WILL SIMULATOR TRAINING IN BASIC DRIVER EDUCATION HELP TO ENHANCE ROAD SAFETY?

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ABSTRACT
Which mental activities take place when people drive and how well do novices drive? And do we know how learner drivers learn to drive? Only when we have an answer on these questions, it is possible to discuss whether simulator training in basic driver training programmes will help to enhance road safety or not. On the basis of what is known of skill acquisition, the effects of instruction and feedback and the problems that may occur with regard to the transfer and retention of skills, it is argued that simulator training probably helps to speed up skill acquisition, but it will not help to make novice drivers safer. Laboratory studies on (simple) task acquisition imply that simulator training may even have an adverse effect on road safety. However, recent studies on complex (motor) skill learning indicate that simulator training during basic driver education probably will not hamper road safety. Now that at least in the Netherlands driving simulators are often used in basic driver training, their effects on safe driving after driving test should be examined.

INTRODUCTION
Driving simulators for basic driver training are popular. At this moment, in the Netherlands about a 100 driving simulators are in use at various driving schools. This is very surprising as the effectiveness of simulators for training purposes in basic driver training programmes is not known. In this paper the technical and didactical qualities of driving simulators for training purposes, are not discussed. Driving simulators are not the central issue in this paper. Rather the opposite approach is taken. The leading questions in this paper are: what do candidates have to learn to become safe drivers and what factors influence the acquisition of driving skills. Only when we have an answer to these questions, the possible contribution of simulator training to safe driving can be assessed. First, the different aspects of the driving task and the safety performance of novice drivers are mentioned. In the following section the theoretical assumptions about skill acquisition in general are discussed. Two important indicators for the quality of skill acquisition are transfer and retention. Transfer is the ability to apply skills in new situations. If retention is poor skills are soon forgotten after they are learned. The implications of what we know on skill acquisition, transfer and retention for simulator training in basic driver training programmes are discussed in the last section of this paper.

THE DRIVING TASK AND THE DRIVING PERFORMANCE OF NOVICE DRIVERS
Driving is among the most complex skills people ever acquire. Yet, for experienced drivers, driving has become such a routine activity that for them it is difficult to conceive how complex it really is. A driver has to execute various complex motor tasks (steering, braking, gear shifting, etc.) simultaneously in order to manoeuvre the vehicle smoothly and to keep trajectory and speed. These motor skills have to be executed with as little as possible conscious attention. This means that they have to be performed almost automatically. The reason for this is that the attentional resources of a driver are needed for mastering traffic situations. A driver has to scan the environment and on the basis of what he sees and what he knows, he has to diagnose the traffic situation. On the basis of this diagnosis he has to make a prognosis of how traffic situations will develop over time. A driver can only do this when he is able to predict adequately how other road users will act. With a set of possible outcome of future traffic situations in mind he has to make decisions in mostly only a few seconds or less about what he should do and then execute these tasks. When making decisions he not only has to assess how the traffic situation will develop, but he also has to assess his own limitations. Driving is partly a self paced task. When for instance a driver starts to drive faster, the task demands will rise. A driver has to learn that he should avoid traffic situations that are beyond his own capabilities. The most skilful driver is not necessarily the safest driver. Besides the aspects that deal with motor skills, cognition and meta-cognition a learner driver also has to develop the willingness to drive safely. A not so skilful driver that doesn't overestimate his own skills and that tries to avoid circumstances that are beyond his own

capabilities, drives safer than a skilful driver that overestimates his own skills. It seems obvious that well structured driver education is necessary in order to learn the proper knowledge, self-knowledge, skills and attitudes. It seems strange, but there is no evidence so far that formal driver training is any better than lay instruction (Mayhew & Simpson, 1996; Christie, 2001: Ferguson et al., 2003). This means that the accident risk of novice drivers who have obtained their driving license after having attended a formal pre-license training course based on a curriculum and driving lessons provided by a qualified driver instructor, is not lower than that of novice drivers that have obtained their driving license only after having driven around with an experienced driver (mostly one of their parents) sitting next to them. Probably the norms for passing the driving test are too low. It seems that people first really learn to drive once they have obtained their driving license. How the accident risk improves with gained driving experienced in the Netherlands, is shown In Figure 1. Similar trends are found in other countries (Maycock, Lockwood & Lester, 1991; Gregersen & Bjurulf, 1996; Sagberg, 1998; McCartt, Shabanova & Leaf, 2003).

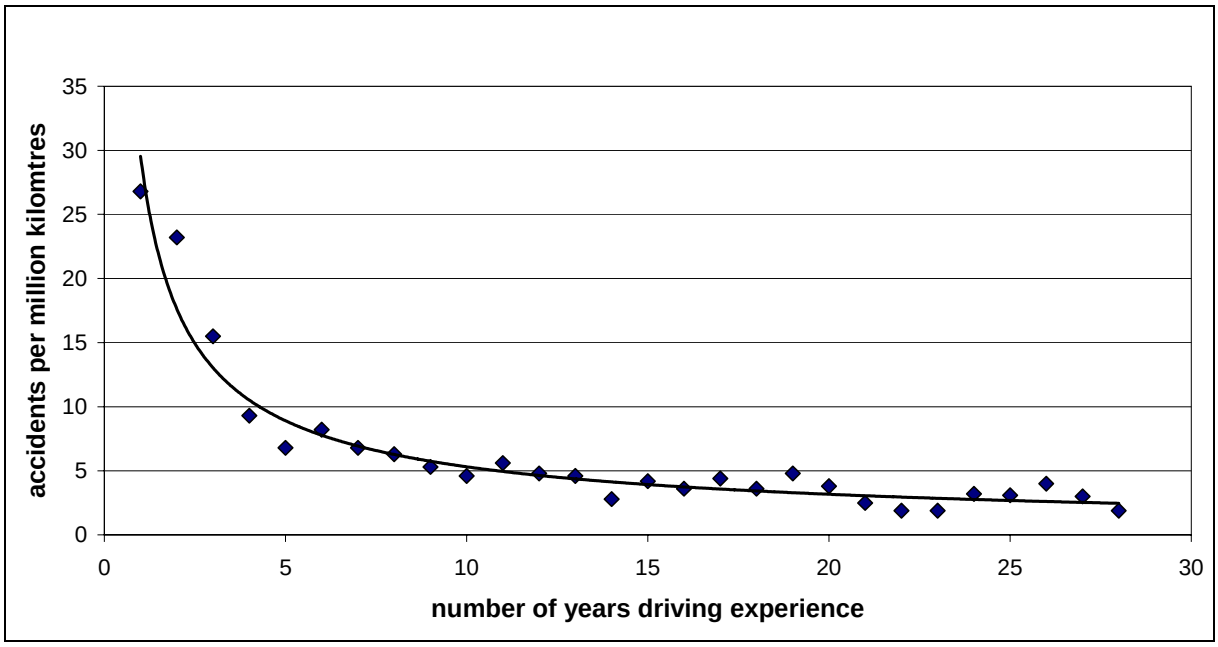

Figure 1 Number of self reported accidents in one year per 1,000,000 kms and years of driving experience for drivers that passed the driving test at the age of 18. Source: Vlakveld, 2005

The improvement of accident risk with gained driving experience after having past the driving test, seems to develop in accordance with the power function of practice (Newell & Rosenboom, 1981). This means that the gain from practice is considerably greater early in learning than it is later in learning. The formula for power functions of practice is:

$$\text{Number of Errors} = \text{Initial Level} \times \text{Amount of Practice}^{-\text{Rate of Learning}}$$

In other words, if it takes 100 trials to half the initial amount of errors, according to the power function of practice, it takes N times N-1 trials (= 9900 trials) to half the number of errors again.

There are some indications that simulator training during basic driver education helps to speed up skill acquisition (Wierda, 1996; Kappé, 2001). Learner drivers probably need less driving lessons (in real traffic) in order to pass the driving test when simulator training is part of the curriculum of basic driver education. From a road safety point of view however, this is not relevant. What is relevant is if simulator training helps to make novice drivers (after having obtained the driving license) safer? The question should therefore be if simulator training during basic driver training (before the driving test) helps to enhance the learning curve that is shown in Figure 1 (That would be a curve that starts at a lower level and that reaches its lowest point sooner). The main reason why there are almost no evaluation studies regarding road safety education programmes is that in order to measure the effects on accident risk of a particular training programme, enormous samples are required. After all, crashes are rare and to certain extent determined by chance. It is however also possible to measure the safety benefits of simulator training by assessing the safe driving behaviour in real traffic. As far as I know this has not been done so far with regard to simulator training, but this definitely should be done in the

near future. Before carrying out such a study, what could be the hypotheses for such an evaluation study? In the remaining part of this paper these hypotheses are explored.

HOW DO WE LEARN TO DRIVE?

Anderson (1982) has developed a theory on skill acquisition. His theory is on skill acquisition in general, but is applied here for learning to drive. Anderson assumes that there are three stages in skill acquisition. These stages are: 'the declarative stage', the 'knowledge compilation stage' and the 'procedural stage'. At first (during the declarative stage), performance is relatively unstable, as possible strategies are tested and rejected. During this stage the learner focuses consciously on isolated components of the driving task. When a driver at this stage also has to perform another task not related to driving (for instance talking with a passenger), task performance on the driving task deteriorates considerably. After enough practice, one reaches the knowledge compilation stage. During this stage verbal mediation of performance is far less and associations between action patterns in familiar conditions become stronger. Without a thorough analysis, familiar situations are recognized and a set of rules for that situation is applied. However, at this intermediate stage, a secondary task not related to the driving task, will still interfere with the driving task. Finally, after still more practice one reaches the procedural stage. At this stage the parts become compiled into procedures which are executed rapidly, almost automatically and without conscious awareness. Verbal mediation at this stage does not exist any longer and task performance is highly consistent, but has also become inflexible. Easy secondary tasks that are totally different from the driving task (for instance talking with a passenger) can be executed at this stage, without interference with the driving task.

Perhaps the procedural stage is not the end in the development of skill acquisition. Karmiloff-Smith (1992) takes as an example a piano player. Piano playing is not the same as driving, but both are complex skills. When one is learning to play the piano, initially there is a period during which a sequence of separate notes is laboriously practiced (the declarative stage). This is followed by a period during which chunks of several notes are played together as blocks (the knowledge compilation stage), until finally the whole piece can be played more or less automatically (the procedural stage). This is what Karmiloff-Smith calls 'reaching behavioural mastery'. However when this stage is reached, the learner can still not start in the middle of the piece or play variations on the theme. She thinks that the performance at the procedural stage is generated by procedural representations which are simply run off in their entirety. It is only later after more practicing but also because of rethinking of what one is actually doing, that one can interrupt the piece and start at, say, the third bar without having to go back to the beginning and repeat the entire procedure from the outset. The ability to play variations on the theme requires even more practicing and rethinking. Karmiloff-Smit hypothesizes that this is not because of improvement in behavioural mastery, but because of improvement of the mental representations that generate the skills. This is what she calls the process of 'representational redescription'. She thinks that there are three recurrent phases of representational redescription. These phases will not be discussed in this paper. What is important here is that skill acquisition probably goes beyond the procedural stage. This development is in the domain of the mental representations. Anderson describes the process by which conscious awareness gradually disappears during skill acquisition. Karmiloff-Smith describes the switching on again of consciousness after the procedural stage has been reached. Suppose that a driver applies his skills automatically and after that, unexpectedly a dangerous situation occurs. Then the driver starts to rethink why he has applied these skills. He wants to understand what has happened. The result of this rethinking is that his mental representations that accompany automatic task execution become more elaborate and flexible. There is so to speak a way down in skill acquisition. This is the process described by Anderson (from the declarative stage to the knowledge compilation stage to the procedural stage). And there is probably also a way up. This is the process of the improvement of mental representation, described by Karmiloff-Smit. Because of this second process piano players or drivers after having mastered the skill, learn to apply the skill in a flexible manner and in various contexts. It could be that the improvement in driving capabilities after having obtained the driving license (the decline in accident risk that is shown in Figure 1) is mainly caused by the process of representational redescription.

So far we only have discussed what is assumed to happen in the mind of the learner when he learns. There are however two very important mechanisms from the outside that help the learner driver to learn. These mechanisms are instruction and feedback. Instruction on how to execute tasks and feedback on how tasks were executed, help to enhance the process of skill acquisition. At the beginning (the declarative stage) instruction and feedback should comprehensive, but should gradually disappear. It is argued that the learner driver has to learn by himself how well he is

performing. If he doesn't learn to appraise his own skills, he will become dependent on feedback, and because of this task performance will deteriorate once external feedback is not provided. In theory simulators offer the opportunity to optimize instruction and feedback. In a real car instructions can only be provided orally, but in a driving simulator it is also possible to give visual instructions. In reality, a driver instructor tells the learner what he has done well and what he has done wrong (feedback). In a driving simulator the performance of the learner can be accurately measured and it is possible to provide automatic on line feedback. This makes driving simulators in principle useful training devices for the skill acquisition process described by Anderson. If simulators can also be used for enhancing the process of representational redescription, is doubtful. This process is on rethinking of what one more or less automatically is doing. Experience in this process seems to be of more importance than explicit instructions and feedback (Groeger, 2000). Simulators cannot offer the rich environment to gain the experience that help to make mental representations flexible.

RENTENTION AND TRANSFER

Two very important indicators for the quality of skill acquisition are *retention* and *transfer*.

Transfer

Transfer means the application of skills in situations that differ from the original learning context. If a skill is applied during a simulator session, but is not applied in real driving situations, there is no transfer. Transfer will always be poor when learner drivers don't develop a conceptual understanding why they have to execute a task in a particular way. The simulator environment is a reduction of the reality. Learning in a reduced reality may help to speed up the acquisition of skills, as it makes it easier for learner drivers to focus on the core of the skill. In several experiments on transfer it appeared when learning visual discrimination skills, those who encounter easy discriminations early in training (i.e. in a simulator environment) learned faster than those that were required to make difficult discriminations early in practice (i.e. during driving in real traffic early in training). However when, later in training, more difficult visual discriminations were required, the one's that were confronted with a rich visual environment from the beginning, learned faster than those that had started in a simplified environment. Because of poor transfer when the training conditions clearly differ from reality, Groeger (2000) thinks that with regard to road safety, the use driver simulators in basic driver training, will be counter productive. He says: "With regard to driving, and especially learning to drive, the findings from studies of transfer of training suggest that training drivers on actual roads, rather than under more simplified track or simulator conditions, offer the best chance of learners transferring what they have learned during training to the situations they will later encounter when driving alone."

Retention

Driver education is not effective when the acquired skills can be executed during the driving test, but are soon forgotten afterwards. Driving simulators allow for both mass practicing of sub-skills and for compression of the training course. When a learner driver takes driving lessons in real traffic, learning is varied and will partly depend on what occurs. If for instance, a learner driver has difficulties to merge onto a heavily used motorway, in real traffic, the driving instructor has to wait for the proper conditions, and the task can only be rehearsed after having left the motorway at the next exit. In a driving simulator, the instructor can set the proper conditions. The task can immediately be repeated and be rehearsed as often as wanted until the skill is acquired. It is a well known fact that with regard to rather simple (artificial) tasks, skill acquisition is faster when the task is divided in part-tasks and the simple part-tasks are trained in blocks (rehearsal of the same sub-task over and over again) than that the compete task and its variations are practiced all at once. In a laboratory study, Shea and Morgan (1979) had people touch each six objects in one of three sequences. One group (the blocked group) trained this task in blocks (rehearsing the first part-task over and over again and than starting with the next part task) and the other group (the random group) trained the task by practicing the various part-task in an random order (after only one trial with for instance the first part task, a trial with the second or the third part task was conducted). The task was trained during six training sessions. Directly after each training session the total time for completion of the whole task was measured. This time was also measured in a test 10 minutes after the last training session and again in a test 10 days after the training session. These two retention tests (10 minutes and 10 days after the complete training programme) could either be in a blocked condition or in a random condition (requiering retrieval). The results of this test are shown in Figure 2 (only the results on the second retention test (10 days after the training course) are presented).

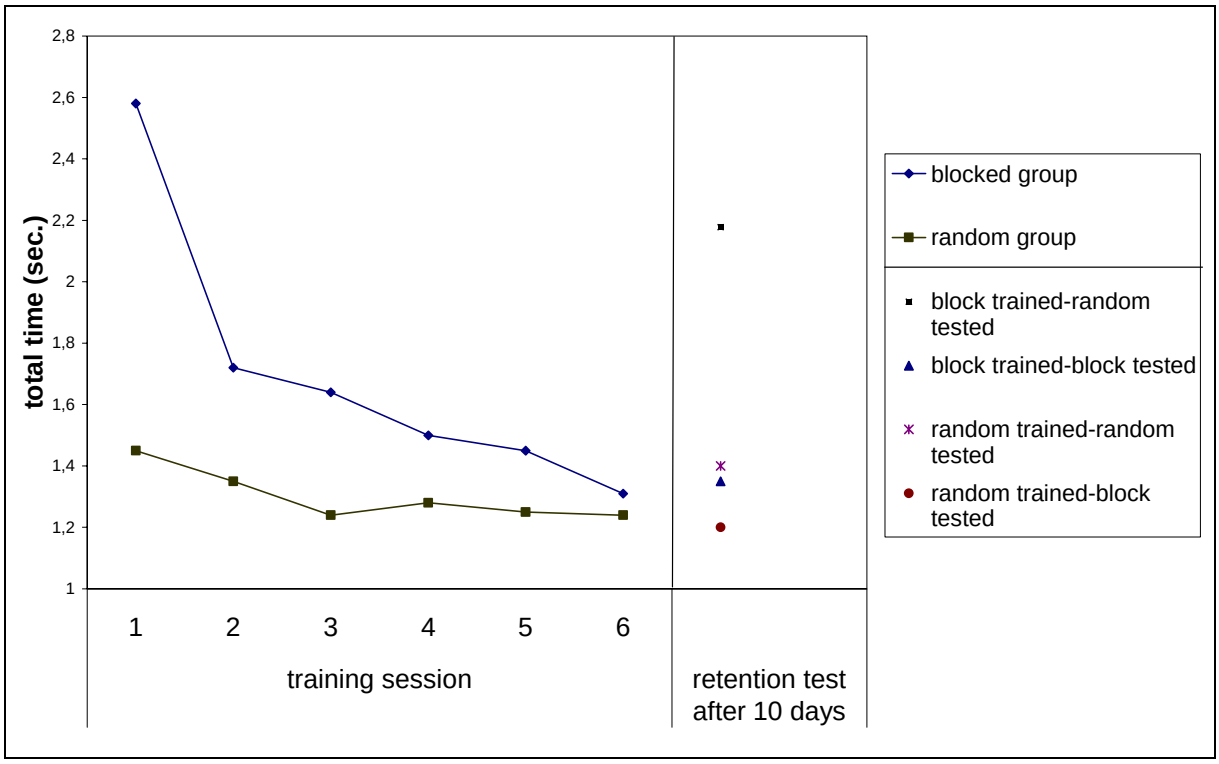

Figure 2 Learning and retention as a function of practice regime. Source: Shea & Morgan., 1979

As can be seen in the left side of Figure 2, in the beginning skill acquisition was much better when the group was trained in blocks. The random group appeared to be slow starters, but after 6 training sessions their performance was about just as good as that of the blocked group. However when both groups were tested after 10 days in a random condition, the group that had trained in blocks performed much worse than the group that had randomly trained. Driving in real traffic resembles much more the random test condition than the blocked test condition, as the driver has to decide which rules he should apply in which condition. Based on the results presented in Figure 2, very structured driver training programmes that driver simulators allow for, help to speed up the skill acquisition process, but may hamper the retention of skills.

One driving school organisation in the Netherlands especially uses driving simulators for condensed driver training programmes. In these condensed programmes, learner drivers train all day long during consecutive days. From various experiments (not related to driving) it is known that this also has an effect on the speed of skill acquisition and retention. This is the so called spacing effect. Baddeley & Longang (1978), carried out a study regarding the training schedules for the training of postman to work with a new sorting machine. They examined four different training schedules, ranging from 1 hour of practice per day (spaced) to 4 hours of practice per day (massed). The learning speed (plotted as keystrokes per minute as a function of hours of practice) was the best for the group that trained during 4 consecutive hours (massed training) and the worst for the group that trained only one hour per day (the spaced group). However retention after completion of the full training programme, appeared to be much worse for the postmen that had trained in the massed training condition than that of the postmen that had trained in the spaced training condition.

The mentioned research indicates that simulator training may improve learning speed, but will probably have a negative effect on the transfer and retention of skills.

IS SIMULATORTRAINING REALLY BAD FOR THE SKILL ACQUISITION OF COMPLEX TASKS?
The hypothesis in the former paragraph that simulator training in basic driver training programmes is bad for the retention and transfer of skills, is based on the results of experiments with mostly very simple artificial tasks in laboratory conditions. In a review of studies on simple and complex motor skill acquisition, Wulf & Shea (2002) come to the conclusion that principles derived from the study of simple (motor) skills do not generalize to complex skill learning. One of the conclusions from tests with simple tasks is that reduced task demands in the beginning of the skill acquisition process (i.e. the

simple road environment in a driving simulator) will hamper the transfer of skills later on in the skill acquisition process. For complex tasks such as driving, this conclusion doesn't seem to hold. A simplified learning environment (such as the simulator environment) where the learner can completely focus on the core of the task helps to acquire the skill. Another conclusion derived from tests on the acquisition of simple task is, that frequent and consistent feedback degrades the learning of skills. It is assumed that frequent external feedback will hamper the development of 'self-feedback'. However, frequent feedback can be advantageous if new complex skills have to be learned. Another finding from simple skill acquisition is that highly structured training in which part-tasks are rehearsed again and again (blocked training) helps to speed up the learning process in the beginning, but retention is poor afterwards. Wulf & Shea have found at least some studies regarding the acquisition of complex tasks where retention was about just as good in blocked training conditions as in random training conditions. And finally from studies regarding simple tasks, it appears that observing others performing the task don't seem to enhance skill acquisition. But Wulf & Shea mention studies on complex task acquisition where observation appears to be effective for complex skill learning. Not all simulators are suitable for observing others and one can also observe other drivers from the backseat of a real car. What cannot so easily be done in a real car but can easily be done in a simulator, is to record one's own behaviour and replay it during a debriefing session. Neither simulators nor cars are good training devices for showing how and why tasks have to be executed in a certain manner. However this can very well be shown and explained in Computer Based Training (CBT). For this purpose training session (be it in a simulator or in a real car) can start with CBT.

CONCLUSIONS

We don't know how effective simulator training for learner drivers is and we desperately need good evaluation studies. There are no indications so far that simulator training in the basic driver training programme, will help to make novice drivers safer. There are indications however that simulator training can speed up skill acquisition. Laboratory studies on (simple) task acquisition indicate that simulator training may reduce transfer and retention. However recent studies regarding complex skill acquisition have shown that this may not be the case. To minimize possible loss of transfer and retention, tasks learned in a simulator should be immediately practiced in real traffic after a simulator session. Whether simulator training can help to improve mental representations once skills are mastered at the behavioural level seems doubtful, but it may be possible. Much more research on the use of simulator training for so called higher order skills is required. Only when we are able to develop effective simulator training sessions for higher order skills, simulator training can help to enhance road safety.

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