may force the instructional designer to organise and structure the learning material compared to traditional class room teachings. This is particularly the case when using complex and large amounts of learning material and when a large degree of freedom in information gathering is possible for the learner.

- Interactivity: Can be thought of as mutual action between the learner, the learning system and the learning material. Compared to traditional learning forms multimedia offers a high degree of interactivity due to the integration of written and illustrated contents. There is a tendency for e-learning material to be more interactive than traditional textbooks and classroom teachings.

- Control of learning pace: Multimedia to a large extend allows the learner to set the pace of learning thus offering the possibility of adjustment of content to individual needs and preferences.

- Novelty: Information presented though various sources (audio-visual and illustrative examples) may be more stimulating than material presented through traditional means. It has been suggested that initial positive findings from multimedia learning compared to traditional classroom learning stems from the fact that multimedia was a novel experience.

- Individual design: it is possible to adopt instruction and feedback to the learning style and capabilities of the trainee

Though the above mentioned aspects of learning processes advocate strongly for the use of multimedia as learning tools in general and within driver training in particularly, it has to be emphasised that these are aspects of the learning process, which can be better utilised in multimedia environment than in traditional learning environments. It does not imply that multimedia per se has a superior effect over traditional teaching methods. As such it has not been consistently proved that use of several media in instructions (redundant information) is superior to one media instruction (monomedia information) though research evaluations of multimedia instructions suggest that if utilised efficiently and appropriately certain advantages will persist. Similarly, it can be stipulated that it is doubtful whether use of traditional instructions methods or content in a multimedia setting has any superior effect in itself. Thus in essence it might be stated that the use of multimedia in driver training should include a thorough understanding of the subject of driver and training in relation to the task of driving.

5.3 Scenarios

Driving simulation can be considered as a form of Scenario Based Training (SBT). An SBT is focused on controlled and systematically constructed scenarios that have been specifically created for training a certain (sub)task. It focuses, more than other forms of training, on the development of practice, diagnosis and feedback. It links training activities to learning goals.

Based on a task analysis, learning goals are derived. From these learning goals, training activities are derived that are modelled in scenarios. These scenarios are presented to the student in the simulator. For each scenario (and the underlying training activities and learning goals) performance measures are defined. After completion of the scenario, the performance of the student is graded relative to a set of standards. In the diagnostic process, it is determined why the student performed as was observed. Why did an error occur? Were the rules not known, was the sign not observed, or was the approaching vehicle not noticed. A good diagnosis is required to give proper feedback. It is of no use to focus on rules, when the student did not see a vehicle approaching because of an improper scanning strategy

Creating traffic scenarios is not trivial. The traffic model should allow a predetermined traffic situation to occur each and every time, on many types of roads, intersections, roundabouts etc. Tutoring requires real time performance recording and evaluation, as well as prioritising and scheduling of instruction and feedback.

The 5th Framework Programme Research project TRAINER developed a new driver training methodology, based on simulator technology, which paid significant attention not only to gain experience of driving and handling the vehicle, but also to the enhancement of risk awareness of learners drivers [Dols et al, 2001].

A number of scenarios for application in simulators were developed. The scenarios addressed the most important needs of learner drivers, based on accident statistics and an extensive literature review. They were structured in accordance with the four hierarchical levels of the GDE-matrix. The results from the project show that it is possible to improve driving behaviour by including simulator training in the driver education. TRAINER intended to develop a new, improved training curriculum for driver trainees, using modern training tools and innovative educational scenarios, which intend to enhance risk awareness and permit a safe use of on-board driver assistance systems]. The focus was put on driving and handling the vehicle itself, but also on the improvement of risk awareness of drivers. For this purpose simulation tools were developed and a number of scenarios for application in the simulators were implemented [Hanzlikova, 2005].

It is technically possible to create any scenario in a multimedia context provided sufficient media are utilised. However in contrast to driving simulation multimedia scenarios are not able to recreate the same level of dynamic interaction between the driver and traffic environment. As such it has been suggested that e-learning is primarily suitable for creating the platform for initial training and understanding of certain (sub)tasks embedded in the driving task and traffic system (Hoeschen et al., 2001). Similarly, it is possible to exploit that e-learning can take different forms according to the media used, the target group and driving task at hand thus giving a range of opportunities to tailor the training content to the drivers' need at a more flexible range than is the case with traditional learning tools.

In the TRAINER and HUMANIST survey most of the applications were only developed and used as supplement to existing training courses. For the majority of applications the purpose was to give the driver additional possibilities of learning existing curriculum and were based on existing training programmes (though not interactive programs).

Some of the applications stated to include a test section, which were based on the existing curriculum and developed as supplement e.g. through focus on traffic situations at intersections. From the TRAINER survey it was found that only 1/3 (five out of sixteen) multimedia tools provided content on both the control, manoeuvring and strategic level of driving, whereas the rest covered various aspects of the three levels but not comprehensively.

5.4 Performance measurement

Simulators allow multiple performance measures to be registered, and an overwhelming amount of information can be generated. The problem is not in *how* to measure, but *when* to measure *what*. In SBT, performance measures are supposed to have a direct relation with the scenario and the learning goals. They should allow the diagnosis of the underlying mental processes of the student that lead to the observed behaviour

Performance measures can be classified taking into account different aspects of the driving task.

5.4.1 Operational level

Performance measures of control tasks relate to steering and speed control, and to vehicle operation. Standard deviation (SD) of lateral position, SD lateral speed, Time to Line Crossing (TLC), number of lane boundary violations, and SD steering angle are typical measures for steering control. Average speed, minimum and maximum speed and number of speed violations are common for speed control.

Errors in vehicle control can be categorized as either sequence errors or operational errors. Sequence errors occur when a subtask is performed too early or too late in a sequence of events. When starting the vehicle, several checks have to be made in a fixed order before the key can be turned. Depending on the driving course, some students are only allowed to start the vehicle after they have checked (and corrected if necessary) if the hand brake is on, the gear is in neutral, and the lights turned off. Such action sequences occur in many basic vehicle operation tasks, like changing gears, braking in 2nd gear, strong braking in 3rd gear etc. An operational error occurs when actions are performed in the right sequence, but are incorrectly performed. This occurs for instance when the clutch pedal is not completely released after changing gears, or when the actions are not performed fluidly.

5.4.2 Tactical level

At the tactical level performance measures are related to the road environment and to other traffic participants. At this level, performance measures can be based on traffic rules. Which rules are valid, depends on the road infrastructure (layout, delineation, signs and signals) and on the type of participants that take part in the traffic scenario (pedestrian, motorcycle, car etc.). Apart from rules, interaction with traffic participants is important at the tactical level. It has been found that time plays an important role in interaction processes. Time related measures, like time headway, Time To Contact, Time To Intersection and the Post Encroachment time have been found to be relevant in traffic.

Scanning is an important aspect of driving, and instructor may spend much time drilling the student to perform the correct strategies. In a simulator, registering the viewing direction is not simple, but there are several systems available in the market. The problem however, is in the interpretation of the data. The human eye roams through the visual environment, and is guided intentionally and unintentionally towards visual landmarks. It is difficult to make sense from the eye movements of an observer, especially in relation to the surrounding traffic. In real life, the instructor can not see the exact viewing direction of his student. Instead he relies on observations of the orientation of the head (yaw angle). Students are told not to look from the corner of their eyes, but turn their heads instead. In some driving courses, the scanning behaviour is quite well described. For instance, when approaching an intersection, students have to check the rear view mirror, look ahead, to the left, ahead, to the right and ahead again. Such a sequence is subject to sequence errors and operational errors. This sequence should also be initiated from a certain Time To Intersection (TTI).

Workload measures indicate the mental effort that is involved with performing a task. In training, they can be a valuable addition to the performance measures mentioned above. There can be large differences in workload, even when two students are performing equally well. A student with a high workload may still be in the cognitive phase, whereas a student with a lower workload may be in the associative or automated phase.

Workload measures come in many varieties [De Waard, 1996]. They can be divided in self-reported workload measures (e.g. Subjective Workload Assessment Technique (SWAT)), Physiological measures (e.g. Heart Rate Variability (HRV)) and double tasks. One double task that has been used successfully in a driving simulator is the Peripheral Detection Task (PDT). In the PDT, a small sign is presented in the student's peripheral field of view. If it is observed, the student 'has to react by pressing a switch. Relevant measures are the average reaction time, and the percentage missed presentations both relative to a baseline. When the workload is high, both reaction time and percentage missed will increase. The PDT has been shown to be a reliable indicator of workload while driving a car [Van Winsum, Martens & Herland, 1999]. The underlying assumption is that with high workloads, students tend have a reduced functional field of view, and only respond to stimuli directly ahead of them. Most driving instructors are familiar with the 'tunnel vision' of students during periods of high workload.

After completing the simulator lesson, a report can be generated by the system. In the report, an overview is given of the student's performance. This provides input for the debriefing by the supervising simulator instructor, and it serves as input for the human instructor for the driving lessons on the road.

5.4.3 Performance measurement and e-elearning

It should be borne in mind that e-learning is not supposed to replace the actual or virtual driving performance, as conducted in real world driving or in simulators. It is therefore difficult to measure the driving performance per se. Instead e-learning should be considered a tool to facilitate that appropriate driving occurs. In that sense it is not e-elearning per se that is in focus but actually to what extent e-learning can facilitate a *positive transfer* from the e-learning process to the application of these skills into practical driving.

As a tool for abstract or illustrative learning of rules and traffic concepts, e-learning holds unlimited possibilities. Practically anything can be illustrated from simple illustrations to dynamic scenarios e.g. through the combined use of text, audio or video sequences. In essence this should provide amble possibilities for learning aspects or principles of driving at all levels at the GDE-matrix. Similarly, within the domain of abstract learning of concepts, rules or traffic situations, multimedia hold promises for extensive feed-back mechanisms. E.g. in traditional choice test it is of course possible to only give correct/wrong scores but due to its interactive possibilities it will also possible to illustrate or animate outcomes of choices or answers.

Measuring of performance in e-learning can take different approaches. When using computers or multimedia in assessment of performance it is only possible to register the interaction between the learner and media of registration. As such thorough understanding of the learner's comprehension of the instructional content is still only possible to register according to the limitations or possibilities in the multimedia.

Thus multimedia holds many promises for enriching the theoretical and abstract aspects of the driver training. It has however not been evaluated whether advantages are to be gained by using multimedia learning environments in driver training. Similarly it remains an open question whether the knowledge obtained trough multimedia actually transfers into driving performance.

From the TRAINER survey it was found that most multimedia applications measured performance from the trainee in relation to giving the right answer or showing the right choice on different scenarios. It was found that aspects covering hazard detection was often used but not sufficiently related to the tasks the trainee had to carry out, thus leaving the trainee in a rather passive role. Similarly, it was found that even fewer scenarios actually illustrated the consequences of a given action the trainee had chosen. This was emphasised as a potential way of strengthening the applications as this could be an improvement towards risk awareness and hazard detection (Hoeschen et al., 2001).

In the TRAINER-project a multimedia training tool was developed on the premises of the TRAINER concept. In this training tool scenarios were grouped into blocks dealing with specific themes. The performance was typically measured as multiple choice scenarios with a corresponding right or wrong answer. The scenarios were weighted according to importance in relation to the driving task in order to obtain a mean weight for each scenario. This gave the opportunity to integrate or supplement the multimedia theme with corresponding theoretical lessons. Feed-back was given immediately after each block or scenario with a possibility to repeat immediately.

5.5 Training of higher order skills

Work by Groeger [2000] and Christie and Harrison [2003] cast some doubts on the usefulness of driver simulators for the acquisition of higher order skills. According to Groeger, simulators make it possible to structure driver training much more, and make it also possible to introduce mass repetition of skills. From laboratory experiments it is known that splitting up tasks into part tasks and mass repetition of part tasks, helps to speed up the learning process; but retention is worse. This is in particular the case when subjects themselves have to conclude from the context what skills have to be applied. Because of this, Groeger thinks that associative learning during many hours behind the wheel (with an experienced driver next to the learner driver) in varied conditions, is better for the acquisition of higher order skills than structured simulator training in a reduced environment.

Associative learning in real life takes more time, but retention is much better. Along more or less the same lines, Christie and Harrison argue that situation awareness is the product of experience rather than education. To speed up the learning process, the context can be arranged (first driving on simple roads with no traffic, and gradually building op the complexity of the context) but it is not useful to split up the tasks and train them separately.

One of the aims of the TRAINER project was to develop guidelines for the use of simulators in driver training. In Sweden these guidelines were used to develop a training module for the improvement of hazard perception skills. Both computer aided instruction and simulator trainings were developed.

Falkmer and Gregersen (2003) have tested how successful the hazard perception training with multi media training on a PC and simulator training was. As training simulators, a so-called Low Cost Simulator (LCS) and a so-called Mean Cost Simulator (MCS) were used. A LCS consists of a driver chair, pedals, a gear lever, a steering wheel, a dashboard, only one monitor (40 degrees field of view) right in front of the driver, and a sound generator. It has no moving base but pedals and a steering wheel counterpoise. A MCS has the same configuration but with 3 monitors (a field of view of about 120 degrees). All the subjects were learner drivers from a driving school. They had professional driver training (on the road) but had not done the driving test yet. The subjects were divided into three groups. The first group first did the multi media training on a PC, and after that received the simulator training on a MCS. The second group also first did the multi media training on a PC, but received the simulator training on a LCS. The third group (the control group) neither did the multi media training nor received simulator training.

To test the acquired training skills, the full mission VTI research simulator with a moving base was used. In this simulator six scenarios were offered. In the first scenario the subject drove in an urban environment. At a junction, a bus approaches from a right hand side road. According to the rules of the road, the bus should have stopped but it did not. This situation demands early detection and immediate reaction in order to avoid a collision. In the second scenario the subject drove on a rural road with forest all around. A moose suddenly crossed the road and, after some seconds, two calves followed. In this condition situation awareness is required for early detection. The third scenario, when driving on a rural road, the subjects receive an SMS on their mobile phone. Directly after the phone signal, the subject passed a traffic sign with a lower speed limit (it was 90 km/h and the sign was 50 km/h). Is the subject distracted by the phone signal or does he/she recognize the change in speed limit in time (by reducing speed)? Scenario four is one long scenario divided into three parts. In the first part, fog gradually reduces the visibility to 100 metres. Does the subject notice gradual decrease in visibility in time and does he/she adjusts his/her speed? The fog disappeared and then the driver entered a second fog bank. In that fog bank a van appeared that is driving in the same direction. If the subject is driving too fast, a rear-end collision will occur. And finally, while driving behind the van, the fog disappears, but then the van starts to accelerate.

There were no significant differences between the three groups with regard to the bus-, moose- and car following scenarios. With regard to the SMS scenario the subjects that were trained in the MCS did significantly better than the control group (group 3) and the group that was trained in the LCS. With regard to the two fog scenarios, the MCS trained group performed significantly better than the control group with regard to timely speed adjustment. Keeping distance to the van in the second fog scenario, the MCS trained group did significantly better than the LCS trained group, but not better than the control group. The results showed that there were some improvements in hazard perception, but not in all scenarios. They also showed that for at least hazard perception training, a LCS offers too few opportunities. This experiment does not answer the question whether higher order skills can effectively be trained on a driver simulator or not. Much more research is required. However, it does indicate that one should be a bit cautious when estimating the potential of driver simulators for the acquisition of higher order skills.

One of the conclusions from the TRAINER project was that training of higher order skills included in the GDE-matrix would imply that present driver training should extend the theoretical and practical training curriculum to areas including confrontation with difficult/risky situations or situations were the drivers' attitudes (motivations, representations and emotions) are challenged.

However, the sequencing for the adaptation of higher order skills is important and it is stated that these should be implemented after the acquisition of skills on the skill-and- knowledge based levels. This in essences underlines that higher order skills are primarily integrated through experience and not solely from the education or training.

In this respect it is stated that e-learning applications should be considered a supplement to the practical driver training following the path of theoretical understanding of higher order skills into corresponding multimedia-based training sessions followed by practical driving lessons were the acquired skills can be put into practise (Pirenne et al., 2002, D5.1).

As mentioned in the previous sections most e-learning applications studies in the TRAINER and the HUMANIST surveys did not cover aspects of higher order skills. Most of the applications were focusing on the manoeuvring level of driver training, whereas the higher order skills were only encountered sporadically in the applications.

6 FUNCTIONAL REQUIREMENTS OF SIMULATORS

A simulator is always an imitation of reality that is not perfect. It is questioned if there will be *transfer* of what is learned in a simulator to the real world if the imitation of reality in the simulator is poor. The idea that it is necessary to copy reality as well as possible has put a lot of emphasis on the technical validity of driving simulators for training purposes. This has made driving simulators too expensive to be used for basic driver training in the past.

The present state of the technology seems to make it possible to implement different driver training applications with a growing level of complexity and fidelity to real driving conditions. Nevertheless, there is a lack of common technical specifications both at national level and at European level that define the minimum conditions that a simulator should have to be suitable for use in the different levels of driver training applications. A framework for these specifications needs to be defined [Pardillo et al, 2005].

6.1 Simulator components requirements

Driving simulators are built from five principal components: vehicle model, visuals, motion, traffic model and scenarios and instruction [Kappe, 2005]. Functional specifications need to cover the requirements of these components.

6.1.1 Vehicle model

Initially, driving simulators used relatively simple, special purpose vehicle models. Such models allowed steering behaviour of a car to be modelled in real time, given the limited computing power available

At present vehicle models use the same models, programming languages, and software tools that car engineers use in the design of their vehicles. This allows the handling characteristics and driving comfort of a vehicle to be evaluated very early in the design phase.

6.1.2 Visual model

Visual perception is a key element for driving as 80% of the information is acquired by visual perception. Therefore presenting visual information is an important issue in driving simulators. The first driving simulators used a camera monitor system hovering over a conveyor belt. This allowed rich, textured visual environments to be presented in the simulator, be it at a relatively low (video) resolution. The first CGI's were a setback in terms of image quality. They were very expensive, had no texturing or shading and with a relatively low resolution and update rate. With the emergence of PC-based computer graphics it is now possible to present complex virtual environments at resolutions of 1024 x 768 pixels or more per channel and update-rates in excess of 30 Hz. Multiple rendering PC's can be clustered and synchronised to present a wide, multi channel view of the virtual environment.

Even though computer graphics have shown a remarkable progress, they only present a fraction of the visual information that is normally available to the driver. Apart from fundamental problems with distance and speed perception [Kemeny and Panerai, 2003], virtual environments generally lack many of the intricate cues drivers use when driving as resolution, luminance and colorimetry are lower than in real life.

The small pellets of gravel in a curve, that shiny icy patch on the bridge, or having eye contact with another person are examples of the many aspects that are not (yet) adequately represented. Virtual environments are generally built from ‘facades’, merely presenting a view of an environment, without representing the underlying physical, biological and/or cognitive properties. For instance, realistic, fully interactive cyclists and pedestrians are very difficult to model, and as of yet, no driving simulator is capable of simulating large numbers of them. It is very difficult to realistically model the physical, motion and/or decision making properties of the objects and participants you observe. And, even if we could model these aspects, we do not seem to know all the visual cues an experienced drivers may use when driving.

The graphic engine limits the display in simulator, by the rendering devices and by the underlying models. These limits concern on one hand the resolution, the luminosity, the colorimetric properties and the frequency of rendering and on the other hand the calculation in "real time" of the effects of light distribution, notably for the meteorological situations "not by clear time". The current devices allow a resolution of rendering about 10 cpd (cycle per degree), while the visual performance is about 30cpd. The dynamics of projectors luminosity is about 100 cd/m² while the one connected to the sun illumination is roughly 10 000 000 cd/m². This point induces a reduction of the contrasts. The spectrum of colours is not covered, thus the shown colours are not faithful. The frequency of restitution, even in 60hz, induces the jerky movement. Because of these numerous constraints, the visibility on simulator is very limited (we consider that a panel of speed limit is read, by clear time, in 80m on simulator, while it is it in approximately 200m in the reality). The overtaking on a bidirectional road in 2 ways is almost impossible to simulate because of the "weak" visibility [Spié et al, 2005].

The modelling and the real-time rendering of the static and dynamic lightings is an important problem. The "classic" methods based on the techniques of ray-tracing are not usable in real-time. Solutions exist for lights carried by the subject vehicle (with limits in the case where lights enlighten a enlightened place, enlightened motorway for instance), and for the simulation of the situations of fog with traffic. The question of the lights of the traffic vehicles

6.1.3 Motion

While visual perception is dominant in most driving tasks, vestibular perception plays an important role in vehicle control. Cars can move briskly, and experiment large accelerations as they increase or reduce speed or drive through curves. The current generation of hexapod motion platforms does not allow such large linear accelerations to be simulated accurately. To provide these cues to some extent, several driving simulators rely on large X, Y, X/Y or rotating motion platforms. Even with these large motion platforms, however, simulating realistic motion cues in driving simulators will remain a challenge for a while. This obviously poses a problem when driving simulators are used to evaluate driving characteristics of vehicles still under development. Even with a 100% correct vehicle model, vestibular cues cannot be correctly presented to the driver. This not only holds for driving in extreme conditions, but is a fundamental problem in everyday 90deg turns as well. We have found that experienced drivers tend to be especially sensitive to such flaws in driving simulators, resulting in high numbers of simulator sickness.

The simulation of a vehicle dynamics is complex due to the frequency of occurrence of the phases of acceleration and deceleration. An additional difficulty results from the contact of the tyre with the pavement and the resulting effects (inertias connected to the mass of the vehicle but also high frequencies connected to the characteristics of the road).

At present it is not possible to render with realism vehicle dynamics. The design of simulators thus leans on the use of tricks to produce the embedding and the carrying of compromise to guarantee a coherence of the produced sensations.

Mobile platforms are used in driving simulators. The Gough-Stewart platform with six degrees of freedom) is used to produce the illusion of acceleration using "tilt coordination" (tilt of the platform, thus the internal sensors are "deceived" and the driver interprets the gravity as acceleration in two directions) [Parker 85].

Two simple examples put in evidence the problems of rendering the accelerations:

1. The rendering of the braking. A braking up to the stop from a 100 kph speed requires approximately 100m (order of magnitude). The rendering on the scale of the braking would require a movement of the subject of 100m.

2. The urban situations. It is frequent in urban situation to carry out multiple changes of lane and\or, for example to carry on a change of way followed by a bend in 90°. The realisation of two linked changes of lane would require a movement about 7m in side, that of the linked the change of lane and the bend approximately 15° on 20m radius.

6.1.4 Traffic model

To be acceptable, computer generated traffic has to accurately reproduce driving behaviour at the control, the manoeuvring and the strategic level. This implies that each simulated car has its own vehicle model, perception and control model, and decision logic. There are many different traffic models currently in use. Some merely present a car moving over a track, with hardly any interaction. Others are fully interactive and scriptable, and can handle complex situations on multi-lane intersections and roundabouts. At close observation, however, flaws exist in these models: physical behaviour is not correct, vehicles are not steered the way a driver normally would, manoeuvres are initiated inappropriately, and decision making is not very ‘intelligent’. Such erratic behaviour is often observed in traffic situations that cannot be handled by obeying the rules of traffic, such as when four vehicles arrive at the same time at an intersection.

In training applications, an additional requirement emerges. When a particular traffic situation is being imposed (for example overtaking with a complex interaction with three or more vehicles), simulation has to combine vehicles with a correct behaviour, with others with speed and position constraints in order to create a conflicting situation. This combination of autonomous and controlled vehicles in traffic models is not yet solved.

6.1.5 Scenarios and instruction

The simulator based training scenarios and instruction program should provide:

- A valid environment to practice 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 for safety.

6.2 E-learning applications requirements

As noted in the previous sections one of the advantages of e-learning applications is the possibility to combine of text, graphics, animations, pictures, video or sound in the instruction or training. However, as it has been stated earlier multimedia is not supposed to replace the existing practical driving training thus the demands for realism do not necessarily need to be at the same level as for the simulators. In essence e-learning is primarily regarded as a theoretical prerequisite for the applications of driving skills and knowledge in real driving (Pirenne et al, 2002).

One of the conclusions of the TRAINER-project was that multimedia in particularly would be suitable for awareness of risk increasing factors at the manoeuvring level and to a lesser extent at the strategic level. Similarly, it was stated that for multimedia tools to be useful a good and simple user interface was required as well as use of realistic audio and images. The latter was in particularly relevant for groups of drivers who could not be expected to be familiar with the use of multimedia e.g. elderly drivers. When utilised according to these considerations it is one of the areas were use of multimedia in training have advantages compared to traditional teaching materials. Through these applications it is possible to tailor and design training content to different trainee groups. Similarly, it was stated that a main advantage of e-learning was the standardisation of content and feed-back. This is a major advantage if e-learning applications are to be employed within different countries.

6.3 Specific requirements for truck drivers training tools

There is little known in relation to truck driving, and little that is directly transferable from aviation, that can inform discussion of what should be delivered in a simulation training package, nor how the costs and benefits might compare to real road training. Information exists, but at present it is difficult to find [Parkes, 2003 and 2005].

So what *degree*, and *fidelity*, of simulation are necessary for effective training of truck drivers? For maximum *face validity* of a truck simulator it would be necessary to specify the highest *degree* and *fidelity* available within a particular budget. But if the training has to be cost-effective when compared to traditional real world training, budgets will be constrained and a compromise might be needed in the views of *top-of-the-range* facilities. At present there is little information available to enable perfect choices between expenditure on a particular motion system instead of on a particular visual system, or even sound and vibration system. Can we even say that motion is necessary for successful training?

There are some very "high fidelity" full-mission simulators in existence, and whilst demonstrating that current and prospective technology can provide a dynamic and involving driving experience, such levels of sophistication come at a financial cost which may be unrealistic for the mass training market. However, the prospective European Directive wording refers to *top-of-the-range*. Herein lies the difficulty. Not only may simulators that can be described as top-of-the-range, or high-end, possibly be over specified, and out of the range of prospective users; the use of such terms implies that only systems that achieve some kind of high face- and performance-validity can have merit and value in training. There is, as yet, no distinction between full mission and part-task simulators, nor acknowledgement that realism (isomorphism with real road training) may not be necessary or even desirable in all circumstances.

Similar arguments might surround the fidelity of visual databases. The simple view is that they need to be as realistic as possible. However, from a training perspective that may not be correct. Certainly in terms of resolution, field of view, brightness, contrast and refresh rates there seems value to having higher fidelity. However it might be argued that the content of the visual scene itself does not have to be high fidelity (if that means close to photo-realistic representation of a real scene). There may be value in taking unimportant elements out of a visual scene, allowing the driver to concentrate on elements salient to the training objective without distraction. Anyone involved in visual database development knows that there is a distinct law of diminishing returns to further expenditure beyond a certain point.

Williges et al [1973] proposed the notion of *essential realism*, relating not to what might be regarded as essential for improved face validity, but instead, essential to the particular training requirements under consideration. There are three important elements that should drive decisions on simulation provision within the training process:

- The efficiency and acceptability of the learning in the simulator
- The transfer of the learning to the real world
- The retention of skills or knowledge learned.

Lee [2004] posed a number of interesting questions about simulator development and concluded that the pursuit of higher levels of fidelity in simulation may not be adequate, or even desirable. The reasons being that increased fidelity can undermine scenario control, limit data collection, dilute training potential, and increase likelihood of causing simulator sickness. For example, if a simulation is able to provide a highly realistic and complex urban environment and a busy traffic situation; it may be a highly impressive demonstration if the state of the art of the simulation industry, but may force the driver to attend to elements peripheral to the current training objective. If the driver is supposed to focus on responding to a particular signal in the scene, a complex environment may present a number of competing signals and it would be difficult for the trainer to be certain which prompted the response by the driver. Taking extraneous noise from the scene (removing competing signals) would allow the particular behaviour or skill to be developed effectively and efficiently. The skill can then be later validated in a more complex and realistic environment, whether that is in a simulator on the real road.

Reports are emerging that point to cost-benefits of simulation training. Welles and Holdsworth [2000] reviewed features necessary to successful training in a range of commercial simulators and concluded that "…data to date, although sketchy, anecdotal or very preliminary, provides strong suggestion that driving simulators ….can reduce accidents, improve driver proficiency and safety awareness, and reduce fleet operations and maintenance costs". They refer to hazard perception training with a particular police force leading to reductions in intersection accidents of around 74%, and overall accident reduction of around 24% in a six-month period following training.

More recently Dolan, Rupp, Allen, Strayer and Drews [2003] presented evidence from a fuel management simulation study that tracked 40 drivers through a two-hour training programme, and later for a six-month follow up. Drivers were given specific training in the operational and tactical aspects of appropriate gear selection in a medium fidelity simulator. Results indicated an average 2.8% improvement, with over 7% being indicated for those drivers with a poor pre-training record.

Such reports are encouraging, but do not take us far toward a minimum specification for systems that can provide a similar transfer of training benefit. Moreover, it is difficult to assess if the improvements come only from the training program or from a set of measures taken by the company.

One of the important skills in database creation is optimisation for the run time environment to ensure that the scene can be processed efficiently. However, the starting point is usually taking realistic road layouts and scenes and making adjustments to levels of detail and so on to make them usable, rather than coming from the other direction of taking what is known about cognitive processing, perceptions of speed and distance and producing an environment that includes salient information that allows training principles to be demonstrated, but which may be far removed from conventional views of realistic road scenes.

Rizzo et al [2002] have demonstrated an interesting concept with a database road scene created specifically to host experiments with cognitively impaired participants and their judgments of speed and distance. The experiment involved a large number of braking manoeuvres in a short space of time; and if conducted in a computer road scene of 'traditional' aspect would have been highly likely to promote high levels of simulator sickness. However, the specially constructed road environment which used aspects of colour, tint, texture, and object obscuration coding to produce a driving environment which lacked face validity (apparent realism) but provided very high utility for the research team. Accurate data could be collected from a large number of participants with very minimal problems of simulator sickness.

Technological developments of simulators will continue as manufacturers seek to develop products for the marketplace and seek commercial advantage through performance improvement. However, improvements in computers and projectors, or motion systems, in themselves will not lead to a dramatic upswing in usage.

A focus on *essential realism* is needed, and the main area for this is in the look and feel of the road scene databases. Such road scenes and scenarios must be developed that support the ability of the driver to interpret salient information without overloading the visual system with unnecessary information. The road scene must be a comfortable place for training to take place.

6.4 Validation

6.4.1 Driving simulators

The question of the validity of the results acquired on a driving simulator is crucial for the use of simulators both in behavioural studies and in driver training [Espié, Gauriat and Duraz, 2005].

There are two approaches to validation of driving simulators:

1. Intrinsic validation: Because of the impossibility to render the totality of the dynamics, transfer functions are used. According to this approach the simulator is valid if, for example, the accelerations caused by a given action correspond to those experimented in the actual world.

2. Validation by objective. The question here is to verify the relevance of the tool for a particular usage (study of the driver's behaviour or training). The object of the study is the human and not the simulator, which is considered here only as a tool.

Behaviour studies and training can be considered separately. In behaviour studies, the main issue is the validity of the tasks carried out by the driver and their transferability towards the reference situation (the real situation). The simulator is considered as valid for a given situation if the driving task is "equivalent" to the one carried out in actual situation (at the tactical and operational levels as well as in terms of workload).

In driver training applications, the aim is to teach the trainee, or to train or retrain a driver. For this purposes only validation by objective is relevant as a simulator that imitates reality perfectly (high intrinsic validity) may even hamper the learning abilities. The simulator is considered as valid if the experiences are transferred in the actual driving.

Driving a simulator is quite far of driving an actual car due to numerous differences in the situations. It is not possible, for example, to reproduce the physics, notably in the visual and in the accelerations domains. Therefore, every simulator is a specific compromise dedicated to certain number of usages. It is not possible to talk about validation without mentioning the usage and the population of drivers. A simulator professional can learn, during an adaptation phase, which is often long, how to transpose from the virtual situation to the actual situation. He adapts himself to the defects of the simulator that he uses, and learns to apply dynamically transfer functions, which allow him to transpose into the reality. He also learns to compensate for the sensory incoherence and to avoid simulator sickness. The simulator can thus be used for vehicle design. For this use the designer can skip a certain number of elements of the road context, and on the global coherence of the rendering. An occasional simulator driver has by definition no opportunity to become used to the defects of the tool. The training course or the experiment is limited in time. Thus the simulator must be conceived in order to privilege a grip in hand as easy as that of an actual vehicle (in a limited time) and to focus more on the relevance of the proposed situation (situation ecology) than on the physical fidelity of the underlying models. The question of the driving task, of the workload of each sub-task (guidance for example), must be carefully studied.

The simulators are nowadays used for various applications. The limits in the driving situation simulation make impossible a driving on simulator "ecologically realistic". The “full purpose” simulator is for the time being a myth. Every simulator is a prototype dedicated to a particular application, which stems from a certain number of compromises. The validity of a simulator cannot be defined without reference to its use. The problem is very different whether the simulator drivers are professionals using regularly the tool, or ordinary people using it in a coincidental way. The transfer of the results acquired on simulator towards the actual situations is an essential question. The resemblance of the driving task (from the cognitive point of view and from the point of view of the mental workload) must be verified in the same way as the performances. The definition of good practices (scientist ones?) of use of the driving simulation must be encouraged; a think tank on the subject would be relevant. Except if one is able to reproduce the phenomena in the scale 1, the naming "hifi" is misleading and should be discouraged.

6.4.2 E-learning applications

In general little scientifically validated knowledge exists on the transfer effects of e-learning in regards to driving behaviour, situation awareness or anticipatory behaviour. Elderly drivers, impaired drivers or drivers with special needs are not targeted in any of these applications though many of these driver groups could potentially benefit from certain elements of these applications. As a general notion it could be stated that e-learning applications potentially could have good chances of reaching these drivers as use of e-learning does not require physical presence of a driving instructor. On the other hand it could be argued that many of these groups are not familiar with these types of training tools meaning they would not necessarily be interested in this form of training.

Finally it still needs to be established whether a transfer effect is actually obtained through e-learning tools. Before these and related question have been addressed more systematically it remains an open question whether or to what extent any of the e-learning applications used within driver training have accomplished an increasing learning effect or moved beyond the spheres of existing driver training.

7 CONCLUSIONS: RESEARCH NEEDS

As a conclusion of the analytical review of driver training and education process and study of functional requirements of driver education tools conducted by Humanist Task Force G, research needs to fill the gaps in existing simulator and multimedia tools to achieve the potential effectiveness in using simulators to improve the driver training process at a European level with harmonized procedures have been identified in the following fields:

- Pedagogical and didactical components
- Technological aspects
- E-learning applications

7.1 Pedagogical and didactical components

1. Specification of training needs and detailed objectives for specific target groups:
    a. Novice drivers
    b. Professional drivers
    c. Older drivers
    d. Disabled drivers
2. Assessment of retention of skills acquired through simulator training and of the long terms effects of simulator training.
3. Assessment of the effectiveness of using simulators for the acquisition of higher order skills such as risk perception.
4. Research on the psychological factors that influence the safe behaviour on roads and assessment that simulator training will not result in negative effects like reducing risk awareness, particularity for young drivers.
5. Criteria for the selection of training media (classroom, slide show, mechanical devices, computer, e-learning, simulation, real driving, etc.) for different training activities
6. Guidelines for the role of the trainer and his task in the process of simulator training.
7. Formulation of ethics in simulator use.
8. Development of effective training curricula (activities, sequence of activities, scenarios etc) including simulator based training specifically designed for the needs of specific target groups.

7.2 Technological aspects

1. Setting of technical specifications that define the minimum conditions that a simulator should have to be suitable for use in the different levels of driver training applications.

2. Validation procedures for driver training simulators.

3. Development of a framework for converting vehicle performance data into usable training feedback for the driver.

4. Development of a driver performance monitoring tool to assess in real time if the driver's decisions and actions in specific driving situations.

5. Development of an advanced traffic model that is able to produce a realistic traffic environment around the learner.

6. Research on techniques to avoid simulator induced sickness.

7.3 E-learning applications

1. Identification of areas in which theoretical driver training could benefit from e-learning applications.

2. Differences in the didactical content and processes of e-learning applications compared to traditional learning as measured by driver performance outcomes.

3. E-learning applications targeting elderly drivers, impaired drivers or drivers with special needs and in particularly whether alternative didacital approaches are better suited for these groups of drivers.

4. Assessment of retention of skills acquired through e-learning and transfer into the real world driving.

5.

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