SWOV Fact sheet

Simulators in driver training

Summary
In 2010, about 150 driving simulators were being used for the basic driver training in the Netherlands. According to theories about how people learn, simulator training has both advantages and disadvantages. In order to be able to learn something from a simulator, its technical quality must be adequate. The quality of the simulator lessons is also important, as is the way in which these lessons are embedded in the total learning path.

In the Netherlands simulators are mainly used for teaching the basic principles of driving. The road safety effect of using simulators this way is unknown. Several international studies have indicated that using simulators for training hazard perception improves viewing behaviour.

Background and content
For approximately ten years, driving simulators have been used as a training device in the basic driver training. After an initial strong growth, the number of simulators has hardly increased in the last few years. In 2010, an estimated 100 simulators were being used in the basic training (Kuiper, 2010). Although simulators have existed since the 1960s, for a long time they remained too expensive to be used widely for training purposes. However, PCs have become ever more powerful, and their price-performance ratio has been getting ever better. This means that the price of simple simulators (that is, simulators that do not imitate the feeling that one is driving) has gone down considerably. Because driving lessons are rather expensive in the Netherlands, training devices that can save money on driving lessons are very attractive, certainly for the larger driving schools who can then offer a cheaper driver training. However, it is not yet clear whether training on a simulator can in fact reduce the number of practical driving lessons. One study showed that the chance of passing the driving test is 4 to 5% higher for learner drivers who followed a simulator training (De Winter et al., 2009), but this study did not take the effect of self-selection into account (see SWOV fact sheet *Contents and assessment of traffic education programmes*). Whether simulator training as it is used in the Netherlands also leads to safer driving after passing the driving test has not been investigated until now.

This fact sheet will discuss the characteristics of a driving simulator and the advantages and disadvantages, in theory, of simulator use in the driver training, the minimum requirements a simulator should meet, the way driving simulators are presently used in the driver training in Netherlands, and, finally, the available knowledge about the safety effect.

What does a simulator consist of?
Simulators are available in many types and sizes. At the upper end of the scale there are 'high-end' simulators that consist of a complete car, mounted on a moving base that can be moved in all directions, and from which the driver can see 360 degrees around him. The moving base ensures that all operations such as accelerating, braking, and going round sharp bends are imitated as life-like as possible. The advanced moving base makes these high-end simulators so big that they need a large hall to put them in. Even these very expensive simulators, of which only a few are to be found worldwide, still give an incomplete imitation of reality. At the lower end of the scale are the simulators that consist of one PC, one screen, and a steering wheel that is also used in computer games.

Simulators with a moving base are mostly used for research purposes. Simulators that are used in the driver training normally do not have a moving base, because they are too expensive. All simulators have some components in common, whether they are used for research or training purposes. These components, however, can vary a lot in quality. These common components are:

– *Mock-up.* This is the imitation of the driver position. It can vary from an office chair and a steering wheel for computer games, to a complete car in which the driver, when operating the pedals and gear lever while driving, experiences about the same counterforces as in a real car.

- *Vehicle model.* This is the software that simulates the manoeuvres of the vehicle one is driving. For example, if one steps on the brake pedal with a certain force, its effect should be visible outside the car (a slowing down of the changes in environment), as well as on the speedometer (a reduction of the indicated speed). In good simulators one also hears the change in the sound of the engine. If a simulator has a moving base, the vehicle model also causes changes in the driving direction and speed of the simulator vehicle to be felt.

- *Traffic model*. This is the software that simulates the behaviour of the other traffic. It is important that the other road users shown on the simulator screen move as naturally as possible, that they comply with the traffic rules – unless one deliberately wants them not to for training purposes – and that they behave in a way that is predictable for themselves and for the simulator car. If the driver of the simulator car does something unexpected, the other traffic should react to it and not just act as if nothing has happened. It is also important for training purposes that the simulator instructor can intervene in the traffic model. For example, if one wants to train learner drivers in giving way at an intersection, one must ensure that traffic is coming from the sidestreets at the moment that the learner approaches the intersection. Some simulators have the possibility of intervening in the traffic model and other simulators only have what is known as randomized traffic which cannot be made to fit the instructor's wishes. Thus, simulators differ strongly in their possibilities, elaborateness, and quality of traffic models.

- *Display*. This can vary from a computer screen right in front of the driver to surroundings that are projected completely around him. In the simulators used for the basic training in the Netherlands, the angle of vision varies from 180 to 270 degrees. The resolutions and update rates of the simulator screens also vary a great deal; at a low update rate the picture is jerky. And it needs to be said that the computer picture will always seem somewhat sterile in comparison with reality, even though the quality of graphics is improving rapidly, partly due to the popularity of computer games. In the early days, the picture was projected by a beamer, but increasingly the beamers are replaced by large plasma or lcd screens.

- *Scenario*. This determines the traffic surroundings and the situations that one comes across during the simulator drive: the roads in the simulator lesson should resemble roads as they really are. If a simulator has not been developed in one's own country, the surroundings can be very different from daily experiences. Furthermore, simulator lessons contain exercises with traffic situations that have been planned beforehand. Simulators vary a lot in the ease with which a scenario can be programmed. Even if it is quite easy to produce a made-to-measure scenario, there can be problems. If a learner, for example, turns left instead of right, he will no longer encounter the planned situation from which he should have learned something. The learner, as it were, simply drives 'out of the picture'. In Germany, the Interdisziplinäres Zentrum für Verkehrswissenschaften (IZVW) has developed flexible scenario software. When a learner drives 'out of the picture', he is automatically returned to the original lesson without him noticing it (Kaussner et al., 2005).

What are the theoretical advantages of a simulator?

The driving simulator has a number of didactic advantages over the instruction vehicle, but only if these didactic advantages are used optimally. According to Fuller (2008) a driving simulator has the following training benefits:

- *Faster exposition to a wide variety of traffic situations*
  Scenarios can be made in such a way that they offer many educational moments in a brief period of time. This makes the training more intensive. During lessons in real life traffic the educational moments often are more scarce.

- *Improved possibilities for feedback from different perspectives*
  It is impossible to learn without receiving feedback. Driving simulators have the possibility to give visual feedback while a learner is driving. For example, the instructor can say that a learner is swerving and illustrate this by projecting a straight line onto the display. In addition, simulators make it possible to afterwards show a recording of the learner's performance from a bird's eye perspective or from another road user's point of view. Furthermore, possibilities are being explored to make a rough registration of in which direction the learner is looking. After having gone through a scenario, the recording can be shown with the visual fields superimposed. The learner is then

faced with the things he missed (e.g. hazards) because he was looking in the wrong direction.

- *Unlimited repetition of educational moments*
  For example, if an instructor in an instruction vehicle wants to practice merging onto a busy motorway, he is dependent on this difficult situation occurring during the driving lesson. In a simulator the desired situation can be stage-managed and repeated again and again.

- *Computerized and objective assessment*
  In a driving simulator, a learner's performance can be measured very accurately and objectively. In a practical learning environment one has to more or less rely on the driving instructor's 'clinical observations'.

- *Demonstration of manoeuvres*
  During a practical lesson the instructor tells the learner how to act. The instructor will rarely go behind the wheel to show how a certain manoeuvre should be performed. A simulator has the possibility to demonstrate manoeuvres first.

- *Safe practice environment*
  Very few learners will have had practical lessons in, for example, dense fog. A simulator offers a safe practice environment for driving in dangerous conditions.

What are the possible disadvantages of learning to drive with a simulator?
Simulators, however, also have a number of possible disadvantages. A simulator is an imitation of reality. Even in the most advanced high-end simulators that are much too expensive to be used in the basic driver training, the imitation of real life is far from perfect. Experiments in educational psychology have shown that there is no *transfer* if the learning environment clearly deviates from reality (Groeger, 2000). This means that what has been learnt in a certain educational environment, in this case the environment presented by the simulator, will not be applied in an environment that is clearly different, in this case in real life.

Another potential problem is the *retention* of what has been learnt, or the extent to which it sinks in. Skills are acquired much quicker in structured training, than when they are learned more or less incidentally. This means that using training blocks in a simulator to repeat an exercise until the skill has really been mastered and then proceeding to the next exercise, is a faster method than learning more or less randomly during a practical driving lesson (Wierda, 1996). However, experiments (Shea & Morgen, 1979) have shown that, although the learning process is quicker in structured training blocks than in accidental events on the road, what has been learnt is forgotten quickly if it is not applied immediately. What one has learned more or less randomly in practice sinks in and is mastered considerably better. Problems with transfer and retention may occur when using simulators in the basic training, but little study has been made of this.

A problem that certainly exists is simulator sickness. Simulator sickness is a type of motion sickness that expresses itself in nausea. Motion sickness occurs because that which the organ of balance registers is not the same as what one sees. If one drives round a bend in a simulator without a moving base, the organ of balance registers nothing because the 'vehicle' isn't moving. The eye, however, does experience taking a bend due to motion of the projected picture. The simulator screen's jerkiness during rapid changes, and the frequent brief delays between the turn of the steering wheel and the motion of the picture also play a role in simulator sickness occurring. However, experience has shown that simulator sickness is not frequent among those who have little or no driving experience. Simulator sickness is a much bigger problem among experienced drivers (Kappé & Van Emmerik, 2005).

Which are the minimum requirements of a simulator used in driver training?
The most important requirement of a simulator for training purposes is that one learns. A good imitation of reality is therefore a precondition because, understandably, without it there is no transfer. That is why the usefulness of a simulator for driver training is always determined by its technical quality. However, this is not the only requirement; the quality of the simulator lessons is also important. If the simulator is good, but the lessons are poor, one still doesn't learn. Driving schools that want to use simulators for training purposes should have a good curriculum. This should ensure that the simulators are used in the training course in such a way that their educational effect is optimal. Important in this is the design of the curriculum, for example, does it progress from easy to difficult? In

addition, the training objectives of each simulator lesson must be clear and it must be possible to test whether these objectives have been achieved. Other important requirements when purchasing a simulator and its training programmes are: 'are instruction and feedback didactically correct?' and 'can the simulator lessons be adjusted to the pace and learning style of the individual learner?'.

How are simulators used in driver training?

In Dutch driving schools with a simulator, learners usually first follow all the simulator lessons before they start the driving lessons on the road. These simulator lessons are subdivided into several modules: vehicle control, intersections, and motorways. Each module consists of a number of lessons and is concluded with a test. Before each simulator lesson the learner is instructed by the simulator with text and illustrations, and during the lessons there is instruction and feedback from what is called a 'virtual instructor'. This is a computer voice that tells the learner what he must do and indicates how well he has done it. In this way the simulator lessons can be followed without a driving instructor actually being present.

There are also basic trainings in which the simulator lessons are integrated in the entire training course. Before every simulator lesson a learner first follows an interactive computer programme. This Computer Based Training (CBT) uses films and animations to show how manoeuvres must be performed and the learners have to answer a number of questions. The CBT is followed by the simulator training. These lessons also use a virtual instructor. The simulator training is followed by the actual practical driving lesson. This driving lesson takes place in real traffic and focuses as much as possible on grinding the skills that have just been learnt in the simulator. After this practical lesson the cycle, i.e. CBT - simulator training - driving lesson starts again with the next block of training objectives.

It is not known whether learners learn better by first taking all the simulator lessons followed by all the practical driving lessons, or whether it's actually better when simulator lessons and practical lessons alternate. Considering the problems with retention and transfer that could occur (see The possible disadvantages in this fact sheet), the integrated programme is preferred in principle.

The virtual driving instructor

Using a virtual instructor can save driving instructor's time. This makes a simulator attractive to driving schools, in spite of the relatively expensive purchasing costs. However, it is not certain that it is didactically a good idea to replace the driving instructor by a machine as much as possible. An advantage of machines is that they will never fail to provide feedback. But in order to learn something that sinks in, it is important to *not* always provide feedback. If feedback is not always automatically provided, learners learn to see for themselves whether they do something right or wrong. Another point is that in the current simulators for training purposes, the virtual instructor cannot see which way a learner is looking. Therefore, a virtual instructor does not give the learners any feedback about their looking behaviour. As we indicated earlier, there are developments concerning methods to register the viewing directions.

Are simulators in the basic driver training good for road safety?

Not much research has been done into the safety value of simulator training in the basic driver training. The research that is available focuses on the effect that simulator training has on hazard perception (see also SWOV Fact sheet *Training hazard perception*). In the United States, for example, Allen et al. (2008) showed that a lower crash rate during the first years after passing the driving examination was found for learners who during their driver training had lessons in skills like risk awareness, hazard perception, and making decisions under time pressure, than for learners who had not received such simulator lessons. These lessons were followed on a fairly advanced simulator (no moving base, but a car as a mock-up and a 135 degrees angle of vision. A minus of this study, however, is that the subjects were not randomly assigned to the different conditions: training on a simple driving simulator, after which there was no decline of the crash rate, and training on an advanced simulator, after which there was a decline of the crash rate. This can have seriously distorted the findings.

Vlakveld et al. (2011) have found that novice drivers looked for potential hazards considerably more after a simulator training in hazard perception. This also happened in situations that had not been trained; this means that transfer had taken place. This simulator training made use of 'error training' which does not give instructions, but works with learning from the errors that are evoked in the training

scenarios. In China, Wang, Zhang & Salvendy (2010) have also developed an effective simulator training for novice drivers.

In the Netherlands, driving simulators in the basic training are only used for learning the basic skills and not for higher skills like hazard perception and risk awareness.

Conclusion

When using a simulator in driver training, its technical quality is important, and so is the quality of the simulator lessons and the way in which these lessons are embedded in the driving course. In no other country than the Netherlands are simulators so widely used for the basic training. Research increasingly indicates that simulator training can contribute to the improvement in novice drivers of higher order skills like hazard perception, In the Netherlands driving simulators are not yet used for that purpose in the basic driver training.

Publications and sources [SWOV reports in Dutch have a summary in English]

Allen, R.W. , Park, G. D. & Cook, M. L. (2008). *The effect of Simulator training on novice driver accident rates.* In: Dorn, L. (ed.), Driver behaviour and training, Volume III; Proceedings of the Third International Conference on Driver Behaviour and Training, 12-13 November 2007, Dublin, Ireland, pp. 265-276. Ashgate, Aldershot [etc.].

Fuller, R. (2008). *Driver training and assessment: implications of the task-difficulty homeostasis model.* In: Dorn, L. (ed.), Driver behaviour and training, Volume III; Proceedings of the Third International Conference on Driver Behaviour and Training, 12-13 November 2007, Dublin, Ireland, pp. 337-348. Ashgate, Aldershot [etc.].

Groeger, J.A. (2000). *Understanding Driving-Applying cognitive psychology to a complex everyday task.* Psychology Press Ltd., Routledge.

Kappé, B. & Van Emmerik, M.L. (2005). *Mogelijkheden van rijsimulatoren in de rijopleiding en het rijexamen*. TNO-rapport: TNO-DV3 2005 C114. TNO Defensie en Veiligheid, Soesterberg.

Kaussner, A., Grein, M., Krüger, H-P. & Mark, Ch. (2005). *SILAB-ein neues Simulatorkonzept*. Proceedings of the TTD-Conference Technology based Training for Drivers, Dresden, 17/18 November 2005.

Kuiper, B. (2010). *Instructeur is voorlopig niet te vervangen; Rijsimulatie: de stand van zaken*. In: Reflector, nr. 8 (oktober 2010), p. 8-9.

Shea, J.B. & Morgan, R.L. (1979). *Contextual interference effects on acquisition, retention, and transfer of a motor skill.* In: Journal of Experimental Psychology; Human learning and memory, vol. 5, nr. 2, p. 179-187.

Wierda, M. (1996). *Leren rijden zonder auto*. In: Steyvers, F.J.J.M. & Miltenburg, P.G.M. (red.), Gedragsbeïnvloeding in verkeers- en vervoersbeleid. Verkeerskundig Studiecentrum VSC, Rijksuniversiteit Groningen, Haren, p. 25-29.

Vlakveld, W.P., Romoser, M.R.E., Mehranian, H., Diete, F, Pollatsek, A. & Fisher, D.L. (2011). *Does the experience of crashes and near crashes in a simulator-based training program enhance novice drivers' visual search for latent hazards?* In: Proceedings of the Annual Meeting of the Transportation Research Board (TRB), 22-27 January 2011, Washington D.C. [Te verschijnen]

Wang, Y., Zhang, W. & Salvendy, G. (2010). *Effects of a simulation-based training intervention on novice drivers' hazard handling performance.* In: Traffic Injury Prevention, vol. 11, nr. 1, p. 16-24.

Winter, J.C.F. de, Groot, S. de, Mulder, M., Wieringa, P.A., Dankelman, J. & Mulder, J.A. (2009). *Relationships between driving simulator performance and driving test results*. In: Ergonomics, vol. 52, nr. 2, p. 137-153.