Transport and mobility

Science topic n°7

Understanding **road user behaviours** by simulating the real world?

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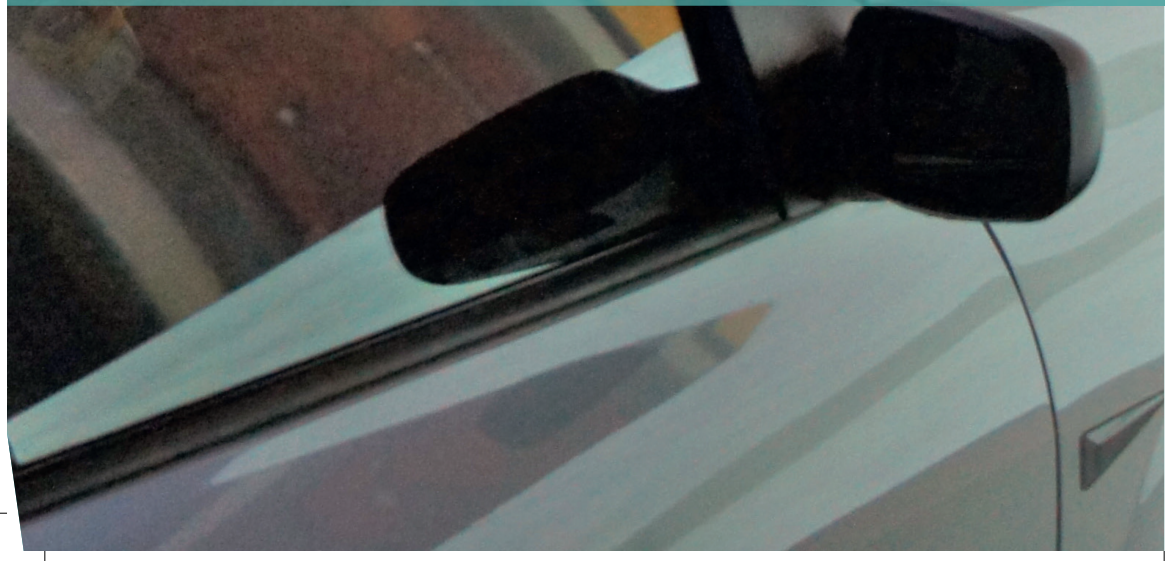

Transport and mobility

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1 Developing simulators
2 Driving simulators validity
3 Risky situations
4 Evaluating road design
5 Eco-driving
6 Bicycle simulator

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UNDERSTANDING ROAD USER BEHAVIOURS BY SIMULATING THE REAL WORLD?

By Fabrice Vienne,
Research engineer
COSYS[1] Department, LEPSIS[2] Laboratory

Simulating reality and being able to move about in a virtual world and interact with virtual entities is no longer a dream worthy of a science fiction novel. Devices that transform the virtual into reality have existed for more than 50 years[3]. Driving simulators are virtual reality devices that make it possible for subjects to perform complex tasks cheaply or allow them to carry out tasks that would be too dangerous in a real situation.

There are several types of movement simulators, which are used for different purposes:

> The most impressive have been developed by motor vehicle manufacturers and are used to study vehicle dynamics and to validate vehicle components.

> At the other extreme, inexpensive driving simulators are used for driver training and to increase awareness of road safety issues. Their chief purpose is to allow drivers to encounter a variety of scenarios that they may meet during real driving, including accident scenarios.

> Finally, universities and research institutes, such as IFSTTAR, conduct research work that aims to improve these virtual reality devices and use them to study the behaviour of drivers and road users in general.

Varied uses for simulators

By studying road user behaviour it is possible to investigate topics as varied as the influence of medication, the design and evaluation of new driving aids, the impact of new regulations or the appraisal of new road designs. They are also used for training and to raise awareness among different groups of road users. Last, simulators can be used to prepare for social changes as society becomes more environmentally responsible and the nature of the road changes as vehicles become more automated and active modes such as walking and cycling regain popularity.

The qualities and limitations of simulators

Simulators have many qualities. They mean the driving environment can be easily modified and participants can be placed in situations that are likely to give rise to an accident without any risk. They also make it possible to control experimental conditions and reproduce them as often as necessary for each participant.

However, some limitations must be borne in mind. As in the case of every experiment, those conducted on a simulator are performed in a

laboratory. Applying the results to real situations and general cases requires researchers to carefully select the experimental conditions. To do this, they draw on their research experience and the knowledge of the rest of the scientific community. The question of the validity of simulators is nevertheless unresolved, and needs further study. Interested readers may refer to the article "How to make relevant a virtual reality situation?".

The simulation of driving and movement at IFSTTAR

Driving simulation has been an important feature of the Institute's activities for over 20 years, and it is continuing to gain ground. A number of IFSTTAR's laboratories have been involved in research in this area which has resulted in two complementary software packages: "Archisim/Sim[2]" for movement simulation and "pro-SiVIC Recherche" for the simulation of sensors. Ten or so simulators of different types are also located on IFSTTAR's four sites[4].

1. COSYS: Components and systems Department
2. LEPSIS: Laboratory for road Operations, Perception, Simulators and Simulations
3. The Sensorama, which was invented by Morton L. Heilig in 1962, is often considered to mark the beginning of virtual reality. The machine projected 3D images, produced stereo sound, reproduced seat movements and even… smells!
4. http://www.lepsis.ifsttar.fr/equipements/laboratoire-de-simulation/

Driving simulators are virtual reality devices that make it possible for subjects to perform complex tasks cheaply or allow them to carry out tasks that would be too dangerous in a real situation.

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INTRODUCTION (END)

In the last few years, IFSTTAR has also started to simulate the movement of vulnerable road users. It was the first Institute to develop a road crossing simulator for pedestrians[5]. It is also one of the few research institutes to have started to develop a motorcycle simulator[6] and a bicycle simulator[7].

Apart from these design activities, simulators are used for research in a number of disciplines such as virtual reality, artificial intelligence and psychology. This research deals with, for example, the validity of simulators, multisensory cueing and the peopling of virtual scenes. Their role is both to improve simulators and provide the fundamental knowledge required to make good use of them.

5. A first version of this simulator has been described in: Lobjois R, & Cavallo V. (2007). *Age-related differences in street-crossing decisions: The effects of vehicle speed and time constraints on gap selection in an estimation task. Accident Analysis & Prevention, 39, 934-943.*
The current version, which is more sophisticated, is described in: Dommes, A., Cavallo, V., Dubuisson, J.B., Tournier, I., & Vienne, F. (2014). Crossing a two-way street: comparison of young and old pedestrians. Journal of Safety Research, 50, 27-34.
6. In collaboration with Université d'Evry and Université Paris-Sud.
7. Only a very small number of bicycle simulators have been developed for research. Examples include those at the Universities of Iowa and Oregon in the United States and the German FIVIS simulator which are three intended for studying the behaviour of cyclists. The KAIST simulator in Korea and that developed by the Nanyang University in Singapore are used for research into mechanics and automatic systems.

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1 DEVELOPING MOVEMENT SIMULATORS FOR THE STUDY OF BEHAVIOUR

By Stéphane Caro,
Research engineer
COSYS[1] Department, LEPSIS[2] Laboratory

In contrast to what the name suggests, driving simulators, and more generally motion simulators, do not strictly speaking simulate driving. Above all, they generate a virtual environment in which participants drive and move by using an interface. The real world is replaced by a synthetic environment obtained by simulation.

From the components of simulators…

In order a simulator to be valid, it must simulate the different elements of the real world, which include:

> The operation of the vehicle that is driven by participants, including its engine[3], its dynamics, as well as on-board devices such as driving aids and sensors[4];

> The behaviour of the other characters and elements in the scene such as the vehicles that make up the traffic[5], pedestrians and cyclists whose movements must be simulated too[6];

> Sources of light and sound, as well as the propagation of light[7] and sound[8].

In order to replace the real world and give participants the impression they are moving, the results of the simulations must be expressed. To do this simulator hardware is made up of an interface equipped with sensors and sensory reproduction devices. A large amount of previous and ongoing research has focussed on the sensory cueing and simulators' immersion capabilities.

… to a process of development

The natural approach when developing a simulator is to reproduce the sensory stimulation produced by the real world as faithfully as possible. This has been done, for example in the bicycle simulator by reproducing the dynamics of the rear wheel of a real bicycle[9]. In this case, the torque participants must apply to the pedals and the inertia of the bicycle (i.e. the difficulty of starting and stopping) are the same as in real situations.

However, it is often technically or physically impossible to faithfully reproduce the characteristics of the real world. This would require, for example, the ability to reproduce the luminance of a sunny day on a screen[10] and the acceleration of emergency braking. In order to overcome these difficulties, researchers have developed techniques that create illusions for participants, by reproducing only the relevant stimulations[11,12]. The development of these techniques relies on an understanding of the mechanisms of perception and tests conducted with participants.

In spite of the use of these algorithms, the lack or inevitable distortion of some sensory cues can interfere with the perception and control of movement in the virtual world. In some cases it is better to develop models which no longer represent physical reality but which are based on the expectations of the participants in terms of operation and sensory feedback. This is what was done for example for the control of balance on the motorcycle simulator[13] or for steering wheel torque feedback as currently implemented on a number of IFSTTAR's simulators.

And the choice of a suitable configuration

In order to select the most appropriate models and reproduction techniques, we need to know the benefits and drawbacks of each and, obviously, take account of how the simulators will be used.

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DEVELOPING MOVEMENT SIMULATORS FOR THE STUDY OF BEHAVIOUR (END)

> **The real world is replaced by a synthetic environment obtained by simulation.**

Video (FR)

1. COSYS: Components and systems Department
2. LEPSIS: Laboratory for road Operations, Perception, Simulators and Simulations
3. See the article on eco-driving in this section and the IFSTTAR MODYVES internal research project (Dynamic and energetic models of conventional electric and hybrid vehicles for driving simulators) (B. Jeanneret & D. Ndiaye).
4. Among other things, the "pro-SiVIC Recherche" simulator aims to provide physically realistic simulation of on-board sensors, communication devices and moving objects for the prototyping, testing and evaluating of Advanced Driving Assistance Systems (ADAS) (Dominique Gruyer).
5. Espié, S. & Auberlet, J.M. (2007). ARCHISIM: *A behavioral multi-actors traffic simulation model for the study of a traffic system including ITS aspects*. International Journal of ITS Research, 5, 7-16.
6. Research is under way to produce realistic animation of pedestrians and cyclists (Isabelle Aillerie).
7. One example is research that attempts to simulate fog.
Dumont, E. (2002). Caractérisation, modélisation et simulation des effets visuels du brouillard pour l'usager de la route. Thèse de doctorat de l'université René Descartes, Paris.
Dumont, E., & Cavallo, V. (2004). Extended photometric model of fog effects on road vision. Transportation Research Record, 1862, 77-81.
8. 6Research in progress on sound synthesis and propagation in collaboration with Genesis in the framework of the FUI Yellow project (Fabrice Vienne). More information available on the Movéo Competitive Cluster website.
9. Presentation of the bicycle simulator project during the 2013 workshops of the Scientific and Technical Network of the Ministry of the Environment and Sustainable Development (MEDDE). Access the presentation of the workshop.
10. The use of new technologies can make it easier for the system to approach 1: 1 reproduction. See the 2014-2015 IFSTTAR internal research project that deals with high luminance dynamic screens (Céline Villa & Maud Ranchet).
11. Algorithms that reproduce tones make it possible to represent wide ranges of luminance on screens with limited capacities. See for example:
Petit, J. (2010). Génération, visualisation et évaluation d'images HDR. Application à la simulation de conduite nocturne. Thèse de doctorat de l'université Claude Bernard, Lyon.
Petit, J., Bremond, R., & Tom. A. (2013). Evaluation of tone mapping operators in night-time virtual worlds. Virtual Reality, 17, 253-262.
12. Motion cueing algorithms allow motion bases with only limited capabilities to produce the essential characteristics of accelerations. See for example:
Mohellebi, H. (2005). Conception et réalisation de systèmes de restitution de mouvement et de retour haptique pour un simulateur de conduite à faible coût dédié à l'étude comportementale du conducteur. Thèse de doctorat de l'université d'Evry-val d'Essonne.
13. Patent No. FR 14 53836 pending
Caro S., Espié S., Lobjois R., Benedetto S., & Vienne F. Méthode de calcul des composantes latérales (roulis et lacet) et du retour d'effort guidon pour simulateur de conduite moto.

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2 HOW TO MAKE RELEVANT A VIRTUAL REALITY SITUATION?

By Régis Lobjois,
Researcher
COSYS[1] Department, LEPSIS[2] Laboratory

When using driving simulators with the goal to investigate road user behaviours, we need to consider its validity. A simulator is valid when its users behave in a natural way without any preliminary training[3]. The main idea behind this is that the simulator should not lead to the adoption of new behaviour or strategies; otherwise it will fail to highlight the real user behaviour in the studied situation.

With regard to the validity of virtual reality devices, four key dimensions are generally taken into account[4]:

> Physical validity, which relates to the properties and performance of the software and hardware architecture of the system, and hence its ability to provide sensory stimulations which are objectively close to those of the real world;

> Subjective validity, which relates to a judgement of resemblance and credibility of the simulated situation;

> Ethological validity, which gauges the similarity between behaviours in simulated and real situations;

> Last, psychological validity, which relates to the similarity between the psychological processes underlying activity, including the mental load generated by the driving activity.

Evaluation of driving simulator validity

It consists of exposing users to the technical and technological choices, and hence to test the features they interact with and which immerse them in the virtual environment.

This testing is essentially based on subjective (by means of a post-exposure questionnaire or interview) and behavioural measures (selected speed, swerving from side to side, decision-making, etc.).

However, these two types of measures have limitations. Subjective measures are less sensitive to the characteristics of the virtual environment than so-called objective measures[5]. On the other hand, while the behavioural measures collected in a simulator can resemble those observed in real situations, the underlying processes may differ.

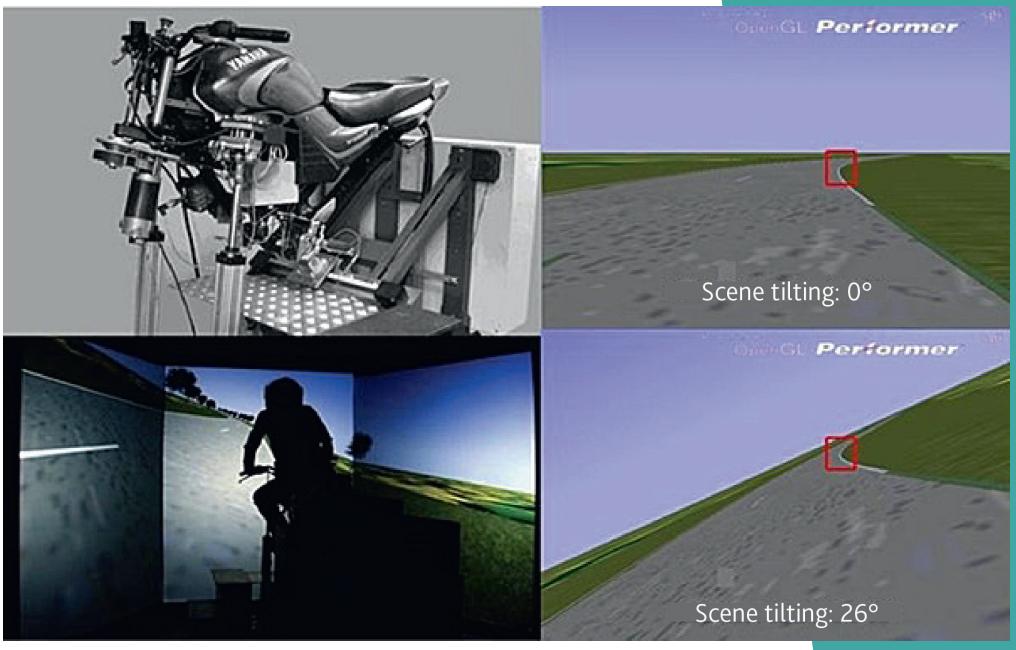
The approach we adopt when designing and evaluating simulators gives priority to what is known as the psychological dimension, by means of relative evaluations (comparing several devices with different characteristics) or absolute evaluations (comparing a device to the real situation). Here are some examples:

• Motorcycle riding simulation

Because in simulation it is not possible to lean the "motorcycle" as a rider would do on the road (due to a feeling of imminent falling[6]), the visual scene is tilted in order to compensate for this limitation and create the illusion of leaning. However, when the visual scene roll angle is

increased, researchers have shown that simulator sickness is stronger[7]. In addition, tilting the visual scene induces changes in the visual strategies which may explain why the control of steering in bend is less smooth.

The psychological validity of tilting the visual scenery is therefore limited as it tends to modify the natural visual processes which are responsible for the locomotor control in bends[8].



▲ Moving base motorcycle simulator (top left) positioned in front of three screens with a height of 2.8m and a width of 1.8m (bottom left). The visual scenes can be rotated in the roll in order to create the illusion of tilting (images on the right, with and without visual tilting).

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HOW TO MAKE RELEVANT A VIRTUAL REALITY SITUATION? (END)

• Road-crossing simulation

The improvements in tracking systems able to record pedestrian motion in a virtual environment has enabled LEPSIS researchers to compare the effect of two response conditions on road crossing decisions. In the first case, the user was simply asked to press a button to state if he would or would not cross the road in the presence of the traffic shown on the screen. In the second case, the participant was able to cross the road while walking over a distance that corresponded to the width of the simulated pavement. In the second situation, crossing behaviour were more opportunistic but less risky. This finding was explained by the fact that natural coupling between the perception of the situation and the control of the crossing action was better preserved in the second case than with the push-button type of response[9].

• Car driving simulation

Car driving simulators are mainly evaluated by comparing the driving performance and behaviour to the real situation. The question is therefore whether or not a given level of performance was achieved in both the real and simulated situations, with the same allocation of attentional resources. With this end in view, we have compared the mental workload generated by the two conditions and shown that mental workload was higher in driving simulation.

> **Taken together, these few findings show how important it is to take into account the psychological processes that underlie actions when we are trying to evaluate virtual reality devices.**

1. COSYS: Components and systems Department
2. LEPSIS: Laboratory for road Operations, Perception, Simulators and Simulations

3. Burkhardt, J-M., B. Bardy, and D. Lourdeaux. 2003. Immersion, réalisme et présence dans la conception et l'évaluation des environnements virtuels. Psychologie Française, 48, 35-42.
4. Malaterre, G., and J. Fréchaux. 2002. Validité des simulateurs de conduite par comparaison de tâches réalisées en situation réelle et simulée. Actes INRETS n° 82, pp. 149-157.
5. Morice, A. H. P, I. A. Siegler, and B. G. Bardy. 2008. Action-perception patterns in virtual ball-bouncing: Combating system latency and tracking functional validity. Journal of Neuroscience Methods 169: 255-266.
6. Dagonneau, V. (2012). Etude des liens entre immersion et présence pour la mise au point d'un simulateur de conduite de deux-roues motorisé. Thèse de Doctorat, Université Paris-Sud.
7. Lobjois, R., V. Dagonneau, and B. Isableu. (2016). The contribution of visual and proprioceptive information to the leaning sensation in a dynamic motor-bike simulator. Ergonomics, DOI: 10.1080/00140139.2016.1149229
8. Lobjois, R., I. A. Siegler, and F. Mars (2016). Effects of visual roll on steering control and gaze behavior in a motorcycle simulator. Transportation Research Part F, 38, 55–66.
9. Lobjois, R., and V. Cavallo. 2009. The effects of aging on street-crossing behavior: from estimation to actual crossing. Accident Analysis & Prevention, 41, 259-267.

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3 STUDYING RISK SITUATIONS SAFELY

By Catherine Berthelon,
Director of the LMA[1]
TS2[2] Department

In the sphere of driving, precisely because they are "risky", "risky situations" can only be investigated in a limited way under real driving conditions. Consequently, driving simulators are a possibility to be borne in mind.

Identifying risky situations

We need to make a distinction between risky situations and the concept of "risk taking" which covers a set of complex phenomena which every individual tends to relate to their subjective perception of risk.

> **Risky situations correspond to situations that are likely to cause accidents and which are often difficult for drivers to deal with.**

Epidemiological studies[3] and detailed accident studies provide us with reliable indications about them and show they are the outcome of a combination of factors present in the human/vehicle/infrastructure system.

Human factors, which are frequently mentioned, such as speeds, driving under the influence of alcohol, drugs or medication, paying insufficient attention due to distraction (by a telephone, for example) and hypovigilance. The youngest (males) and oldest age groups are the most vulnerable, and riding a motorcycle or walking increase the severity of the outcome. Last, accident risk on trunk roads other than motorways is high.

Some studies made possible by driving simulators

Driving simulators have become indispensable tools for understanding and analysing interactions between the driver, the vehicle and road geometry. Their use has increased over time because of their many advantages: the reproducibility of the situations, control of parameters and absence of real risk as the driver operates in a virtual environment. They are thus particularly well-suited to studying situations that occur randomly or very rarely as well as ones that involve risk. For example, it is possible to simulate risky situations and present them to different groups of drivers. The aim of this research is to better identify the mechanisms responsible for a malfunction of the human-vehicle-environment system that have the potential to cause an accident.

A wide range of issues are investigated in connection with risky situations. These relate, for example, to the state of the driver in relation to the environment:

- Vigilance i.e. "sleepiness" due to driving in excessively monotonous situations[4];
- Workload, or difficulties encountered in a complex environment[5];
- Distraction and inattention[6];
- Ingestion of psychoactive substances (alcohol, drugs of medication)[7,8].

In spite of their benefits simulators have some limitations

The absence of a real risk, which is considered an advantage in driving simulation, nevertheless raises a number of questions when studying situations that are objectively risky. The issue of "behavioural validity" relates to the ability of a simulator to generate driving behaviours that

are identical or similar to those which would be observed in a natural situation: the absence of risk can thus make it more difficult to interpret behaviours. Moreover, the "physical validation" of the simulator is linked to the match between its dynamics and that of vehicles. It therefore assumes that the dynamics of the simulator correspond to those of the real vehicle, but also that the way in which the road environment is simplified does not generate actions which differ from those in the real driving situation. Cognitive fidelity, which is related to knowledge acquisition, thus becomes a crucial factor in simulator validation.

The most effective way of carrying out this validation is to compare the driving behaviours obtained in the simulated situation with those obtained in the real situation. This is however difficult, and even impossible in the case of risky situations on ethical grounds, for example. So, from the safety standpoint, making a driver drink or testing a driver who has been deprived of sleep is not acceptable on the road while it is possible on a simulator. Simulators are therefore essential for studying risky situations, in particular in order to evaluate changes in behaviour due to the driver's state.

▲ One of Ifsttar's driving simulators

1. LMA: Laboratory of Accident Mechanism Analysis
2. TS2: Transport, health, safety Department
3. These are studies of populations that investigate the frequency and distribution of health-related problems over time and across different locations as well as the role of the factors that cause them.

4. Contardi, S., Pizza, F., Sancisi, E., Mondini, S., Cirignotta, F. (2004). Reliability of a driving simulation task for evaluation of sleepiness. Brain Research Bulletin 63, 427–431.
5. Paxion, J., Galy, E., Berthelon, C. (2015). Subjective overload depending on driving experience and situation complexity: which strategies faced with a pedestrian crossing? Applied Ergonomics, 51, 343-349.
6. Fort, A., Gabaude, C., Lagarde, E., Lemercier, C., Cour, M., Maury, B. (2003). Impacts des inattentions sur la conduite automobile: approche multidisciplinaire. Compte-rendu de fin de projet ANR-09-VTT-04, 33 pp.
7. Berthelon, C., Gineyt, G. (2014). Effects of alcohol on automated and controlled driving performance. Psychopharmacology, 231, 2087-2095.
8. Bocca, M-L., Marie, S., Lelong-Boulouard, V., Bertran, F., Couque, C., Desfemmes, T., Berthelon, C., Amato, J-N., Moessinger, M., Paillet-Loilier, M., Coquerel, A., Denise, P. (2011). Zolpidem and zopiclone impair similarly monotonous driving performance after a single nighttime intake in aged subjects. Psychopharmacology, 214, 699-706.

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4 EVALUATING ROAD DESIGN THROUGH DRIVING SIMULATORS

The development and marketing of driving simulators has helped democratise their use, even if the issue of the transferability of the results remains a clear challenge. Even so, their use, essentially by researchers, has shaped our ideas and even provided some practical solutions.

By Jean-Michel Auberlet,
Researcher
COSYS[1] Department, LEPSIS[2] Laboratory
Lara Désiré
Researcher Cerema[3]
et Florence Rosey
Researcher Cerema[3]

Simulators for appraisal and harmonisation

In the framework of the RoadSense project, an IFSTTAR driving simulator has been used to evaluate three audio-tactile warning devices (rumble strips). The main purpose of these is to avoid roadway departures and head-on collisions on county roads. In this case, the main value of the simulator was to enable us to test corrugated devices installed at the centre and/or edge of the road. These are used a great deal abroad because of their effectiveness, but are not yet used in France, or only experimentally on a few motorway sections. The simulator experiment therefore made it possible to test these devices prior to an experimental appraisal on real roads. The ultimate purpose was to be able to propose rumble strip configurations that are suitable for the French county road system. It would then be possible to draft installation recommendations that would help to harmonise these networks.

> **It would then be possible to draft installation recommendations that would help to harmonise these networks.**

A future application of driving simulators concerns what signing to use to show when hard shoulders are open to traffic. Currently, a number of signing devices are used both abroad and in France on an experimental basis. An evaluation of the impact of the different variants on driver behaviours using a driving simulator will help us develop recommendations in order to propose specific signing for this situation with a view to harmonisation.

While fostering road innovation…

In the SARI project the use of IFSTTAR simulators has enabled us to identify appropriate road designs for vertical crest on straight roads prior to their construction. This research has demonstrated the positive impact of rumble strips (experimental laboratory devices) and night-time markings that are visible during rain under real conditions for an application other than that for which they were designed. In the framework of the promotion of products developed during the SARI project, representatives of motorway companies have expressed their interest in the driving simulator based road design method.

One possible future use of driving simulators is to serve as a decision-making aid tool for road design and road improvements. In order to evaluate the constraints involved in this type of use, Cerema has considered a highway project[4] that aimed to implement the "self explaining and calming roads[5]" concept. This research, which used Cerema fixed-base simulator and IFSTTAR's

driving simulation software, has identified the challenges that face this type of use, in particular the creation of the best possible visual database of the geometric characteristics of road projects. It also allows us to develop techniques to facilitate transfers from highway design tools to 3D simulation tools.

And sharing professional knowledge and expertise

The feedback from the experiment has revealed two challenges. The first consists of establishing methodological gateways between researchers and civil engineering departments. This is because more systematic use of driving simulators means that it is necessary to facilitate and accelerate the transfer of road projects from design tools to simulation tools. During this transfer the geometric characteristics and the features of the road must be retained as far as possible. Firstly, this means the findings are more widely applicable and secondly, it means that road managers can take account of the results of these studies. The second challenge relates to the link between two worlds, that of researchers who evaluate the impact of road design by measuring the behaviours of individual drivers and that of road managers who evaluate the performance of highways by measuring the behaviours of vehicle flows.

▼ The CEREMA driving simulator

1. COSYS: Components and systems Department
2. LEPSIS: Laboratory for road Operations, Perception, Simulators and Simulations
3. Cerema : Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement
4. http://www.ouest.cerema.fr/route-apaisee-a-notre-dame-des-landes-a199.html
5. http://www.infra-transports-materiaux.cerema.fr/la-route-autrement-pour-une-conduite-apaisee-a4483.html

Further readings

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Auberlet, J-.M., Vienne, F., 2014, Dossier 'I.A. & Systèmes Immersifs', Bulletin de l'AFIA, 82, pp. 10-13.

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Auberlet, J-.M., Pacaux, M.-P., Anceaux, F., Plainchault, P., Rosey, F. (2010). The impact of perceptual treatments on lateral control: a study using fixed-base and motion-base driving simulators. Accident Analysis and Prevention, 42 (2010), pp. 166–173.

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Credit: Ifsttar and Cerema

5 DEVELOPING AND EVALUATING ECO-DRIVING AID SYSTEMS ON SIMULATOR

By Rochdi Trigui, *Senior researcher – LTE[1] Laboratory, AME[2] Department*
Dominique Gruyer, *Director of LIVIC[3] – COSYS[4] Department*
Olivier Orfila, *Deputy Director of LIVIC[3] – COSYS[4] Department*
and Hélène Tattegrain, *Director of LESCOT[5] – TS2[6] Department*

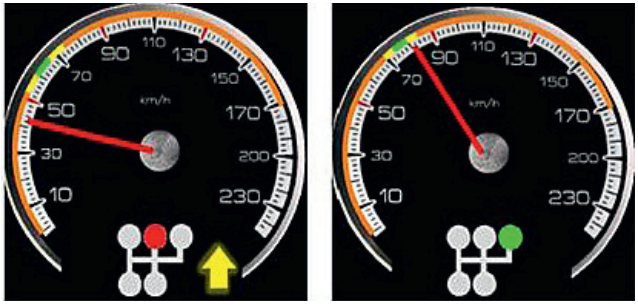
Eco-driving is a strategy that reduces the energy consumption and atmospheric CO2 emissions of vehicles. It involves following several recommendations about how to drive. These include not accelerating too rapidly, reducing one's driving speed, keeping a low engine speed and anticipating traffic conditions.[7] The low purchase cost of eco-driving aids and the fact that they can be installed on older vehicles means they can have a considerable and immediate impact. Therefore, in recent years, several IFSTTAR research projects have dealt with the development and evaluation of this type of device. These studies were conducted on driving simulators, but nevertheless required specific development work.

From computing the ideal trajectory to applying it while driving

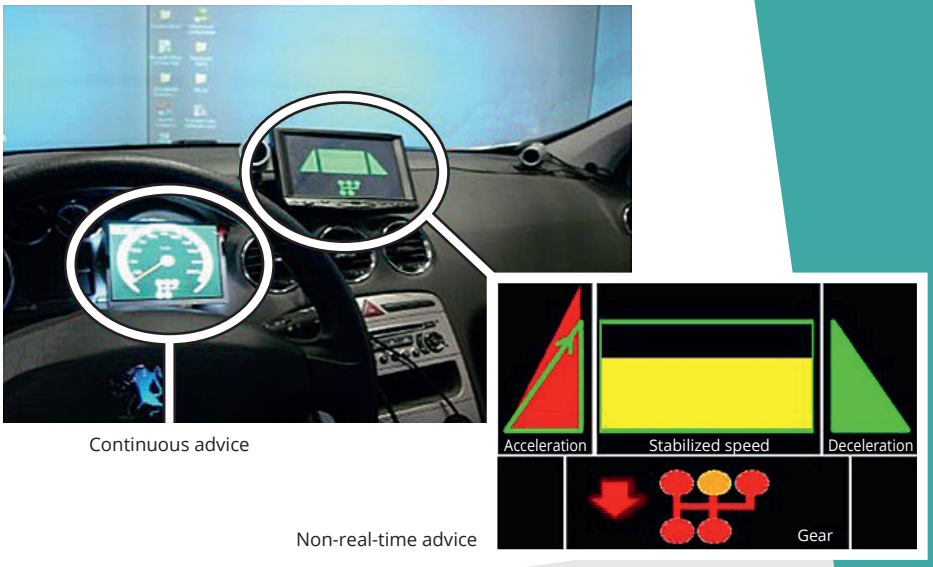
Collaborative research between LTE, LESCOT, LEPSIS and the Ampère laboratory in Lyon[8], was conducted with the primary goal of quantifying the savings resulting from eco-driving for vehicles of different types (conventional, electric or hybrid). This involved the use of digital optimisation techniques. After this, an eco-driving tool based on this optimisation was designed and tested for a conventional vehicle. The design process took account of the various constraints that may be present. The device thus took account of traffic conditions and pollutant emissions and the receptiveness of drivers and their ability to assimilate the information they receive.

Moreover, taking account of traffic constraints has shown that the potential savings resulting from eco-driving diminish as traffic becomes more congested, even if it still remains a way of appreciably reducing vehicle consumption. The inclusion of emissions constraints has led the researchers to conclude that eco-driving provides the same emissions levels as normal driving and can reduce them in the absence of journey time constraints[9].

Finally, optimisation algorithms were integrated within the effective and secure assistance system by using a driving simulator. Twenty individuals were recruited to take part in the evaluation of the system as drivers with and without the aid system. The results showed that an optimised eco-driving system that displays simple information can be both effective and relatively well accepted by drivers. The average reduction in fuel consumption during the experiment was approximately 11%.



▲ The eco-driving aid system communicates with the driver via two screens. The screen on the left is integrated with the vehicle's speedometer and continuously displays a recommended range of speeds, except in risky situations. The screen on the right provides non-real-time advice (after a sequence of driving actions) and serves an educational purpose.



Continuous advice

Non-real-time advice

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DEVELOPING AND EVALUATING ECO-DRIVING AID SYSTEMS ON SIMULATOR (END)

Eco-SiVIC, an eco-driving and 3D immersion platform

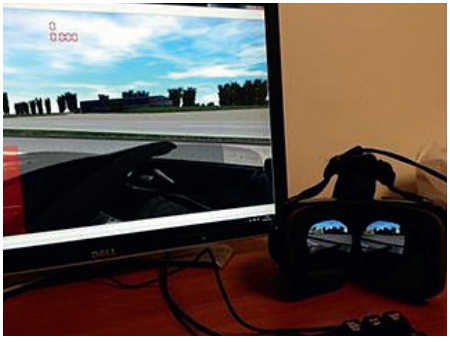
Other research has been carried out on a platform known as pro-SiVIC (Virtual Vehicle, Infrastructure and Sensor Simulator) developed by the LIVIC. This platform is mainly used for modelling sensors and prototyping driving aids. In more concrete terms, it enables us to simulate the operation of sensors that are installed in vehicles (such as video cameras, RADAR systems, laser telemetry, GPS devices, etc.). The result of these simulations is then used to develop driving aids that use the sensors in question. In this context, a consumption sensor for internal combustion engines has been implemented, making eco-driving projects possible.

In the last few years work has been conducted to extend this platform to allow participants to drive it. This involved providing an interface for the platform with driver controls (steering wheel and pedals) and computing and displaying stereoscopic images[10] with a virtual reality headset, thereby providing full 3-D immersion.

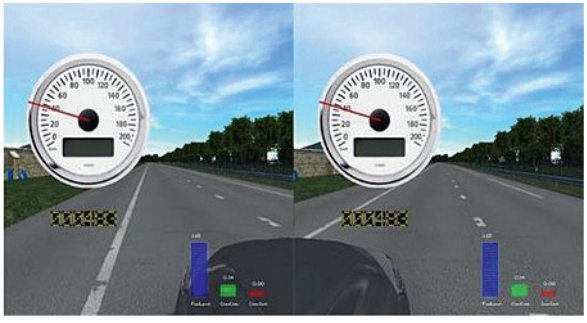
This platform, which is fitted with driver controls, was presented to the public during the "Fêtes de la science" and the 2014 Paris motor show[11]. In this context, the drivers' aim was to travel as far as possible with a small amount of fuel (0.15 liters).

The participants were given a score based on the distance covered, showing them whether or not they had complied with the rules of eco-driving.

On the scientific level, the aim of this platform is to be able to quantify the impact of driving on consumption in specific situations such as crossing an intersection. In addition, the research



◀ A virtual reality headset that displays 3D images and measures head movements.



◀ An example of stereoscopic images with speed and fuel consumption displays.

team is considering quantifying how certain vehicle parameters affect consumption. Possible parameters include the vehicle's capacity to accelerate and brake, or how well the tyres grip the roadway. Future research will aim to extend these studies to hybrid technologies.

The value of simulation tools for eco-driving

This work, which has been carried out in several of IFSTTAR's laboratories, has shown that installing consumption evaluation devices on driving simulators can open the way for various research projects which would be difficult to implement in real situations.

> **The first results indicate that eco-driving aids have a beneficial effect.**

1. LTE: Transport and Environment Laboratory
2. AME: Planning, Mobilities and Environment Department
3. LIVIC: Laboratory for Vehicle Infrastructure Driver Interactions
4. COSYS: Components and systems Department
5. LESCOT: Laboratory Ergonomics and Cognitive Sciences applied to Transport
6. TS2: Transport, health, safety Department
7. A definition of eco-driving can be found, for example, in the following: Barth, M., & Boriboonsomsin, K. (2009). Energy and emissions impacts of a freeway-based dynamic eco-driving system. Transportation Research Part D, 14, 400-410.
8. As part of the PhD thesis of Félicitas Mensing, defended in 2013: "Optimal energy utilization in conventional, electric and hybrid vehicles and its application to eco-driving".
9. The detailed results are presented in: Mensinng, F., Bideaux, E., Trigui, R., Ribet, J., & Jeanneret, B. (2014). Eco-driving: An economic or ecologic driving style? Transportation Research Part C, 38, 110-121.
10. Stereoscopic images make it possible to see the scene in 3D. On of the images corresponds to what is seen by the left eye and the other, which is slightly different, corresponds to what is seen by the right eye. The slight differences between the two give an impression of image depth.
11. The eco-SiVIC platform is now presented by CIVITEC (a subsidiary of the ESI group) and a licencing agreement to enable them to exploit the system is due to be signed with this firm in 2016.

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6 FACILITATING URBAN CYCLING USING SIMULATION

By Nadine Chaurand,
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AME[1] Department, LPC[2] Laboratory
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Research engineer
COSYS[3] Department, LEPSIS[4] Laboratory

As a means of transport, cycling has many recognised benefits. As far as individuals' health is concerned it provides additional regular physical exercise. As far as mobility is concerned, over short distances travel times by bicycle are lower than those by car, and it is easy to park and reduces urban traffic congestion. In addition, from the environmental standpoint, the bicycle is a green means of transport that generates no pollution. Consequently, measures are taken to facilitate and encourage bicycle use, and the level of urban bicycle use has been gradually increasing during the last decade in most developed countries.

Nevertheless, cycling in towns requires specific knowledge and know-how that novice riders sometimes lack. In particular, cyclists need to assess risks rapidly[5] in order to select the riding behaviour with the best benefit/risk ratio. In addition, the increasing number of cyclists on the roads changes the nature of traffic and creates new situations. Thus, other road users must anticipate the behaviour of cyclists in order to react in an appropriate way and avoid accidents. It is therefore vital to understand the behaviour of cyclists in order to encourage the development of cycling and enhance cyclist safety.

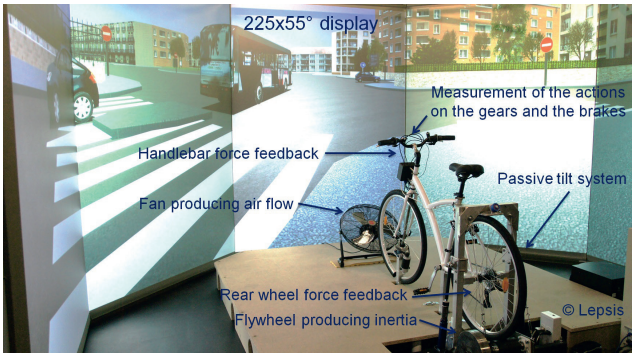
A shortage of measurement tools

Most of the research mentioned in the literature on cyclists' riding activities is based on official data or questionnaires. However, for research into cyclists' behaviours and their potential conflicts with other road users, we need to be able to study the actual behaviour of cyclists. Research in real environments is not always appropriate because of its cost, bias related to uncontrolled variables and the risks faced by participating cyclists.

In this situation simulation has undeniable benefits. A bicycle simulator enables us to put cyclists in a riding situation and to accurately measure their effective behaviours, while controlling the variables at play and avoiding the risks associated with a real environment.

The IFSTTAR bicycle simulator

To meet this need, a bicycle simulator has recently been developed as a result of collaboration between two IFSTTAR laboratories: LEPSIS and the LPC. Its design involved solving several issues in order to provide participants with an experience that is as near as possible to the real situation so as to provide reliable data. First of all, the pedalling torque is the same as that of a real bicycle and changes according to the gradient of the road. The simulator also reproduces



▲ Descriptive image and a video showing the bicycle simulator

the inertia of the bicycle in terms of difficulty starting and stopping. The feeling of wind is particularly important on a bicycle and the simulator has been fitted with a ventilation device which produces an air stream that varies according to the participant's speed.
Evaluation of the simulator will be particularly concerned with the participants' feelings, regarding comfort of use and immersion in the simulation. It will also consider the behavioural aspect, in terms of control of the bicycle and similarity with the behaviours exhibited in real situations.

Video (FR)

▲ Video demonstration presenting the bicycle simulator

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FACILITATING URBAN CYCLING USING SIMULATION (END)

To improve riding practices

Once it has been validated, the simulator will be used in a variety of research areas. One initial area will relate to the environmental determinants of cyclist behaviour. These studies will make it possible to:

> Identify the elements in the environment that cyclists consider in order to match their riding behaviour to the road environment (speed, vehicle gaps, etc.)[6], and how cyclists adjust their riding practices according to the road users they interact with[7];

> Specify riding situations which are considered the most risky, and to determine how cyclists anticipate these risks and what strategies (equipment or behaviours) they employ to cope with them;

> Investigate cyclists' riding errors and behaviours that are inappropriate for the situation and the environmental and personal factors that contribute to behaviours of this type.

A second area of research, which will be launched later, will provide an opportunity to test training and communication materials that aim to encourage the adoption of more appropriate behaviours by cyclists.

The total impact of this research will help improve cyclist comfort and safety and foster the peaceful sharing of urban space by cyclists and its other users.

1. AME: Planning, Mobilities and Environment Department
2. LPC: Mobility and Behavior Psychology Laborator
3. COSYS: Components and systems Department
4. LEPSIS: Laboratory for road Operations, Perception, Simulators and Simulations
5. Chaurand, N., Delhomme, P. (2013). Cyclists and drivers in road interactions: A comparison of perceived crash risk. Accident Analysis & Prevention, 50, 1176-1184.
6. Cho, G., Rodríguez, D. A., & Khattak, A. J. (2009). The role of the built environment in explaining relationships between perceived and actual pedestrian and bicyclist safety. Accident Analysis & Prevention, 41(4), 692 702.
7. Research on cyclists' interactions with other road users, in particular bus drivers, is already under way in the framework of the ANR Cyclope project. http://www.agence-nationale-recherche.fr/?Projet=ANR-14-CE22-0008 http://www.ifsttar.fr/ressources-en-ligne/lactualite-ifsttar/toute-lactualite/fil-info/article/mobilite-durable/

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