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Training Simulator for Extreme Environments

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Current technological advancements have enabled the achievement of excellence in design of training simulators. This work highlights the challenges faced by operators in extreme environments and harsh conditions in an attempt to underpin the necessary features of extreme training simulators.

Keywords: Training Simulator, Extreme Environment, Performance Assessment

1. Introduction

The use of training simulators have gained extensive attention in recent years. The possibilities of simulating various scenarios, enabling the operators to learn, practice and acquire skills, the reduction in cost of training simulators, and the ease of availability are some of the attributes towards the increase in use of training simulators. When it comes to operator training simulators (OTS) it is rather common to find software tools devoted to Control Room Operators (CROPs) by the industrial or maritime workers. Training of Field Operators (FOPs) is less frequently addressed, as it requires immersive environments where 3D representations of the working site allow reproducing the real in-the-field experience. Usually, OTS for FOPs feature virtual reality augmented virtual reality, 3D spatial sounds, and stereoscopic vision (Manca et al., 2013). All the same, even advanced plant or vessel simulators lack important features related to both extreme work environments and harsh conditions.

The term "extreme environments" identifies working sites and conditions that are severe and dangerous for operators or may affect their health. Most extreme environments are given by weather conditions mainly linked to very hot/cold temperatures, and intense humidity. Similarly, extreme environments are also those featuring high altitude, lack of gravity, positive/negative accelerations, deep depth, lack of light, high wind velocities, etc.

The term "harsh conditions" identifies characteristics also found in conventional/normal environments where loud noise, presence of toxic components require the operator to don individual protective devices that may significantly impact on their performance by impairing their movements, reduce their breathing capabilities and in general be a detrimental point for their activities.

Both extreme environments and harsh conditions call for a new generation of OTS capable to cover those issues. Once the ETS is designed, programmed, and deployed a new problem arises, which is about the critical points of training with ETS. The trainers should be aware of the challenges and modifications of performance, capability, and situation awareness that FOPs/seamen encounter in extreme environments. For instance, training period should be inversely proportional to the low/high temperatures faces by the FOP. Lack of proper lighting conditions impairs the operator efficiency. Loud noise may reduce the capability to exchange information with CROPs. Remote instructions may also be misunderstood or misinterpreted in case of problematic communication between operators.

The paper is provided into 4 sections. Firstly, an introduction of operator training simulators is provided which is followed by brief details on extreme environment as well as harsh conditions within the context of process and maritime operations. Some insights are provided into the performance assessment methodology for ETS before conclusions. On account of limitation of space, this paper provides insights to the concept of ETS, which will be followed by a comprehensive journal paper.

2 . Operator Training Simulator

The Operator Training Simulator (OTS) is a replication of parts or all of the screen-based control system and the safety system in the control room. The safety system provides to levels of protection against undesired events and hazard conditions (HSE risks), and is independent of the control system (ISO, 2003). The alarm and communication system, including loudspeakers, telephone and portable radios, are used to warn and guide personnel in the event of a hazardous or emergency situation. (The Norwegian Oil Industry Association (OLF), 2008) The control room operators communicate with the field operators using radio communication and monitor the outside operations via CCTV cameras.

Many of the commercial OTS include automatic operator assessment tool based on pre-made fixed scenarios. An overview of the largest operator training simulator vendors in the oil and gas industry is listed in Table 1 (Abel & Avery, 2012).

Table 1: Largest operator training simulator vendors in the oil and gas market in alphabetical order (Abel & Avery, 2012)

Vendor	OTS product	Website
ABB	Symphony, 800xA	www.abb.com http://new.abb.com/control-systems/service/customer-support/800xA-services/800xA-training/800xa-simulator
AspenTech	HYSYS Dynamics Run-Time, aspenONE	www.aspentech.com
DNV GL AS	Stoner Pipeline Simulator	www.dnvgl.com
Emerson	DeltaV OTS	www.emersonprocess.com
Energy Solutions International	PipelineTrainer	www.energy-solutions.com
GSE systems	EnVision, JPro	www.gses.com http://www.gses.com/training-simulations
Honeywell	UniSIM	www.honeywellprocess.com
Kongsberg	K-Spice, LedaFlow	http://www.kongsberg.com/en/kogt/
Mynah technologies	MiMiC	www.mynah.com
RSI	IndissPlus	www.simulationrsi.com
Schlumberger	OLGA	www.software.slb.com
Schneider-Electric (Invensys)	SimSci DYNSIM	http://software.schneider-electric.com/simsci/
Siemens	SIMIT	www.industry.siemens.com
Yokogawa	VMmaster, OmegaLand	www.yokogawa.com

When a virtual reality environment is connected to the control room part of the operator training simulator, the field operator can play her/his part into the simulation scenario. The (control room) operator training simulator can be connected to the virtual reality environment for example through a TCP/IP-link, thus, transferring data on control room operator actions and process measurements from the OTS to the VR environment, and the field operator actions from the VR to the OTS environment. Nazir and Manca (2014) have covered the technical details of training simulator with immersive environment. The effectiveness of such training simulator was experimentally verified by Nazir et al. (2015), where they have compared the performance of participants based on distinguished training.

Extensive academic studies in virtual reality environment have been conducted related to safety and assessment (Manca, Brambilla, & Colombo, 2013; Nazir, Sorensen, Øvergård, & Manca, 2015), and learning transfer between VR environment and work situation (Ganier, Hoareau, & Tisseau, 2014). In recent years, applications of virtual reality simulator to operator training have appeared in the petroleum and power industries (Coppin, 2013; Keldenich, 2015).

3. What are Extreme Environments?

The term extreme environments (EE) entail places where living organisms can survive after some adaptation. However, those places call for quite a difficult survival and may bring organisms not yet adapted to a short if not ephemeral existence. High/low temperatures and pressures, low oxygen contents (for aerobic organisms), high exposure to radiation, acid/basic/salty conditions, water deficiency, and presence of polluting/toxic substances are just a few examples of EE.

EE may include work on the Earth in outer space or in the depth of the ocean space. The exposure of such operators to EE may be reduced to few seconds/minutes and usually does not go beyond 8 hour shifts even if a fraction of the conditions characterizing EE may be suffered for longer periods (for instance operators living and working at high altitudes for prolonged time). These operating conditions may induce short to medium-term adaptation of workers (i.e. weeks, months), where long-term adaption is the one that occurs to living species over ages (i.e. human evolution). However, there are a number of places/conditions where no short-term adaptation is achievable (e.g., very low oxygen content, extremely low/high temperatures, radiation exposure, extreme wind velocities, toxic concentrations beyond safety thresholds). With respect to living organisms, human beings have developed the capability of temporarily adapting to environments by donning protective measures that make their survival less hard. Indeed, EE conditions may be somehow mitigated by specific clothes and wearable devices (e.g., overalls, helmets, protective shields, earplugs, air bottles), which all the same, may also play a hampering/coercing role with respect to normal operating conditions. Temperature and pressure are probably the most important variables that hamper the work of operators with further elements such as wind, noise, gravity, external forces, radiation, humidity, lack of oxygen, and lighting conditions playing a synergic role in increasing exposure, inconvenience, stress, fatigue, and weakening.

4. What are Harsh Conditions?

The term harsh conditions (HC) can somehow be put beside extreme environments. This paper refers to HC as either artificial environments or artificially induced conditions that take the operator far from nominal/standard working conditions. Instances of HC can be:

- the engine room of a ship where temperature, humidity, and noise can be heavily in excess of comfort thresholds;
- mining operations where temperature, humidity, noise, darkness, and air properties usually do not meet standards or work at the surface
- a bathysphere where extreme silence broken by sudden and unexpected cracklings, darkness, and the angst of mechanical risk can distract the attention and concentration of operators;
- (non)periodic alternation of light and dark with possible flashes as in welding activities, or flashing environments;

- external operations in airports with loud noises, flashing lights, high wind speeds from engine turbines;
- (petro)chemical sites with loud noises, variable lighting conditions, odours, and toxic atmospheres;
- Ocean-going chemical tankers with isolation from the outside world, cramped spaces, and restricted areas where breathing masks and protective overalls must be donned independent of the alert level.

It is worth pointing out that this paper does not focus on workplace health and operator safety. Rather, we are interested in highlighting how discomfort, nuisance, unease, affliction, distress, and pain can modify the working capability of operators and limit their ordinary ability to carry out specific tasks. These elements of inattention diminish the situation awareness (SA) of operators and can impact on their efficiency and skill by inducing fatigue or bodily discomfort. In addition, fatigue and discomfort may lead to slips and unintentional erroneous actions, which are among the highest causes of abnormal situations, near misses, and possible accidents in industrial, maritime, and military/space environments. For this reason, we will emphasize the discomforts and disorders produced by short (i.e. acute) exposure to either EE or HC and overlook long (i.e. chronic) exposure to hazardous sources. Our target is to stress the importance of being concerned about those elements to improve the preparedness of operators by suitable training methods and tools.

The aforementioned points highlights some of the many challenges realted to EE and HC which shall be considereted during the development of ETS.

5. Assessment of ETS

The success of any training simulator should be judged by the transferability of training (Grossman and Salas, 2011; Manca *et al*., 2014). The evaluation of training can be conducted by using well-defined performance indicators. Such performance indicators can be developed in accordance with the tasks, conditions, and challenges faced by operators/seamen in extreme environments. Even though the advancements in training simulators can be seen in recent years, little is done on the assessment methodology of the training simulators. Therefore, we will like to consider the assessment feature in the development of ETS rather than considering it after the development. Thus performance assessment will be achieved by developing suitable performance indicators, which can be conceptually represented in Figure 1. The details of development of performance indicators, their categorization, and implementation in training simulators can be found in Manca *et al*., (2015).

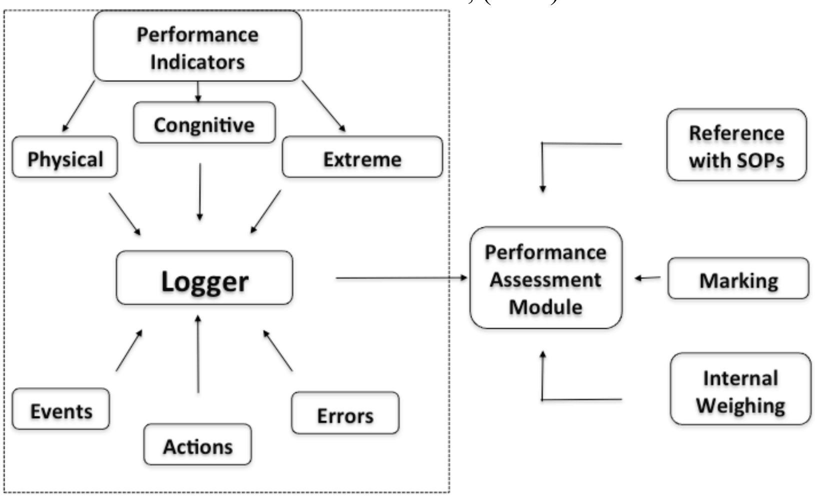

Figure 1 Conceptual framework for Performance Indicators (PIs) for ETS

As ETS is focused on skills required in extreme environment, therefore, it would be essential to conduct detailed task analysis before devising the performance indicators. Experts may collect the data regarding PIs through questionnaires and interviews. While, the weighing criteria can be developed by using well established mathematical tools (for instance Analytical Hierarchal Process; Saaty, 2008).

6. Discussion

In recent years the gap between how the work is designed and how the work is performed has been a topic of interest for researchers as well as for practitioners. Unfortunately, the challenges faced by operators/seamen in extreme environments have been under the shadow of Human Factors research. That technological revolution has dramatically changed the roles and goals of operators. Nevertheless, certain extreme environments (e.g., intense temperature, climate, noise, vibrations, sea waves, heights, etc.) are unavoidable. Evidently on-the-job training is not a viable solution for such conditions. Current technological advancement provides the possibility to simulate extreme environments, where operators can be acclimatized, trained and assessed before embarking those tasks, and where safety procedures and drills can be trained to reduce the dangers of accidents and injuries on the job. This paper has provided some insights into extreme environment and harsh conditions with the hope of encouraging more research on this area which may result in advance Extreme Training Simulators (ETS).

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