

Measuring behaviour in a manoeuvring simulator

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Introduction

Several sources state that 70 to 80 percent of maritime accidents are caused by human error. Technical improvement in vessel design or operational equipment generally contributes to more safety on board and to a decrease of accidents in the maritime field. As a result, the contribution of human errors as one of the causes of maritime accidents relatively increases. The human factor is not negligible in complex manoeuvres.

To study the human factor in a maritime environment is possible in several ways. A manoeuvring simulator provides a quite realistic setting in which it is possible to study for example workload and performance in relation to task demand.

At MARIN any combination of two full mission bridges and four additional cubicles makes it possible to simulate nautical operations in applications like nautical research into new harbour and fairway layouts or the development (and training) of operational procedures. Human factor aspects like workload and performance measured during these simulator runs provide (objective) feedback to human behaviour.

Workload and performance measurements

The relation between workload, performance and task demand as mentioned by De Waard [2] is the basis for a methodology in which several parameters identify the performance and workload. The certainty of the results increases when more parameters point in the same direction.

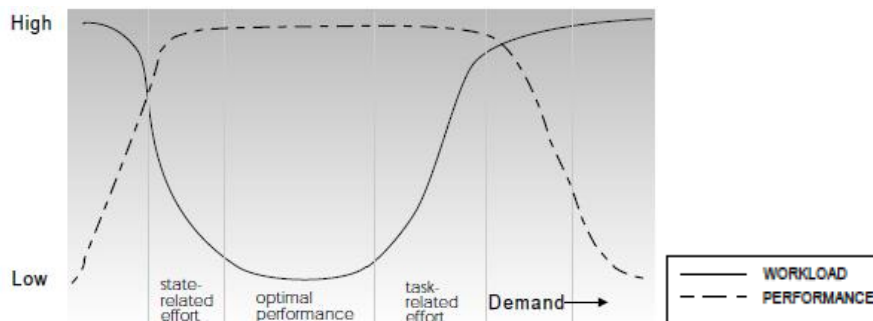


Figure 1. Workload and performance in six regions [2]

Subjective effort ratings: For subjective effort rating the RSME developed by Zijlstra [9] is used. This rating scale runs from 0 to 150 and contains levels from “absolutely no effort” to more than “extreme effort”. The candidate puts a mark on this scale.

Control equipment (Decon Medical Systems, Weesp, The Netherlands) records Objective heartbeat measurements. An elastic belt around the chest of the trainee contains a device to record an electrocardiogram and determines inter beat intervals (RR intervals). Via a wireless connection between the belt and an antenna connected to the measurement laptop the results are directly visible on the screen.

For on board measurements, when WiFi is not preferred, the Firstbeat Bodyguard is used. This device is attached to the skin with two chest electrodes and also determines RR intervals. With associated software it is possible to download locally stored data. The Bodyguard is designed also for long-term recordings (24h).

For both measurements, KUBIOS-software [4] is used to analyse RR interval time traces. From this Heart Rate Variability analysis both the time and frequency domain results are used in the interpretation of workload.

During the experiments, subjective performance rating is done by simulator instructors, who are experienced former seafarers and supervisors of the runs.

An objective performance judgement is based on independent simulator data. Predefined criteria for rudder usage, used power, swept path and speed for example help to quantify the controllability of the vessel during the manoeuvre.

A peripheral detection task measures focus on the main task. The secondary task applied in the experiments consists of reacting to a flash light in the peripheral view of the candidate, see Figure 3. The reaction time and missed stimuli are the indicators for focus on the main task [3].

Observations during the simulator runs by the researcher and recorded by video cameras provide behavioural information. For example someone standing at the bridge close to the displays and holding the tillers or VHF permanently shows another behaviour than someone standing back and overlooking the situation.

Technical or behavioural analysis boundaries

During the analysis of the results, simultaneous interpretation of all workload and performance indicators creates an overall picture of the situation. Statistical data of parts of the time trace are compared. Depending on the research questions the effect of events within one run are studied or several runs are compared to study the effect of changes in the scenarios.

Boundaries of analysis intervals are determined in several ways. When the focus is on the impact of a certain part of the manoeuvre on the operator, “technical” triggers (like the position at the fairway or the distance to an encountering vessel) mark the analysis boundaries. When more cognitive aspects matter, boundaries are related to the moment the operator perceives specific visual or auditory information. A combination of both gives insight into the effect of task demand or demanding circumstances on the duration and quality of the cognitive process before the operator takes action.

Practical examples

Since 2010 several experiments are executed at full mission bridge manoeuvring simulators, using above mentioned measurements. In the beginning the experiments focussed on the applicability of the methodology. Later on the measurements are applied to study questions related to workload. Some examples are described below.

Experiment 1: Effect of increasing task demand on workload [5]. In this study pilots trained a complex journey before they had to sail a new built vessel in real life. During the training the focus is to the more demanding parts of the journey. Based on his experience the instructor classifies the runs as easy, moderate or difficult. The results show that in the difficult runs performance decreases and workload increases, compared to the easy runs. After the training the measurements are also executed on board. For some candidates a direct comparison between the simulator and real life situation was possible. Especially in the difficult situations the results indicate a higher workload level as experienced in the simulator. The effect of longer working hours and the pressure of the real operations are expressed in this result.

Experiment 2: Application of workload and performance indicators in order to follow training progress [6]. During a Maritime Resource Management (MRM) training for Maritime Officers at the Maritime Simulation Training Centre at Terschelling workload and performance indicators are related to the conscious competence

learning curve [1], see Figure 2(left). A total of forty-eight students participated in the experiment. For only twenty-four students a combination of workload and performance measurements are available. The results show that seventeen out of twenty-four students made one or two steps within the learning curve, see Figure 2(right). Nine of them reached the end of the learning curve, characterised by a decrease in workload and increase in performance. The other eight benefited from additional training to master the new skill.

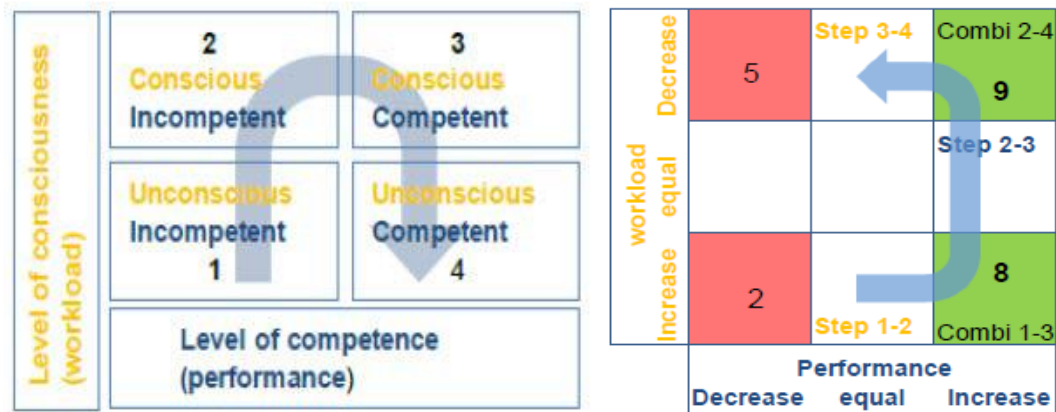


Figure 2. left: conscious competence learning curve related to workload and performance, right: amount of students per increased / decreased workload and performance

Experiment 3: How differences in working strategy express workload differences for pilots and skippers [7]. While sailing at the same channel, changes in workload are studied for both pilots and skippers. Both experienced more workload in a condition without lights, but the amount and origin of the change differs. Due to differences in vessel and bridge design, skippers and pilots developed different working strategies. The pilots are more used to controlling the process and anticipate on future actions. On the other hand, skippers are busier with reacting to actual disruptions and correcting effects of past actions. For the skippers workload increases due to an accumulation of demanding factors, while for the pilots the main cause lays in the absence of reference lights in the environmental view.

The skipper mostly uses the radar for course keeping. He detects an encountering vessel at the radar, but has to complete the picture with information from the outside view. Due to inappropriate instruments for this inland condition, the pilot mainly uses the outside view for course keeping and collecting information. Event analysis demonstrated for example that during the non-lighted condition the skippers need more time to react to the second encountering vessel, while the pilots perform the same.



Figure 3. Candidate wears the secondary task helmet (left), impression of experimental setting with skippers (right).

Experiment 4: The effect of watch schedules on mooring master's workload during offloading operations [8]. This recent work is part of an ongoing thesis about offshore offloading operations which also includes a financial risk analysis. Mooring masters participated voluntarily in the experiments. HRV data and rating scales obtained during mooring master training in the simulator will be compared to on board data. The goal is to study the effect of

watch keeping schedules on fatigue and performance and its relation to operational risks. The probability of an accident is calculated for one or two mooring masters on board, working in different schedules.

Connection with real-life and future additions

The pilot's contribution in experiment one increased their awareness of human failure, especially related to fatigue. During the next real operation they scheduled more recovery moments to increase alertness. Safety is an important factor in the offshore world. In experiment four, mooring masters are willing to voluntarily execute measurements during their work on board, driven by personal motivation and safety awareness.

Although, the technical simulator setting is utterly reliable (the modelled vessel behaviour in external environmental forces, bridge equipment, and outside view), more social and human factor related topics are missing in veracious simulations. For example experiment 1 demonstrated the differences in workload due to the operators being out of their daily activities and stress, working in the simulator during office hours and staying in a hotel. And in the offshore setting from experiment 4 the journey with associated jet lag at the start of the operation plays an important role.

When translating answers from a simulator setting to on board situations, it is a challenge to minimise the gap between simulator and on board settings and take into account the non-technical aspects. Collecting on board data and comparing these measurements with data from the simulator is essential in this.

To overcome this gap MARIN works towards a Maritime Human Factor Observatory: an environment to study behaviour of maritime personnel, using the above mentioned methodology extended with task registration, eye tracking and other tools, observing not only in an advanced simulator but also on board using mobile toolkits. Topics like fatigue during 24/7 operations, decision making, (individual) task optimisation, team work and communication can be studied in a controlled but realistic setting and translated into on board working limits.



Figure 4. The human factor observatory provides possibilities to study individual and team task optimisation

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