JOURNAL OF MARITIME RESEARCH

Vol XVII. No. III (2020) pp 68–73

ISSN: 1697-4040, www.jmr.unican.es

Modelling the relationship between performance and ship-handling simulator

Juan Ignacio Alcaide[1]

ARTICLE INFO

Article history:
Received 13 November 2020;
in revised form 14 November 2020;
accepted 7 December 2020.

Keywords:
ship-handling simulator, workload, performance, training.

ABSTRACT

Past catastrophic events as consequences of human navigational errors shows fail of the assessment methods adopted by maritime education and training institutes. Navigation simulators are an exceptional means of training in which the trained person performs tasks similar to those that are exposed in reality. However, the International Maritime Organization does not establish specific methodology with respect to training and assessment through the use of multi-task with simulators. The aim to apply to the simulation an adapted evaluation model that allows estimating a student's performance evaluation based on their workload and level of stress. Practical assessments of mariner skills are executed in the controlled environment than the simulators provide. A feasible scenario is set up using a ship-handling simulator and an experiment is conducted, participants were maritime navigators and students. The results conclude the validity of the adapted assessment model to obtain the performance. Linear regression analyses indicated a direct relationship between the variables workload, stress level and situations to be controlled and positive self-reported learning effects of mariner competency.

1. Introduction.

The international shipping industry is responsible for the carriage of around 90% of world trade. Shipping is the safest and most environmentally benign form of commercial transport (Allianz, 2019). The statistics show a slow but steady decline in maritime accidents over the past years, yet thousands of accidents still occur each year and the great majority of these involve human error. The shipping is also a highly regulated domain, and regulations have been reinforced in the last decades (UNCTAD, 2019). The International Maritime Organization (IMO) has made great efforts to generate a maritime safety culture that is aware of the importance of importance of the training or knowledge of seafarers, and that this will make it possible to reduce the relationship between the human factor and maritime accidents (IMO, 2020).

The global fleet depends on competent, well-trained seafarers to ensure safety of life at sea, maritime security, efficiency of navigation and protection and preservation of the marine environment. The shipping industry expect new officers to manage information and technology, while demonstrating the ability to make safe and efficient use at sea (Berg, Storgård and Lappalainen, 2013; Manuel and Baumler, 2020).

A report by the European Maritime Safety Agency (EMSA), based on the analysis of 794 investigations initiated during the period 2004-2019, showed that most of the safety recommendations were human factors (for 19% of investigation reports) 46% of which relate to training and skills. In 47% of ship related procedures, 29% of which are actual for operations. In another 15% of security recommendations, 42% of which relate to ship equipment/system, 4% shore and water equipment and 15% other procedures. Poor surveillance in itself could be related to inadequate manning, misuse of skills on the bridge, or incompetence. This study includes ships under flag Member State occur within of European Union (EMSA, 2020a).

Past catastrophic events as consequences of human navigational errors shows fail of the assessment methods adopted by maritime education and training institutes. Therefore, the better the education and training received by seafarers is, the safer shipping industry will become (EMSA, 2020b). It is more

[1]University of Cadiz, Spain.

than necessary to establish systems of constant improvement in training and endorsement systems for degrees.

1.1. Simulation.

In recent decades, the huge technological developments and the lowering cost of hardware and software is allowing new simulators with high visual quality and a realistic environment. Furthermore, there is a need to reduce the cost of this training (IMO, 2011). Simulators are presented as a study support tool with specific advantages, especially when compared to training on board a real ship, as well as the ability to provide the student with the ability to react as they actually do.

Simulation is close to real replica of equipment, systems, phenomenon or process. The word simulation comes from the Latin verb "simulare", meaning "to imitate". It is important to recognize the simulation technology using simulations as a tool to solve realworld problems (Rybing, 2018). It is generally a mathematical model with a set of initial conditions, visualization and interface/controls and instructor control system. Simulation is used in many contexts, such as simulation of technology for performance optimization, safety, testing, training and education. Use of approved simulators to demonstrate certain competence has been specified in STCW 2010. The basic operational features are: representation of real operational scene, provision of control of the scene, the exclusion of the operational scene, recording, playback or debriefing (IMO, 2011).

Under STCW the simulators need to comply with prescribed standards. Instructors and assessors engaged in simulator-based training need to be properly qualified in the use of such equipment. Simulation in general can be described primarily by their attributes: fidelity, resolution, and scale (Birta and Arbez, 2019). The skills requirement which can be enhanced with the use of simulation include: technical and functional expertise training, problem-solving and decision-making skills and interpersonal and communications skills or team-based competencies (Lateef, 2010).

In today's world of navigation simulators, trainers face new challenges and a unique change in the execution of training improvements. Navigation simulators opportunities integrate feedback, debriefing, interactive environment or real situations have demonstrated the ability to facilitate the link between theory and practice, increase students' ability to synthesize knowledge, and promote insight in a safe space. Navigation and training simulators are an exceptional means of training in which the trained person performs tasks similar to those that are exposed in reality (Carson-Jackson, 2015). However, the International Maritime Organization (IMO) does not establish specific methodology with respect to training and assessment through the use of multi-task with simulators (IMO, 2001, 2011).

Instructors are challenged to implement teaching strategies that promote learners' navigation competency and crew resource management skills (IMO, 2011). This challenge has derived from advances in technology, increased levels of certification for seafarers, a major transformation in maritime digitalization, identified issues smart shipping and cyber security (Komianos, 2018), and mandates by International Convention on Training, Certification and Watchkeeping for Seafarers (STCW Convention) 75/95 and Code 2010 Manila Amendments (ITF, 2010).

The goal of any simulation is to provide a controlled environment where the participant performs tasks that are similar to what they should execute if they were exposed to the real environment. The simulators allow intensive training, in which pressure situations are generated with unexpected problems and inconveniences, thus giving the student practice in decision-making in a controlled environment. Instructors are to create learning environments that facilitate students' critical thinking, self-reflection, and prepare officers for practice in a complex, dynamic navigation environment (Carson-Jackson, 2015).

The use of simulators provides a learning platform where all three elements of learning (knowledge, skill and attitude) can be integrated into a valuable learning experience. The four elements involved in providing training based on simulators show an intensive interaction: simulator equipment, training programme, student and instructor. The role of the instructor for ensuring the successful implementation of simulation training programmes. It is the skill and teaching techniques that can allow the simulator to be used as a powerful means for a student to practice in a safe environment (IMO, 2011). Navigation simulation training concepts then begun to be gradually introduced into safety navigation and other areas of shipping industry like radio communication, radar equipment, cargo operation, etc.

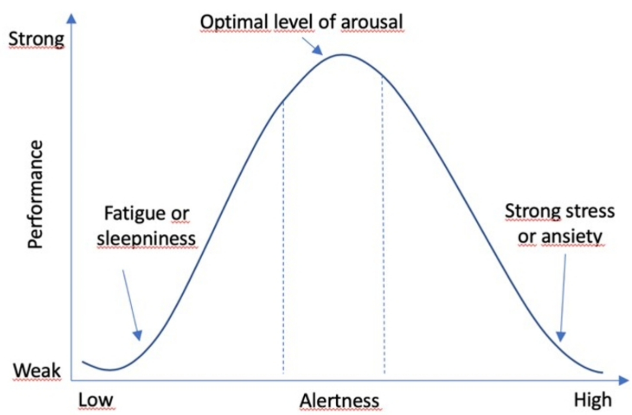
Simulation can be the help to developing professionals' knowledge, skills, and attitudes, whilst protecting navigation from unnecessary risks. Simulation training techniques, tools, and strategies can be applied in designing structured learning experiences, as well as be used as a measurement tool linked to targeted teamwork competencies and learning objectives (Carson-Jackson, 2015; Lee, 2017). Simulation itself is not new. It has been applied widely in the aviation industry, military or medical education. It helps to mitigate errors and maintain a culture of safety, especially in these industries where there is zero tolerance for any deviation from set standards (Lateef, 2010; Farmer *et al.*, 2017).

The aim to apply to the simulation an adapted evaluation model that allows estimating a student's performance evaluation based on their workload and level of stress. This paper describes the scenario used in the simulation, the participants in the study, the measurements used, and method employed. We evaluated the human performance using questionnaire for evaluating training effectiveness of a virtual navigation scenario.

2. Methodology.

To support the development of the simulations, we have used different methodologies, among which we highlight Problem Based Learning (ABP) (Hmelo-Silver and Barrows, 2006; Boud and Feletti, 2013), the experimental learning methodology or Learning by Doing (Gibbs, 1998), and the concept of stress, focusing on Yerkes Dodson law (Teigen, 1994). It is important to point out the situations generated during navigations in the simulator, it can generate different levels of attention influenced by the officer's perception and, therefore, we can relate attention, arousal, motivation and perception in the same variable, stress, together with the other personal conditioning factors of the person (psychological, physical and environmental) (Figure 1).

Figure 1: Illustration of Yerkes-Dodson law.



Source: Adapted from (Teigen, 1994).

2.1. *Participants and materials.*

48 seafarers, in the rank from deck cadet to master, participated in this experiment. Each participant was an enrolled student in the University of Cadiz. A low prevalence of female participants: 43 of 48 participants were males (89%). All participants needed to possess a certificate of competency according to international regulation (IMO, 1978). Participants were randomly assigned to one of four groups and had an average age (n = 48, M = 25.3, SD = 9.5) and years in service (n = 48, M = 1.1, SD = 10.3). After analysing the results of experiments and submitting the data to a study of analysis of the variances, it was found that the results obtained from groups were analogous, therefore, in the validation and analysis of the results, they will be treated together.

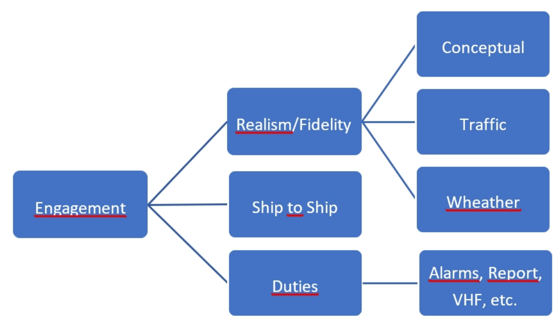
The validity of the groups participating in the simulation was verified using an ANOVA test (SPSS software), with an observed significance value (0.000)/ Cochran's Q (482,32) that validates the hypothesis of equality of means, in addition to similarity between the groups under study (Bakieva, Such and Jornet, 2010). To carry out the simulations, the Polaris V6.3 navigation simulator from Kongsberg Maritime AS at the University of Cádiz was used. Polaris is a functional system that includes: Instructor station; 1 Full mission bridge (OwnShip); and 5 Part Task (OwnShip) Bridges - with ECDIS, Radar/ARPA, Multifunction Stations, panel control, etc. certified under STCW.

2.2. *Scenario.*

The detail of the simulation exercise was designed by the relevant simulator instructors, and was conducted in exactly the same way during the different sessions. The scenario was constructed carefully to ensure a high level of realism. The voyage was constructed to emulate a real voyage in the Strait of Gibraltar and, including port manoeuvre, duties of watch keeping and navigation on a ship's bridge, navigation and collision avoidance situations, mandatory radio reporting points, etc. The following figure shows the officers' levels, sequence in the simulation (Figure 2).

The voyage between Algeciras port and Tanger Med port was repeated in all simulations (only 45 minutes from departure), and many of the events the participants experienced were also repeated because they were normal routine activities on the bridge, and sometimes in same route/localization. On the simulation, an identical amount of traffic was set for each start and was considered realistic for the waters involved. It varied in intensity from light to relatively heavy traffic. Maximum vessel speed (7 Knots/port and 19 knots/open sea) for OwnShip and Target. A feasible scenario is set up using a shiphandling simulator and an experiment is conducted. The weather conditions were consistent (Wind: West, 7-9 Knot); reduced visibility (middle bay, > 2 miles); tidal conditions (HW 1.5 m, Algeciras Port); current/drift (West 1-3 Knot) (Figure 3).

Figure 3: A model of fidelity in simulation.



Source: Author.

Considerations and rules of the scenarios: All vessels in the exercise navigation under COLREGS and international regulations (VTS, Reports, etc.). No groundings or collisions were allowed. Normal events (or situations) were those which a seafarer on a similar vessel would typically encounter during a voyage in the Strait of Gibraltar. These normal events were Keeping communication (port, pilot, vessels or VTS), ship's position, vessel's logbook. Traffic was realistic for the area and a basic voyage plan was given to the participants during the familiarisation period (15 mins). Finally (40 mins), a fire on board incident occurring on another vessel in the vicinity or in the own ship.

2.3. *Variables and data collection.*

For the compilation of the study data and its subsequent analysis, a coding of the indicators or variables was carried out, which in turn were related to Workload (WL), Situations controlled (SC) and Level of difficulty (LD) during the simulation with a scale of values from 1 (None) to 7 (Extremely high). The different items were recorded at 10 minutes intervals during the simulation. A comparison of sets of results resulted in a Spearman Rank Difference mean correlation 0.650, indicating a strong relationship. The following Table I shows the coding

Figure 2: Sequence and duration of events of simulation.

Source: Authors.

of the variables and their interval, as well as the approximate location of the vessel.

3. Research results.

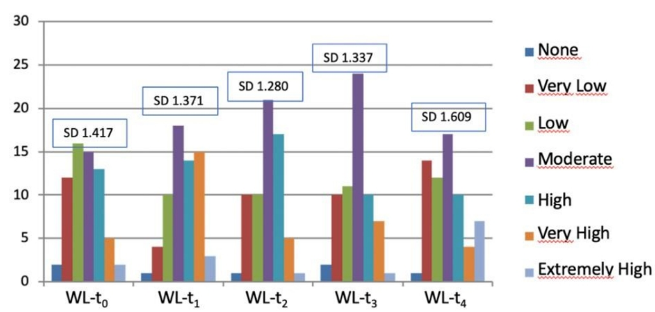
In this section we will proceed to perform the statistical analysis of the data obtained during the practical simulations, for which the frequency of assigned values, mean and variance that each of these represent in the different items will be studied independently during the time line of the exercise.

In order to improve the feedback from the simulations, participants were asked to rate the grade of difficulty (GD) at certain times (t_0 - t_4) on a scale of 1 to 3, presenting the most repeated value (Medium=2) in "t_1" (67.7%). The answer is 1.63 for "t_0", 2.05 for "t_1", 1.91 for "t_2", 1.89 for "t_3" and 1.58 for "t_4". The median value remains stable at 2.00 during "t_0", "t_1", "t_2" and "t_3", and falls to 1.0 at "t_4".

3.1. *Workload.*

The Figure 4 shows the frequency of values assigned by officers to the perceived workload during the simulation, presenting the most repeated value (High) in "t_3" (36.9%).

Figure 4: Frequency of values assigned to the workload (WL) during the exercise.



Source: Author.

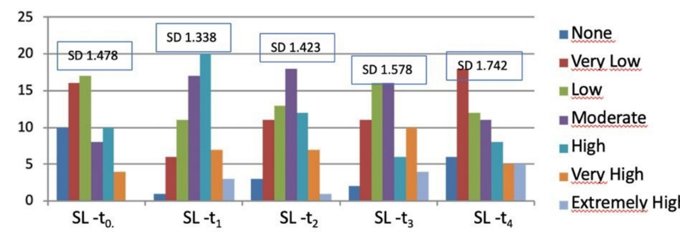
3.2. *Stress level.*

The Figure 5 shows the frequency of values assigned by officers to the perceived workload during the simulation, presenting the most repeated value (Very high) in "t_1" (30.8%).

3.3. *Situations under control.*

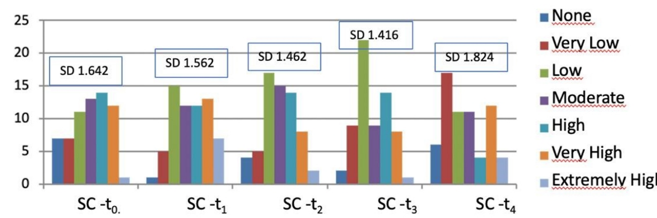
The Figure 6 shows the frequency of the values assigned to the situations to be controlled during the simulation, presenting the most repeated value in "t_3" (33.8%).

Figure 5: Frequency of values assigned to the Stress level (SL) during the exercise.



Source: Author.

Figure 6: Frequency of values assigned to situations controlled (SC) during exercise.

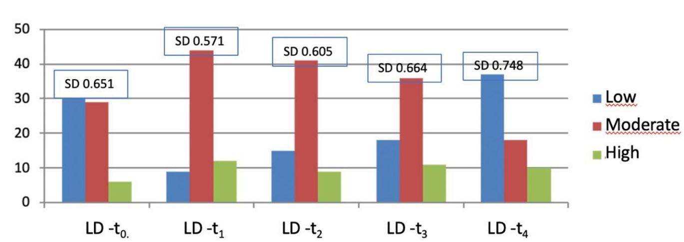


Source: Author.

3.4. *Dificulty level.*

The Figure 17 shows the frequency of the values assigned to the level of difficulty during the exercise, presenting the most repeated value in "t_1" (67.7%).

Figure 7: Frequency of values assigned to the Level of difficulty (LD) during the exercise.



Source: Author.

3.5. *Discussion.*

The results obtained show great variations between "t_0" and "t_1" for all variables (WL, SL, SC and LD). These variations are related to the degree of immersion of the officers.

Table 1: Variables and data collection.

Item	Definition	t_n Time/moment	Port/berth
$WL\_t_0\text{-}t_n$	Workload (WL)	t_1	Leaving the port
$SL\_t_0\text{-}t_n$	Workload (WL)	t_2	Middle of the bay
$SC\_t_0\text{-}t_n$	Situations controlled (SC)	t_3	Leaving the bay
$LD\_t_0\text{-}t_n$	Level of difficulty (LD)	t_4	VTS

Source: Authors.

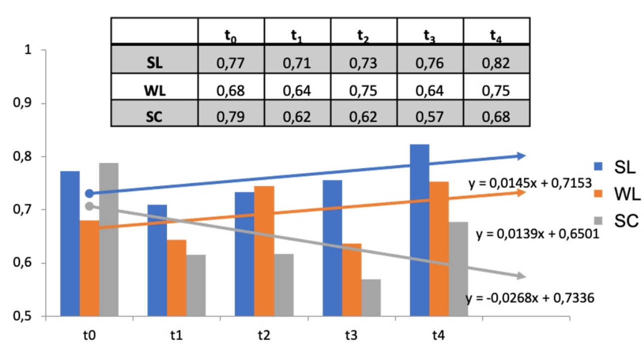
Low levels at "t_0" show low motivation or immersion in simulation. The extreme values (SD) of the items evaluated for "t_1" show the moment in which the students "submerge" in the simulation and become aware of the situation they are in and of their responsibilities or duties.

The items with the highest standard deviation value are found in "t_4", this is due to the fire generated in the ship during the last phase of the exercise, the students who generated this fire evaluated their load levels very highly work, stress and situations to control, while the rest of the ships that were navigating the VTS, with low traffic, and showed at much lower levels.

3.6. Model fit evaluation.

The model was adjusted using the determination coefficient, also called R-Square, this coefficient determined the quality of the model to replicate the results, as well as the proportion of variation of the results that can be explained by the model. The values obtained for the coefficient of determination are those shown in Figure 8. The results allow us to predict the value of two indicator items in the model based on one known, allowing us to calculate student performance in a given situation using a linear regression. a moment "t_n". In the adjustment, the strongest values were those of the (stress level).

Figure 8: Trend lines of the determination coefficients.



Source: Author.

Conclusions.

The participants need time to adapt to the simulation and real immersion in it. Therefore, in future simulation exercises it would be advisable to give the participants time to adapt to the simulation environment, so that they begin to assess their load levels work, stress and situations to control once they are more focused on navigation or simulation. In the simulations, it was observed that above a certain level of stress, the participants did not respond adequately to the problems posed, even going so far as to "crash" and give practically no performance in certain situations. It was also observed that this level of the stress in which the "blockage" occurred varied widely depending on the officer on duty regardless of his professional experience.

The participants rated the simulations very positively, which had kept them alert and active practically all the time, arguing that the scenario only differed from reality in the traffic situation, but that, during the simulation, generated its own tension of a real manoeuvre. The influence of stress level on performance is an important factor to bear in mind both in the learning process and in planning methodology in navigation simulators.

There was significant variability in the competition shown by the bridge officers. This was due to the randomness of the candidate selection process. In this sense, some officers showed enormous cognitive ability to adapt to a change of scenery in navigation. In addition, some watch keepers were apparently more resilient to stress, but we need to investigate what factors might influence this. Results of this study will be used in the future to guide simulation practitioners in the optimization of human performance using training simulation. It is hoped that the results will make a contribution to the improve training quality and safety navigation. .

References.

Allianz. Safety & Shipping Review 2019 in numbers. Allianz, 2019. Date of access: September 2020. Available from: <https://www.agcs.allianz.com/news-andinsights/news/safety--shipping-review-2019.html>

Bakieva, M.; Such, J.; Jornet, J. SPSS: ANOVA de un factor. Valencia: Universidad de Valencia. Grupo de Innovación Educativa, 2010. Date of access: September 2020. Available from: < https://www.uv.es/innomide/spss/SPSS/SPSS_0702b.pdf >

Berg, N.; Storgård, J.; Lappalainen, J. The impact of ship crews on maritime safety. *Publications of the Centre for Maritime Studies.* Turku, Finland: University of Turku..2013. A, 64. Date of access: September 2020. A Available from: <https:-//www.merikotka.fi/wpcontent/uploads/2018/08/Berg_TheImpactOfShipCrewsOnMaritimeSafety.pdf >

Birta, L. G.; Arbez, G. Modelling and Simulation Fundamentals A: *Modelling and*

Simulation. Springer, 2019. pp. 19-53. Available from: < https://doi.org/10.1007/978-3030-18869-6_2 >

Boud, D.; Feletti, G. I. (2013) *The challenge of problem-based learning*, 1^{st} ed. London: Taylor & Francis, 1997. ISBN 9781315042039. Available from: <https://doi.org/10.4324/978-1315042039 >

Carson-Jackson, J. *A simulation instructor's handbook: The learning game*. London: The Nautical Institute, 2015. ISBN 9781906915162.

European Maritime Safety Agency. *Preliminary annual overview of marine casualties and incidents 2014-2019*. Lisbon, Portugal : EMSA, 2020. Date of access: September 2020. Avaible from: < http://www.emsa.europa.eu/news-a-press-centre-/externalnews/item/3869-preliminary-annual-overview-of-marine-casualties-and-incidents-20142019.html >

European Maritime Safety Agency. *Visits and Inspections related to standards for seafarers* . Lisbon, Portugal : EMSA, 2020.

Farmer, E. et al. *Handbook of simulator-based training*. London: Routledge, 2017. Avaible from: < https://doi.org/10.4-324/9781315253671 >

Gibbs, G. *Learning by Doing: A guide to teaching and learning methods*, *Oxford Brookes University*, 1998. Date of access: September 2020. Avaible from: < https://thoughtsmostly-aboutlearning.files.wordpress.com/2015/12/learning-by-doinggra-ham-gibbs.pdf >

Hmelo-Silver, C. E.; Barrows, H. S. Goals and Strategies of a Problem-based Learning Facilitator. *Interdisciplinary Journal of Problem-Based Learning*. Bloomintong: Indiana University, 2006. 1(**??**) Date of access: September 2020. Avaible from: < https:/https://doi.org/10.7771/1541-5015.1004 >.

International Maritime Organization. International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW): Adoption: 7 July 1978; Entry into force: 28 April 1984; Major revisions in 1995 and 2010. In: *IMO* [online]. [Date of access: July 2020]. Available from: <http://www.imo.org/en/About/Conventions/ListOfConventions-/Pages/InternationalConvention-on-Standards-of-Training,-Certification-and-Watchkeeping-for-Seafarers(STCW).aspx>.

International Maritime Organization. *Model course 6.09. Training course for instructors.* London: IMO, 2001. ISBN 9789280151152.

International Maritime Organization. (2011) *Model Course 6.10. Train the Simulator Trainer and Assessor: STW 43/3/4,*. London (UK): IMO, 2012.

International Maritime Organization (2020) *Human Element* [online]. IMO. Date of access: February 2020. Available from: <http://www.imo.org/en/OurWork/HumanElement/Pages/Default.aspx> International Workers' Transport Federation. *STCW: A Guide for Seafarers. Taking into account the 2010 Manila amendments*. London: International Transport Workers' Federation. 2017.

Komianos, A. The Autonomous Shipping Era. Operational, Regulatory, and Quality Challenges. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*. Gdynia, Poland: TransNav, Faculty of Navigation, Gdynia Maritime University , 2018 12(2), pp. 335–348. Date of access: September 2020. Available from: <https://doi.org/10.12-716/1001.12.02.15>

Lateef, F. Simulation-based learning: Just like the real thing. *Journal of Emergency Trauma and Shock*. New Delhi: INDUSEM, 2010. 3(4), pp. 348–352. Date of access: September 2020. Available from: < https://doi.org/10.4103/0974-2700.70-743 >

Lee, A. T. *Flight simulation: virtual environments in aviation*. [s.l.]: Routledge, 2017. ISBN 1138246190

Manuel, M. E.; Baumler, R. The Evolution of Seafarer Education and Training in International Law. *Maritime Law in Motion*. [s.l]: Springer, 2020. pp. 471–494. Date of access: September 2020. Available from: <https://doi.org/10.1007/978-3-030-317492_22>

Rybing, J. *Studying Simulations with Distributed Cognition*. Linköping, Sweden: Linköping University Electronic Press, 2018. ISBN 9789176853481. Date of access: September 2020. Available from: <https://www.diva-portal.org/smash/get/diva2:-1191736/FULLTEXT01.pdf >

Teigen, K. H. Yerkes-Dodson: A Law for all Seasons. *Theory & Psychology*. London: Sage, 1994. Date of access: September 2020. Available from: <https://doi.org/10.1177/0959354394-044004 >.

United Nations Conference on Trade and Development. *Review of Maritime Transport 2019 - Sustainable Shipping The United Nations Conference on Trade and Development: UNCTAD/RMT/2019*. Geneva, CH: United Nations Pub, 2019. Date of access: September 2020. Available from: <https://unctad.org-/en/PublicationsLibrary/rmt2019_en.pdf >