DSC North America 2003 Proceedings, Dearborn, Michigan, October 8-10, 2003 (ISSN 1546-5071).

VIRTUAL INSTRUCTION IN DRIVING SIMULATORS

Dr. B. Kappé, Drs. M van Emmerik, Dr. W van Winsum°, Mr. A. Rozendom*

TNO Human Factors
Kampweg 5, 3769 DE
Soesterberg, The Netherlands
Tel: +31(0)346356248
Fax: +31(0)346353977
Kappe@tm.tno.nl
www.tm.tno.nl

°ST software
P.O. Box 2043
9704 CA Groningen
The Netherlands
Tel +31 50 5778768
Fax +31 50 5775835
info@stsoftware.nl
www.stsoftware.nl

* VVCR Virtual-Reality
Markeloseweg 94
7461 PB Rijssen
Tel: +31 548 514137
Fax + 31 548 514255
a.rozendom@vvcr.nl
www.vvcr.nl

Submitted [24-9-2003]

ABSTRACT

Driving simulators are a valuable tool for driver training. They allow basic vehicle handling and traffic participation to be trained effectively. Since traffic situations can be controlled, many situations can be presented in a short time-span. This makes a simulator training more effective than training in the real world. In addition, if simulator didactics are at a sufficient level, one instructor can train multiple students at the same time, which substantially increases the cost-effectiveness. In this paper we describe some of the steps that were undertaken in the development of such a 'virtual driving instructor'. We will describe what it is to drive a car, how to learn that in practice, and how to learn that in a driving simulator. These steps are the basis for a discussion on virtual instruction in driving simulators, in which we present some of the current and future work on a cost-effective driving simulator.

INTRODUCTION

Most of us are able to drive our car almost effortlessly. In city traffic, we are able to negotiate complex and highly interactive traffic situations with relative ease. This is remarkable, since driving in modern traffic is one of the most difficult and most widespread tasks that man can learn. While driving, many subtasks have to be performed simultaneously, in an environment with many rules and complex interactions. The reason why we can manage such a complex task is because the brain has learned to handle such tasks efficiently (i.e., 'automated'), with a relatively low cognitive workload. The difficulty and complexity of traffic becomes more obvious if you, as an experienced driver, go back to the time you were learning how to drive a car. Initially, students tend to have a very high workload. During the learning process, cognitive workload is gradually reduced, and driving (sub)tasks are more and more automated. One of the primary tasks of a driving instructor is to guide the student through this process. By structuring the learning trajectory and giving instructions and feedback, he guides the students to master more and more driving (sub)tasks in the correct manner, while keeping the cognitive workload at acceptable levels.

Currently, driving simulators are on the verge of a wide-scale introduction in the training curriculum of novice drivers. By controlling the traffic environment, a driving simulator allows specific, well-chosen, traffic situations to be presented to the student. This allows an instructor to control the learning environment, and to train specific driving (sub)tasks. Students no longer need to drive lengthy stretches of uninteresting or non-instructive traffic environments. In a simulator, students can be trained with a very high intensity of instructive, targeted exercises. Thus, students can learn much faster in the simulator than they can in the real world. Using a driving simulator, driving instructors have estimated that, 1 hour of simulator training is equivalent to 3 hours training in the real world. Such a number is an important factor in the cost-effectiveness of a driving simulator system. Since driving instruction is a 1 on 1 training situation, a further cost reduction can be obtained if the instruction is given by the simulator itself, using a virtual driving instructor. This allows one (human) instructor to supervise several students at the same time.

TNO Human Factors has contributed to the VVCR driving simulator (1,2). This cost-effective driving simulator is currently in use at ANWB driving schools in the Netherlands. It is based on a suite of simulator software developed by ST software, a spin-of from the driving simulator research at the University of Groningen (3,4). Its most recent version allows for large, multi-lane road networks, with complex intersections and roundabouts. Its scenario specification language and scenario editing tools allow complex traffic scenario's to be developed for city traffic. In the scenarios, the traffic model can be used as a normative model to evaluate driving performance. In this driving simulator, a virtual instructor will be used to standardize training, and to reduce cost. Commissioned by VVCR, TNO Human Factors is developing a virtual driving instructor. TNO cooperated with ST software to extend their software suite with a virtual driving instructor. In this paper, we report on some of the initial steps that were undertaken. In this process we have analyzed the driving task, how to learn that in practice, and how to learn that in a driving simulator. These components are the basis for a discussion on virtual instruction in driving simulators.

DRIVING A CAR

Before we can understand (virtual) driving instruction, we must first understand the nature of car driving itself. The driving task has been analyzed in many different ways, and for many different goals. Three of them are presented here. We will discuss driving from a psychological, an analytical and a functional point of view.

In his analysis of the driving task, Michon (5) discriminated 3 levels; operational, tactical and strategic. Michon's taxonomy originates from a psychological viewpoint.

Operational tasks are tasks that involve the direct control over the own vehicle, typically with a short time-scale (less than about 1s). At the operational level, the driver is typically involved with lane choice, lane position keeping, speed choice, braking and accelerating, starting and stopping. In terms of training, operational tasks are relatively simple, and they can be mastered in a few hours. Many operational tasks involve the execution of procedures or action sequences, e.g. changing gears, starting and stopping. These action sequences are generally automated, and the execution of such tasks does not increase cognitive workload. Most drivers are able to manage operational tasks quite well. Operational tasks are only demanding in extreme conditions, like when skidding, during emergency braking or when racing.

At the tactical level, the driver is interacting with other traffic. The time-scale is in the order of 1 to 10s. Traffic rules, road infrastructure, traffic participants and situation awareness are of primary importance here. This is where the driving task unfolds in its full complexity. Negotiating a two-lane roundabout in dense traffic, merging into a busy highway, or driving in built-up areas with many pedestrians and cyclists are typical examples of such complex tasks. The tactical level can be described in action sequences or scripts, just like the operational level. However, these scripts can only be partially automated, are subject to substantial variation, and may pose a substantial cognitive workload. When negotiating an intersection the driver generally has automated the traffic rules, control actions, scanning and the use of the mirrors, and the perception of the basic trajectories of other participants. This may automatically lead to a good sense of situational awareness. Aspects that increase cognitive workload are the interpretation and prediction of the behavior of surrounding traffic, making eye contact, deciding when to initiate a maneuver etc. There is a wealth of information in the driver's environment that allows such 'higher-order' aspects to be derived. Typically, it takes a few years of driving experience before drivers are skilled in picking-up such information.

At the navigation level, the driver is involved with route planning, and route selection. The typical time-scale for these tasks is in the order of 10s or more. The navigation level primarily involves cognitive skills, like planning and weighing different aspects, such as route length, traffic density, safety and scenery.

The driving task can be structured along different lines. McKnight and Adams (6) have scrutinized the driving task in all its aspects. This resulted in a highly detailed and complex task analysis, with a total of 1700 tasks, grouped in 45 main tasks. As a consequence of its complexity it is not easy to use, and it has a substantial degree of overlap in subtasks. In an attempt to reduce the complexity (and increase the usability) of the task analysis, van Winsum and Korteling (7) have chosen a different approach. He defined so-called 'Elementary Driving Tasks' (EDT's). An EDT may consist of a sequence of elements that must be executed in a fixed order, i.e. a driving procedure. EDT's have a minimal overlap with other EDT's, can be performed simultaneously, and can be defined in such a way that the driving task can be covered with a minimal set of EDT's.

Most driving instructors will not describe the driving task according to the previous psychological or analytical taxonomies. If you ask an instructor, driving a car is something like 'following the road', 'overtaking', 'negotiating an intersection', and 'making a right turn'. This is a *functional* or *descriptive* type of task analysis, describing the tasks that a driver has to be able to perform when driving his vehicle. Generally, instructors will also mention *normative* aspects of driving tasks, i.e. 'overtake without disturbing oncoming traffic'. In the Netherlands, the driving task, learning goals, traffic rules, performance criteria and driving standards are described in detail (8, 9, 10) Generally, driving tasks are related to vehicle operation (start, stop, change gears etc.) and traffic infrastructure (highways, roundabouts etc.). Table 1 shows an overview of the driving tasks that are trained in the Netherlands

Table 1 Driving tasks trained in the Netherlands

Vehicle handling, operational tasks	Vehicle operation, starting, driving-off, stopping, changing gears, braking & steering
Traffic participation, tactical tasks	Scanning strategy, lane selection, curve negotiation, situation awareness
	Single and multiple intersections, mini-roundabouts
	Intersections with conflicting traffic, merging from parallel roads, overtaking.
	Traffic, lane technique, traffic signs, independent driving
	Roundabouts, merging, exiting, overtaking
	Driving on highways and motorways, driving outside the built-up area

Each task that is mentioned here is composed of several task elements or sub tasks. For instance, 'Crossing an intersection', consists of: 'recognize the presence and type of intersection', 'judge the visibility of crossing traffic', 'look in the rear view mirror for traffic from the rear', 'adjust speed according to visibility', 'look in front, to the left, in front and to the right', 'drive across the intersection, giving right of way if required'. For each subtask, performance measures can be set. For instance: 'recognize the type of intersection in time', 'select approach speed to allow for a successful emergency braking maneuver', 'perform the scanning techniques correctly' and 'correctly apply the priority rules'.

We have analyzed the driving task by means of a functional task analysis. To a large extent, it follows the taxonomy that instructors use in their description of the driving task. For each subtask, we specified specific learning goals are specified, as well as the items that should have the specific attention of the instructor (i.e. the 'performance measures'). As an example, we will give the learning goals for the subtask 'approaching an intersection', as they are found in the instructor's manual, see Table 2.

TABLE 2 Task, task elements and learning goals

Subtask	Task elements	Learning goals
Approaching an intersection	Recognize the presence and type of intersection Judge the visibility of crossing traffic Look in the rear view mirror Adjust speed according to visibility Look in front, to the left, in front and to the right	Recognize type of intersection in time Select a safe approach speed Perform scanning techniques correctly Apply rules correctly

As can be observed in the example above, tasks and performance standards are generally not defined in a way that is useful to a driving simulator. Task are described in common language, like 'judge if the speed has to be adjusted', 'keep a safe distance from leading vehicles', 'drive off smoothly', 'switch on the indicator lights briefly before merging onto the highway'.

A functional description of the driving task is the basis for many driving courses. It couples task elements with learning goals, in a way that is clear to both the driver and the instructor. This is a good start for the development of a simulator driving course (see section on simulator training). However, it is not sufficient for the development of automatic instruction and performance evaluation in driving simulators. Here 'safe distances' have to be defined as a minimal time-headway margin, and smoothness in m/s^3. Defining an acceptable standard for such measures requires detailed knowledge of vehicle control and traffic psychology. In the development of a simulator curriculum, much effort goes in defining the correct performance measures and in the definition of their standards.

HOW DO YOU LEARN HOW TO DRIVE?

When learning how to drive, students have to master almost all aspects of the driving task. During initial driver training, at driving schools or otherwise, students first master tasks at the operational level, then the tactical level, and ultimately the navigation level. During this learning process, there's a gradual shift from cognitive processing and associative processing to automatic processing of action sequences. By automation we mean that information processing required for driving (sub) tasks is more and more performed by dedicated brain programs ("wetware"), that develop during the training process and that do not or no longer require cognitive attention. The process of automation can be divided in three stages (11). In the cognitive stage, students are thinking actively with each individual action. In this stage, students use most of their mental resources to perform the task. There's almost no capacity left for other stimuli, like surrounding traffic or instructions from the instructor. In this stage, instructors primarily attend to the correct order of task elements, not to the timing in which they are executed. In the associative stage, the students have automated the task to a large extent, but with increased workload performance tends to drop dramatically. In this stage, the instructor not only attends to the correct sequence of task elements, but also to the timing and style. Finally, once tasks are fully automated, students should master the order and timing of task elements. The task has become a routine, and the student may use his cognitive capacities for other tasks. The task will be executed correctly, even at high workload levels. Once mastered, routines are difficult to change.

These stages can be distinguished on different levels during the training process: students will begin with simple operational tasks, such as starting and stopping, changing gears, braking, signaling and steering. It is very important that students learn these action sequences in the correct order. A good instructor will drill the student in performing these sequences correctly. As soon as students are comfortable with basic vehicle operation (end of associative stage, beginning of autonomous stage), the training of traffic participation begins. Just like starting and stopping, action scripts can be defined for negotiating traffic situations. Again, students start with a basic set of simple situations to master the basic principles. Once the action scripts are associated or automated, more difficult variations are trained, with more traffic and/or more complex road infrastructure.

Apart from the type of instruction, a driving instructor will select a specific route for a student. In the beginning, the student will be driving in quiet suburbs. During the curriculum, the complexity of the traffic infrastructure that has to be negotiated is gradually increased. In this phase many instructors will try to focus a driving lesson to a specific type of infrastructure, for instance large multilane intersections. Near the end of the curriculum, situations are mixed, and students are rehearsing real-life driving situations and the routes that are driven during their test.

The instructor will adapt his instruction to the phase of the learning process. Three phases can be discriminated: briefing, tutoring and debriefing. In the briefing phase, the instructor prepares the student on the lesson. Here, the relevant rules may be reviewed, and the student may get some tips or instructions what to attend to. Tutoring takes place during the driving lesson. Here the instructor refrains from extensive instruction, simply because there is not enough time. Tutoring can take place in different forms. The student may Act On Command (AOC) of the instructor, fully guided through every step of the procedure. After that, instruction is reduced, and the instructor will focus on giving feedback. Now, the student may Act At Will (AAW). At the very end of the curriculum, some instructors will 'test' the student by providing neither instruction nor feedback, and just give a review after the completion of the driving lesson. In this debriefing, the instructor reviews the driving lesson, summing up what was good and what aspects require some more training.

HOW DO YOU USE A SIMULATOR?

The ability to control the traffic and present instructive traffic scenarios at will is one of the principal advantages of a driving simulator. No longer does training depend on the irregular occurrence of 'random' traffic situations. Instead, a balanced, intensive training curriculum can be developed that focuses on a particular aspect of the driving task. Such situations can be presented at short intervals, without the need to drive lengthy stretches of road with unrelevant or already mastered traffic situations.

Driving simulation can be considered as a form of Scenario Based Training (12, 13, 14). An SBT is focused on controlled and systematically constructed scenarios that have been specifically created for training a certain (sub)task. It focuses, more than other forms of training, on the development of practice, diagnosis and feedback. It links training activities to learning goals (15). Figure 1 shows an overview of the SBT development cycle. Based on a task analysis, learning goals are derived. From these learning goals, training activities are derived that are modeled in scenarios. These scenarios are presented to the student in the simulator. For each scenario (and the underlying training activities and learning goals) performance measures are defined. After completion of the scenario, the performance of the student is graded relative to a set of standards. In the diagnostic process, it is determined why the student performed as was observed. Why did an error occur? Were the rules not known, was the sign not observed, or was the approaching vehicle not noticed. A good diagnosis is required to give proper feedback. It is of no use to focus on rules, when the student did not see a vehicle approaching because of an improper scanning strategy.

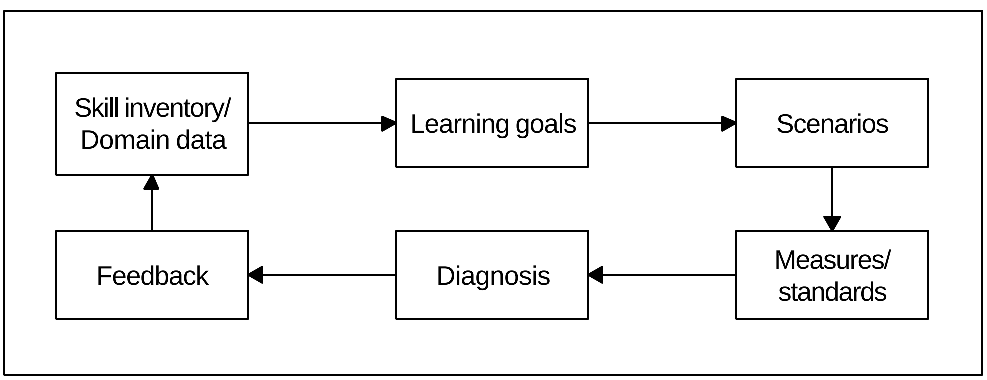

FIGURE 1 The Scenario Based Training (SBT) cycle

After completion of the scenario a new learning goal can be selected and a new cycle is started. The driving task and the learning goals have been discussed here, just like some of the training activities. We will discuss two simulator specific elements here: scenario and performance measurement.

Scenarios

SBT has its roots in command and operational tasks, such as a fire commander ordering his firefighters in a blaze. In SBT, a scenario is generally considered as sequence of events. Thus, scenario's can be quite long, containing several events. In a driving simulator, training can be centered on individual traffic scenarios: 'making a left turn at a priority intersection with traffic from the left', or 'merging on to a highway with busy traffic'. These scenarios can be modeled in the traffic model, using a Scenario Specification Language (SSL). SSL not only allows control over the simulated traffic. It can also be used for the tutoring process, i.e. on the fly instruction and instantaneous feedback. This leads to 'stand-alone' traffic scenario's that allow a student to be trained in a specific situation in traffic. Obviously, many different scenarios exist, with different types of instruction (AOC, AAW) and feedback, for different types of traffic infrastructure and traffic. A driving simulator lesson is composed of a sequence of such scenarios.

Creating traffic scenarios is not trivial. The traffic model should allow the predestined traffic situation to occur each and every time, on many types of roads, intersections, roundabouts etc. Tutoring requires on the fly performance registration and evaluation, and the prioritizing and scheduling of instruction and feedback. For example, it makes little sense to provide feedback on the use of the indicator during an overtaking maneuver when there is a vehicle near and approaching fast in your lane.

The tutoring process in fundamentally different in AOC and AAW scenarios. In the first, the student's behavior is prescribed, and the chain of events is paced by the simulator system. The student has to follow the instructions, and errors can be signaled right away. In the second, the student initiates his own actions, and the student paces the execution of the task. This does not allow instantaneous feedback, since the simulator may not know what the student is up to.

Performance measurement

Simulators allow a multitude of performance measures to be registered, and an overwhelming amount of information can be generated. The problem is not in *how* to measure, but *when* to measure *what*. In SBT, performance measures are supposed to have a direct relation with the scenario and the learning goals. They should allow the diagnosis of the underlying mental processes of the student that lead to the observed behavior. Performance measures can be classified for different aspects of the driving task: the operational level, the tactical level, workload measures.

Operational level

Performance measures of control tasks relate to steering and speed control, and to vehicle operation. Standard deviation (SD) of lateral position, SD lateral speed, Time to Line Crossing (TLC), number of lane boundary violations, and SD steering angle are typical measures for steering control. Average speed, minimum and maximum speed and number of speed violations are common for speed control (16).
Errors in vehicle control can be categorized as either sequence errors or operational errors. Sequence errors occur when a subtask is performed too early or too late in a sequence of events. When starting the vehicle, several checks have to be made in a fixed order before the key can be turned. Depending on the driving course, some students are only allowed to start the vehicle after they have checked (and corrected if necessary) if the hand brake is on, the gear is in neutral, and the lights turned off. Such action sequences occur in many basic vehicle operation tasks, like changing gears, braking in 2nd gear, strong braking in 3rd gear etc. An operational error occurs when actions are performed in the right sequence, but are incorrectly performed. This occurs for instance when the clutch pedal is not completely released after changing gears, or when the actions are not performed fluidly.

Tactical level

At the tactical level performance measures are related to the road environment and to other traffic participants. At this level, performance measures can be based on traffic rules. Which rules are valid, depends on the road infrastructure (layout, delineation, signs and signals) and on the type of participants that take part in the traffic scenario (pedestrian, motorcycle, car etc.). Apart from rules, interaction with traffic participants is important at the tactical level. It has been found that time plays an important role in interaction processes (17, 18, 19). Time related measures, like time headway, Time To Contact, Time To Intersection and the Post Encroachment time have been found to be relevant in traffic.

Scanning is an important aspect of driving, and instructor may spend much time drilling the student to perform the correct strategies. In a simulator, registering the viewing direction is not simple, but there are several systems available in the market. The problem however, is in the interpretation of the data. The human eye roams through the visual environment, and is guided intentionally and unintentionally towards visual landmarks (20). It is difficult to make sense from the eye movements of an observer, especially in relation to the surrounding traffic. In real life, the instructor can not see the exact viewing direction of his student. Instead he relies on observations of the orientation of the head (yaw angle). Students are told not to look from the corner of their eyes, but turn their heads instead. In some driving courses, the scanning behavior is quite well described. For instance, when approaching an intersection, students have to check the rear view mirror, look ahead, to the left, ahead, to the right and ahead again. Such a sequence is subject to sequence errors and operational errors. This sequence should also be initiated from a certain Time To Intersection (TTI).

Workload measures

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

Workload measures come in many varieties, see De Waard (21) for a review. They can be divided in self-reported workload measures (e.g. Subjective Workload Assessment Technique (SWAT)), Physiological measures (e.g. Heart Rate Variability (HRV)) and double tasks. We will briefly discuss one double task that has been used successfully in a driving simulator: the Peripheral Detection Task (PDT). In the PDT, a small sign is presented in the student's peripheral field of view. If it is observed, the student 'has to react by pressing a switch. Relevant measures are the average reaction time, and the percentage missed presentations both relative to a baseline. When the workload is high, both reaction time and percentage missed will increase. The PDT has been shown to be a reliable indicator of workload while driving a car, see Van Winsum, Martens & Herland (22) The underlying assumption is that with high workloads, students tend have a reduced functional field of view, and only respond to stimuli directly ahead of them. Most driving instructors are familiar with the 'tunnel vision' of students during periods of high workload.

Report

After completing the simulator lesson, a report can be generated by the system. In the report, an overview is given of the student's performance. The report does not display all the performance data that are used in the simulator. Instead, it presents performance information on a meta-level. For instance the aggregated number of errors negotiating intersections or roundabouts. This provides input for the debriefing by the supervising simulator instructor, and it serves as input for the human instructor for the driving lessons on the road.

Embedding a simulator in the curriculum

In the past, we have seen that many (driving)simulators fail to be effective, or only become effective after a few years of operation. Not that they were not good simulators, but because they were not integrated in the training curriculum of the school. Even the best simulator system will perform sub optimal if it is not an integral part of the training curriculum. A student should progress logically through the training, and books, CBT, simulator and driving in the real world should be integrated. Such an integration requires methodic approach, and detailed analysis of the training curriculum, the learning goals and a training needs analysis. Ideally, it is performed prior to the acquisition of a simulator system (Verstegen (23)).

VIRTUAL DRIVING INSTRUCTION

Working along the lines of the SBT development cycle, we have developed a basic virtual driving instructor for ANWB driving schools (ARO), a large driving school in the Netherlands. We based the scenario development on the task lists used by ARO and on our knowledge. In close cooperation with their instructors, lessons were defined around a certain topic, see Table 3. The lessons covered basic skills, like changing gears and braking, and traffic participation. In the traffic participation lessons, students initially receive extensive instruction to master the procedures. Using AOC and AAW type of instruction, it focuses on a particular topic, such as negotiating single lane intersections. Later on in the curriculum, lessons were composed of mixed traffic situations, with the emphasis on feedback. One 'test' lesson was developed, in which students did not have instruction nor feedback, and only received instructions on the route to drive. This resulted in a set of 19 lessons of about 20 minutes each with in total 492 scenario's, covering in total 360 minutes of simulator training, see Table 3 for an overview.

Table 3, Driving tasks trained in the driving simulator, and the number of scenarios in each lesson

Lesson	Tasks	Scenarios
1	Starting, driving-off, turning off, gears 1-2, braking	6
2	Gears 1-2-3, Gears 3-2, braking at higher speed	4
3	Scanning at intersections	19
4	Lane choice, driving curves	26
5	Single lane intersections	50
6	Multiple lane intersections	22
7	Single and multiple intersections, lane choice	43
8	Mini roundabout s	15
9	Lane technique, signs	44
10	Driving independently	52
11	Roundabouts	17
12	Driving outside the built-up area	19
13	Merging, exiting, weaving, following, overtaking on highways	10
14	Driving outside the built-up area	9
15	Merging, exiting, weaving, following, overtaking on highways	12
16	Single & multi-lane intersections, (mini) roundabouts, lane technique	50
17	Roundabouts	49
18	Lane technique, multi-lane intersections	27
19	(Busy)highways, sudden traffic jams	18
	Total	492

It has never been our intention to develop complete 'stand alone' driving simulator curriculum. You cannot train 100% of the curriculum in a driving simulator. A simulator is an abstraction of reality, and many aspects cannot be resented with sufficient detail or realism. For instance, things like having eye contact with drivers or pedestrians, and other subtle cues that allow the inference of their intentions are difficult to simulate. Thus, we restrict virtual instruction to the initial stages of driver training, with prototypical infrastructure and standard (both simple and complex) traffic situations. We train the basic procedures of negotiating traffic, and help students to automate them before going on the road. The human instructor will focus on tuning the acquired skills, and on the more subtle, higher order, cognitive aspects of the driving task.

Even for the tasks that are trained by the virtual instructor, we cannot do without a human instructor. We have not yet found a method that allows the virtual instructor to train and judge the scanning behavior of a student. A human instructor is required to keep an eye on this important aspect. The human instructor also plays a role as a 'remedial teacher' to diagnose and solve problems with the virtual instruction process. To allow the human and the virtual instructor to team-up, special care was given to the design of instructor-interface. The interface allows the instructor to keep an eye on the students scanning, in relation to the developing traffic scenario. See Figure 3 for an example. With the current setup, an instructor is able to monitor 3 simulator students at a time. A camera monitor system provides a view of the students head, and of the virtual environment

Future developments

Flexible simulator lessons

The current set of driving simulator lessons is linear: all students go through an identical training curriculum. This ensures that all students have had an explanation of the same basic procedures. This suits well in a highly structured driving course, like the ARO's, but it does not fit well to courses that are more flexible. We are developing methods to generate tailor-made simulator lessons. Thus, the virtual instructor is making a selection of the scenarios that would suit a particular student best. In theory, such an adaptive curriculum would allow each student to be trained at his or her optimal learning curve.

Augmented cueing

Traditional verbal instruction has some disadvantages in a simulator setting. Verbal messages generally take a few seconds, and once started, it is difficult to stop them in a natural way. This results in relatively slow, inflexible instruction. In a simulator, verbal messages can be replaced by visual or aural cues, e.g. a briefly presented sign with the maximum speed instead of the message ‘you are driving to fast’. It allows a brief instruction or feedback message that can be presented in parallel with other augmented cues and verbal instructions. Augmented cueing may also be helpful to teach students where to attend to while scanning the environment, by marking relevant elements in such a way that they attract visual attention.

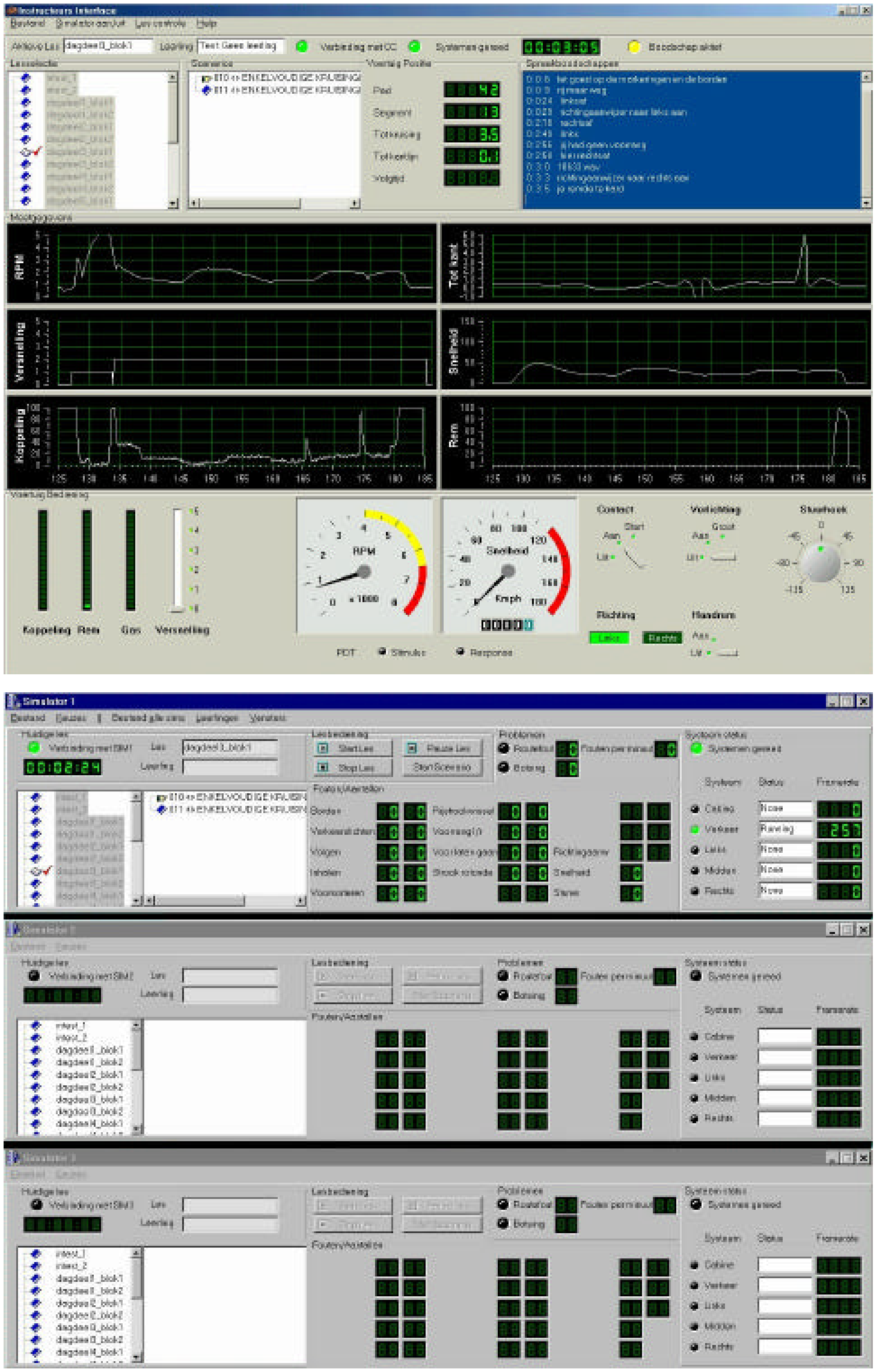

Figure 3, the instructor interface for each simulator (top) and the overview console (bottom).

CONCLUSIONS

A virtual driving instructor is a valuable option in a training simulator. It allows an instructor to teach multiple students at the same time, and it allows the instructional process to be standardized. However, automated driving instruction is a complex process, requiring an extensive analysis on the selection, timing and form of instruction and feedback. It also requires insight in the state and the mental processes of a student. Human instructors are able to evaluate such processes relatively easy, but virtual driving instructors are not. We feel that a virtual instructor has to be complemented with a human instructor. The human and the virtual instructor should be able to cooperate, each attending to their own specialties.

ACKNOWLEDGMENTS

We would like to thank the ANWB driving school for their help in the development of the traffic- and training scenarios.

REFERENCES

1. http://www.vvcr.nl/trainingen/Simulator/ENG/SimulatorMainENG.html
2. Kappe, B., van Winsum, W. & van Wolffelaar. P. (2002) A cost-effective driving simulator. Driving Simulator Conference DSC '02, Paris, France, pp. 123 - 135
3. Van Wolffelaar, P.C. & Van Winsum, W. (1994). A driving simulator for traffic research using a graphical workstation. In: Computers in Psychology 5. Applications, methods and instrumentation. Eds. F.J. Maarsse, A.E. Akkerman, A.N. Brand, L.J.M. Mulder and M.J. van der Stelt. Swets & Zeitlinger, Lisse, pp. 218-229
4. Van Wolffelaar, P.C. & Van Winsum, W. 1995. Traffic modelling and Driving simulation-An integrated approach. Driving Simulation Conference DSC'95, Sophia Antipolis, France, pp. 236-244.
5. Michon (1985). A critical review of driver behavior models. *Accident Analysis & Prevention, 21*, 341-353.
6. McKnight, A.J. and Adams, B.B. (1970). *Driver education task analysis. Volume 1: Task descriptions*. Alexandria, VA: Human Resources Research Organization, Final Report, Contract No FH 11-7336.
7. Van Winsum, W. and Korteling, J.E. (1998). Low-cost simulators 3b: Task analysis for driving simulation. (Report TM-98-A041), TNO Human Factors, Soesterberg, The Netherlands.
8. Rijprocedure B (1997), BOVAG, CBT, OCRIJ, PVI. Best, The Netherlands, Veka Best Verkeersleermiddelen.
9. Vlakveld, W. P. (2000). *Leerdoelen voor het rijbewijs B*. Rotterdam, The Netherlands: Adviesdienst Verkeer en Vervoer, Ministerie van Verkeer en Waterstaat.
10. Van Beersum, W. (2000). Praktijk begeleidingsboek voor de leerling. ANWB rijopleiding. Eindhoven, The Netherlands.
11. Fitts, P. M., & Posner, M. I. (1967). Human Performance. Belmont, CA: Brooks Cole.
12. Fowlkes, J., Dwyer, D.J., Oser, R.L. & Salas, E. (1998). Event-based approach to training (EBAT). *The International journal of Aviation Psychology, 8(3)*, 209-222.
13. Cannon-Bowers, J.A., Burns, J.J., Salas, E. & Pruitt, J.S. (1998). Advanced technology in scenario-based training. In: J.A. Cannon-Bowers & E. Salas (Eds.), Making decisions under stress: implications for individual and team training, pp 365 –374. Washington, DC: APA.
14. Oser, R.L. (1999). A structured approach for scenario based training. *43rd Annual Meeting of the Human Factors and Ergonomics society*. Orlando, Fl.

15. Bosch, K. van den, & Riemersma J.B.J. (in press). Reflections on scenario based training in tactical command. In: Samuel G. Schiflett, Linda R. Elliot, Eduardo Salas, & Mike D. Coovert (Eds.), *Scaled Worlds: Development, Validation and Applications.* Aldershot: Ashgate

16. Östlund, J & Törnros, J (2002) *Driving performance measures*. HASTE, Project grd1/2000/25361, Deliverable 1 Development of experimental protocol.

17. Lee, D.N. (1976), A theory of visual control of braking based on information about time-to-contact, *Perception*, *5*, 437-459.

18. Godthelp, J. Milgram, P. and Blaauw, G.J. (1984) The development of a time-related measure to describe driving strategy. *Human Factors, 26,* 257-268.

19. Horst, A.R.A. Van der (1990). *A time-based analysis of road user behavior in normal and critical encounters*. Thesis. TNO Human Factors, Soesterberg, The Netherlands.

20. Theeuwes, J (1991). Exogenous and endogenous control of attention: the effects of visual onsets and ofssets. *Perception & Psychophysics, 49, 83-90*.

21. De Waard, D.(1996). *The measurement of drivers' mental workload*. Thesis, Rijksuniversiteit Groningen, Groningen, The Netherlands.

22. Van Winsum, W., Martens, M., Herland, L. (1999). The effects of speech versus tactile driver support messages on workload, driver behavior and user acceptance. (Report TM-99-C043) TNO Human Factors. Soesterberg, The Netherlands.

23. Verstegen, D.M.L. and van Rooij, J.C.G.M (2003). Keep systematic training system design efficient!. *Proceedings of the Human Factors & Medicine Panel symposium on Advanced Technologies for Military training, Genova, Italy*