Automation of training and assessment with DATA Centred Design (DCD)

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Introduction

Operators of complex systems not only have to follow procedures but also have to recognize changes in the system and anticipate. Car drivers have to control their vehicle and participate in traffic at the same time. Traffic itself is a complex dynamic system with interaction between the operator, other traffic participants and traffic regulation systems. Novice operators make more mistakes due to the complexity of the system and have a high failure risk. All operators suffer from so called erosion of skills (EOS) in situations where automated behaviour is not stimulated enough. Ecological Interface Design (EID) is a world wide accepted design methodology for interfaces of complex real time dynamic systems. Operator failures due to erosion of skills are not within the scope of EID. EOS can result in severe system failures. This problem can also occur with the automation of driving tasks in smart vehicles solutions. In this presentation I propose a new method for interface design that incorporates EOS.

Erosion of skills – EOS -

The erosion of skills due to computer based automation is a major issue in aviation. Many plane crashes are directly related to EOS. Antonovich [1] reported that flight crews loose situational awareness as a result of automation. Other reported concerns include: loss of manual skill, overconfidence in automation, and difficulty in predicting and monitoring what the automation is doing or will do. These concerns are related to erosion of skills and pose a significant threat to air traffic safety.

Antonovich reported that the decrease of instrumental feedback due to automation is one of the factors behind EOS. Olson [2] stated that "in the absence of salient indications (i.e., Dashing lights, colour changes, etc.), pilots often do not pay attention to potentially relevant information." Without salient information the crew is likely to overlook or miss important or critical information.

EOS due to computer automation is widely known as "out of the loop syndrome.". The real cause however is not computer automation but brain automation. The automation of behaviour is a process in the brain that helps us to process the enormous load of information without much mental effort. The repetition of stimuli associated with a stored reaction (behaviour) strengthens the nerve connections that form patterns (information clusters) in the brain. In contrast to little stimulation can weaken a brain pattern. When a particular brain pattern is too weak, the reaction to the stimuli will not be activated. The behaviour seems to be forgotten. Because we are not aware of this process, the skill can erode unnoticed. The frequency and strength of stimuli have a direct influence on the process of strengthening or weakening of brain patterns. This confirms the observation of Olson about the absence of salient indicators and the observed performance drop of flight crews.

The relationship between performance and information load is described in the so called Yerkes–Dodson law [3]. Yerkes-Dodson's law incorporates the influence of stress and arousal, on performance. In high and low levels of information load the performance drops. Low levels of information can lead to boredom. When salient stimuli are missing, EOS starts.

Erosion of skills is not only a specific problem for operators who have to deal with computer automation, but it is a generic process related to the working of the brain. Automation of behaviour and skill acquisition, are the result of stimuli repetition. A high frequency of stimuli (that exceed the action potential threshold) increases automation but when the frequency drops the erosion of skills starts. Staying "in the loop" will help to stabilise or increase performance of (novice) operators during and after training and in the case of computer automation.

Ecological interface design – EID -

Jens Rasmussen [4] and Kim Vicente [5] developed a method for interface design, Ecological Interface Design (EID), aimed at improving the performance of operators and at the same time increase system stability. The term ecological originates from 'ecological psychology'. This area of psychology focuses on relations between mankind and his natural environment. EID differs from 'user centred design' (UCD), which focuses only on the operator. With UCD the emphasis lies on the operator of the interface and his experience executing a specific task. EID goes further and projects the operator's experiences in the operation of the total system. A system oriented approach instead of an operator oriented approach.

Ecological Interface Design is a structured method that keeps the mental workload low to improve the learning process and prevent operator failure as the result of an overload of working memory. EID stimulates knowledge based reasoning. Knowledge based reasoning supports the operator in unknown situations in which he cannot rely on automated behaviour. Low workload is necessary for knowledge based reasoning because the mental effort required is high. Automation of tasks supports the improvement of operator performance but it can also result in erosion of skills. EOS occurs in case the operator gets insufficient (salient) feedback from the system to keep automated skills at the desired performance level. EID should be improved to take account of EOS.

Data Centered Design – DCD -

EOS is an unconscious process. Therefore it is difficult for the operator to take precautions. External feedback is necessary to prevent operators from EOS. Accompanied driving for novice drivers is a good example of how to prevent younger car drivers for EOS after they get their driver's license. Parents deliver the necessary strong human feedback the instructor gave during driving lessons. After many kilometers the younger drivers learn how to interpret the weaker feedback from the traffic system. It takes about 5.000 kilometers to decrease accident risk by 50%.

EOS can be monitored by continual observation, data recording and data analysis. Data analysis is useful for pattern recognition. This can support the operator in the process of reasoning to find solutions for unexpected situations. This results in reduced load on working memory. Kirschner et al. [6] emphasizes that knowledge based reasoning is not an effective method to solve problems.

Data recording and data analysis are not components of EID. Therefore the author proposes a new method for interface design, Data Centered Design (DCD), a data oriented approach. The data from the system is the main objective and not the description of the system like EID has. System relations are often to complex to describe and analyze with human observations. Data analysis provides the most insight into the changes in components of the system. Relations between events are found more easily than with knowledge based reasoning.

EID enhances the performance of system operators through automation of skills, keeping the workload low. DCD enhances the performance of system operators through monitoring EOS. Avoiding EOS is more important than automation of skills. DCD encloses monitoring of workload and automation of skills, like EID.

Virtual assistant

I used the DCD methodology to develop a virtual driving assistant for the automation of training and assessment of novice car drivers. The main target was to teach students the basic driving principles on a driving simulator without the help of a driving instructor. In order to accomplish this a didactical model called 'dynamic balance' was developed. The basic principle of this model is the automation of driving tasks with respect to the limitations of the short-term (working) memory, the capacity of the long-term memory and the erosion of skills. Feedback mechanisms have a central role in this model. Strong (salient) feedback makes the operator dependent and weak feedback increases the possibility of EOS. Continuous observation of the students' performance on driving tasks (successes or failures) gives insight into the automation and erosion of skills. With help of real time adaptive instruction the level of feedback increases or decreases during training. The 'virtual instructor' called Victor, uses 3 adaptive instruction levels:

1. Do on instruction: the student gets precise instruction on every step in a driving task procedure.

2. Do with less instruction: the student gets indirect instruction. The driving task is introduced but not explained in detail.

3. Do without instruction: the student is only corrected.

Real time assessment on success or failure of driving task steps is necessary for adaptive instruction. The amount of feedback is based on the performance level of the student. Too much (overload), or too few (underload), instructions will slow down automation of behaviour. Separation of driving tasks is also necessary to prevent overload of working memory. A new driving task can only be added to the training in case the active task is automated. In other words, the student performs the task several times successfully without any feedback to prevent to high workload and a slowing down of the learning process.

In the driving simulator administration system the achieved instruction levels are reported per lesson (Figure 1). Quick students can achieve level 3 on driving task within a driving lessons. An average student will sometimes need 2 lessons. When a student stays at level 1 the lesson should be rehearsed. The student is not ready for a new driving task. A failure on a driving task forces the instruction to a lower level. In case the student fails one time in a row, the full instruction is given once at level 1. The level remains at 3. Two or more mistakes in sequence will lower the instruction level permanently. The automated skill has eroded. In the student report (Figure 1) this is the case for the driving task 'maximum speed' and some 'giving right of way' tasks. After a set of successes in sequence, the instruction level goes up again.

Dutch Driving Simulator - Operator Programme

File   Administration   Student   Tools   Help

Student

Students | Lessons | Results | Reports | Overview | Set

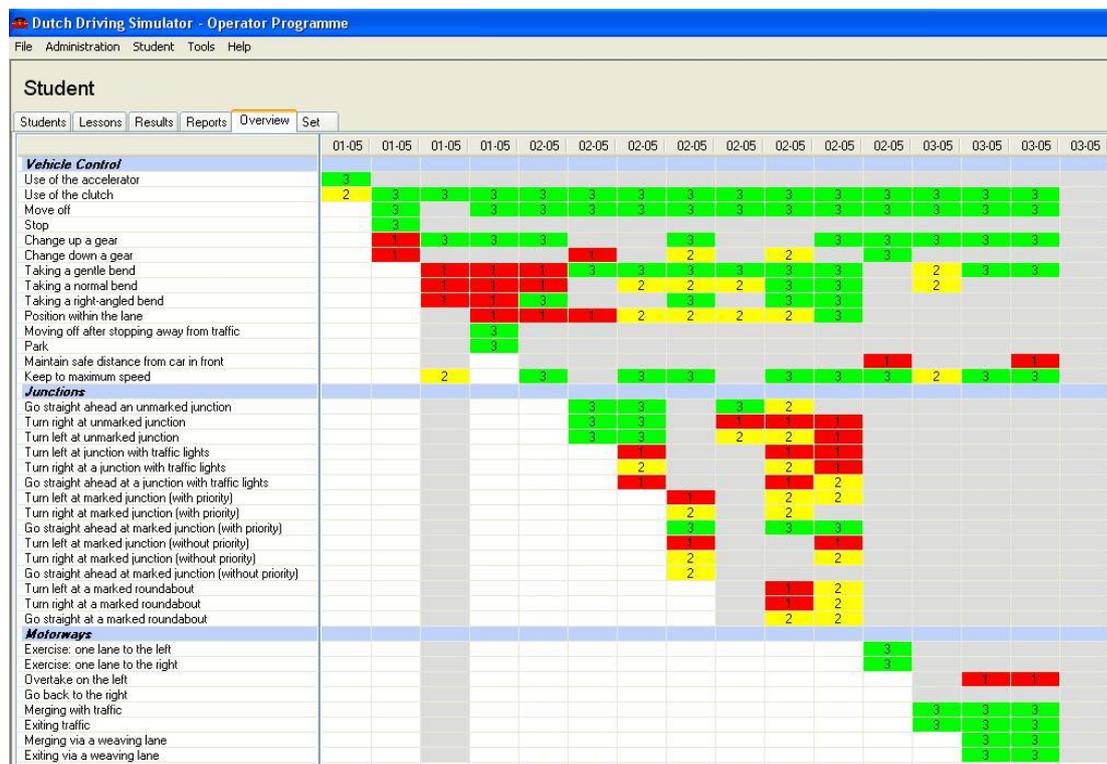|	01-05	01-05	01-05	01-05	02-05	02-05	02-05	02-05	02-05	02-05	02-05	02-05	03-05	03-05	03-05	03-05
Vehicle Control																
Use of the accelerator	3															
Use of the clutch	2	3	3	3	3	3	3	3	3	3	3	3	3	3		
Move off		3			3	3	3	3	3	3	3	3	3	3		
Stop		3														
Change up a gear		3	3	3				3				3	3	3	3	3
Change down a gear		1				1		2		2		3				
Taking a gentle bend					3	3	3	3	3		2					
Taking a normal bend		1	1	1		2	2	2	3	3		2				
Taking a right-angled bend			1					3	3	3						
Position within the lane			1	1	1	2	2	2	2							
Moving off after stopping away from traffic		3														
Park		3														
Maintain safe distance from car in front												1	1		1	
Keep to maximum speed		2		3		3	3		3	3		2	3	3		
Junctions																
Go straight ahead an unmarked junction					3	3		3	2							
Turn right at unmarked junction					3	3		1	1	1						
Turn left at unmarked junction					3	3		2	2	1						
Turn left at junction with traffic lights						1		1	1	1						
Turn right at a junction with traffic lights					2			2	1	1						
Go straight ahead at a junction with traffic lights					1			1	2							
Turn left at marked junction (with priority)								1	1	2						
Turn right at marked junction (with priority)							2		2							
Go straight ahead at marked junction (with priority)							3	3	3	3						
Turn left at marked junction (without priority)							1		1							
Turn right at marked junction (without priority)							2		2							
Go straight ahead at marked junction (without priority)							2									
Turn left at a marked roundabout							1	2								
Turn right at a marked roundabout							1	2								
Go straight at a marked roundabout							2	2								
Motorways																
Exercise: one lane to the left												3				
Exercise: one lane to the right												3				
Overtake on the left														1	1	
Go back to the right																
Merging with traffic												3	3	3		
Exiting traffic												3	3	3		
Merging via a weaving lane														3	3	
Exiting via a weaving lane														3	3	

Figure 1. Screenshot of the Administration System 'Overview: instruction levels'

De Winter [7] compared the performance on the first examination between driving simulator students and those who only followed car lessons. The driving simulator students got instruction from the virtual driving assistant. The graduation percentages of 804 simulator students (reference group N=1774) were compared with the average national graduation percentage in 2005.

The results showed a 4% to 5% higher passing rate of the driving simulator students on their first examination than the national average. The scores are not corrected for self-selection, however driving schools with a simulator have a relative high number of students and tend to the average. A regression analysis showed a relatively strong negative association between the number of simulator training blocks and the duration of driver

training. These results indicate that driving lessons with the virtual driving assistant are an effective alternative for on road driving lessons.

The interface design methodology DCD seems to be effective for the training of novice car drivers. However no research been conducted to this point measuring the effects of simulator instructed driving, on road safety. After passing the examination the novice car drivers where no longer observed. They didn't get feedback on eroded skills anymore. I suppose that unless DCD methodology is also used after licensing, EOS will remain a major cause of traffic accidents.

Acknowledgment

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