# Simulator Programs (2-D and 3-D): Influence on Learning Process of BSMT and BSMAR-E Students at Maritime University Philippines

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This study aims to determine the 2-dimensional and 3-dimensional simulator programs and their influence on the learning process of BS Maritime Transportation and BS Marine Engineering students at Maritime University, Philippines. The participants in this study were the 160 BSMT and BSMar-E students of the Maritime University (JBLFMU-Molo) for school year 2010-2011. Participants in the study were enrolled at the Deck Simulator Program and Engine Room Simulator (ERS), which introduced the 2-D and 3-D simulator programs as part of the different tasks for skills development of maritime students (BSMT and BSMar-E) at Maritime University in the Philippines. The researchers instructed the respondents to write down all their comments, suggestions, observations, and remarks on the perceived influence of using the 3D and 2D simulator programs. After the gathering of the qualitative information, the researchers classified and categorized the write-ups of the respondents into different "categories." The analysis of comparison in relation to learning process brought about by the two (2) simulator programs was processed by the researchers. The "categories" were used towards establishing the concepts/views whether these simulation programs influence the learning process of nautical (BSMT) and marine engineering (BSMar-E) students at Maritime University (JBLFMU-Molo) in the Philippines. The results revealed that the 2-D and 3-D simulator programs are good learning aids which are helpful to maritime students. Sustaining the maritime students' "competent skill" in performing the different tasks in simulator is needed and should be enhanced.

**Keywords:** *2-D simulator program, 3-D simulator program, influence, learning process, skills development, learning aids, and competent skill* .

## 1. INTRODUCTION

Video tapes, computer simulations, and multimedia software can encourage the students to think like scientists (Brungart & Zollman, 1996). This kind of instructional technology stimulates students to learn and to like their subject (Harwood & Mc Mahon, 1997; Sumanpan, 2008) even though it seemed difficult to understand. These software and technological-instruction activities can facilitate the learning process, more likely to those students who are interested in manipulation and skills. The instructors in higher education institutions should be innovative and creative in dealing with students in order to convey and translate their ideas to achieve effective learning process.

Studies in the field revealed that simulation activity offers education providers a significant educational tool to meet the needs of today's learners by providing them with interactive and practice-based, instructional technologies. Using simulations in teaching and testing has the following potentials that can enhance the total learning process: more effectively utilize faculty in teaching of basic engineering skills, allow learner to revisit his skill in the simulator a number of times in an environment that is safe, non-teaching and conducive to learning, actively engage students in their learning process where they can display higher-order of learning rather than simply mimicking the teacher role model, contribute to the refinement of the body of knowledge related to the use of simulation in maritime education by providing insights in order to formulate best practices related to design and use of simulation technology (Tumala, Trompeta, Evidente, & Montaño, 2008). Furthermore, the authors underscored the

use of virtual environment for instructional use in relation with the learners' characteristics. In this study, the authors stressed that learners benefited from the use of simulator as a learning tool irrespective of the type of cognition. In the same vein, the authors have found out the role of the learning program as an indicator of successful learning that now depended on simulation itself. The need to join hands in coming up with programs and program designs that will best cater to the desired learning outcomes of the learners is well stated in this particular study.

The key issue in successful application of simulator classes is ensuring that simulation serves its purpose. The primary aim of any simulator experience is to create a certain level of skills performance among students. In the study entitled "Attitude, Skills Performance, and Implications of using Simulators among Marine Engineering Students of JBLFMU-Molo, Iloilo City, Philippines" conducted by Alimen, Ortega, Jaleco, & Pador (2009), it was emphasized the following: students do not seem to be sold completely to the use of simulator as indicated by "moderately positive attitude" towards simulator use, sustaining the marine engineering students' 'competent skill' in performing the different tasks in simulator is needed and it should likewise be enhanced, the significant correlation between the attitude and skill performance in simulator is reinforced by several studies which support the relationship between learner attitude and their performance. It is also stated that technology has been apparent in this regard as it has reached a threshold where virtual or simulated approaches can meet or exceed the learning outcomes of expository (teacher-centered) approaches, the implications suggested that simulator should consist, more than anything else, of a set of updated and upgraded computer software to address the observations and comments from the students.

## 2. STATEMENT OF THE PROBLEM

The present study aimed to determine the use of 3D and 2D simulator programs and its influence on the learning process of nautical (BSMT) and marine engineering (BSMar-E) students at the Maritime University (JBLFMU) in the Philippines.

To further understand the study, the following questions were advanced:

(1) How do marine engineering students perceive the 3D and 2D simulator programs in terms of learning at the maritime university?

(2) What are the comments, suggestions, and remarks about the 2D simulator program of nautical and marine engineering students?

(3) What are the common remarks and suggestions of the nautical and marine engineering students related to the 3D simulator program?

(4) Which are the perceived 2D and 3D simulator influences in the learning process of the nautical and marine engineering students?

## 3. THEORETICAL FRAMEWORK

The present study was anchored on the theory advocated by Alimen, Ortega, Jaleco, & Pador (2010) in their study entitled "Attitudes, Skills Performance, and Implications of Using Simulator Programs among Marine Engineering Students of JBLFMU-Molo" by employing descriptive-qualitative mode of data collection. Moreover, in terms of the qualitative study, Yamut (2008) employed a series of descriptions and information to determine the theme, characteristics, opinions, reflections, and views of the subject of the study. In this study, the researchers allowed the respondents to express their ideas, opinions, and views on 2-D and 3-D simulation programs and their influences on the learning process of marine engineering students at the Maritime University in the Philippines.
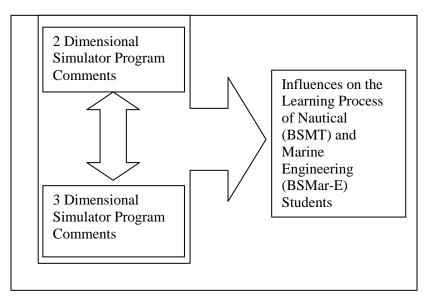
## 4. CONCEPTUAL FRAMEWORK



**Figure 1 2D and 3D simulator programs and their**
**influences on the learning process of nautical and marine engineering students**

## 5. METHOD

This study used the descriptive research design. The respondents of the study were the nautical (BSMT) and marine engineering (BSMar-E) students at Maritime University (JBLFMU) who were using the 3D and 2D simulator programs. The research process involves the description, interpretation, and comparison of the comments, suggestions, and remarks of marine engineering students on simulator programs at the Maritime University.

## 6. PARTICIPANTS

The participants in this study were the 180 nautical (BSMT) and marine engineering (BSMar-E) students of the Maritime University (JBLFMU) for the academic year 2010-2011. Participants in the study were familiar with Deck Simulator and Engine Room Simulator (ERS), which includes the 2D and 3D simulator programs as part of the different tasks for skills development of nautical and marine engineering students at Maritime University (JBLFMU) in the Philippines.

## 7. PROCEDURE

The researchers instructed the respondents to write down all their comments, suggestions, observations, and remarks on the perceived influence of using the 3D and 2D simulator programs. After the gathering the qualitative information, the researchers classified and categorized the write-ups of the respondents into different "categories." The analysis of comparison in relation to the learning process brought about by the two (2) simulator programs was processed by the researchers. The "categories" were used towards establishing the concepts/views whether these simulation programs influence the learning process of nautical (BSMT) and marine engineering (BSMar-E) students at Maritime University (JBLFMU) in the Philippines.

# 8. RESULTS AND DISCUSSION

This section of the study focuses on the results and discussion about 2D and 3D simulator programs and their influences on the learning process of marine engineering students at Maritime University (JBLFMU-Molo) in the Philippines.

**Table 1 Perceived Influences of 2D and 3D Simulator programs on the Marine Engineering Students Learning Process at JBLFMU-Molo**

*2D and 3D programmes are educational and can be used for learning in BS Marine Engineering;
*More computers should be available for 2D and 3D so that learning would be more efficient;
*2D and 3D simulator programs are good learning aids which are helpful to marine engineering students
*The 2D and 3D simulator programs are helpful in terms of improving and adding to students' learning;
*They are very useful for the students to familiarize with the different parts of machines and equipment on-board;
*Extend the number of hours on 2D and 3D simulator programs in order to enhance the knowledge and skills of marine engineering students;
*2D and 3D simulator programs are suitable in the learning process of marine engineering students.

**Table 2 Perceived Influences of 2D programs on the Marine Engineering Students Learning Process at JBLFMU-Molo**

*2D and 3D programmes are educational and can be used for learning in BS Marine Engineering;
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*Extend the number of hours on 2D and 3D simulator programs in order to enhance the knowledge and skills of marine engineering students;
*2D and 3D simulator programs are suitable in the learning process of marine engineering students.

**Table 3 Perceived Influences of 3D programs on the Marine Engineering Students Learning Process at JBLFMU-Molo**

*3D is more practical than 2D so therefore it should be given more attention;
*I prefer 3D to 2D because it is more challenging and it gives critical thinking opportunity to the students;
*The 3D set-up reflects the reality on-board that gives thorough learning to the marine engineering students;
*3D is slightly confusing and sometimes difficult to handle;
*3D  seems real but the leaking system should be put into higher resolution to achieve more realistic view;
*3D simulator program is a state-of-the-art learning tool. It is a great opportunity for the students to experience real engine operation through virtual simulation;
*3D is a higher version of simulator program necessary to marine engineering students in terms of skill-development programs at JBLFMU-Molo, Iloilo City.
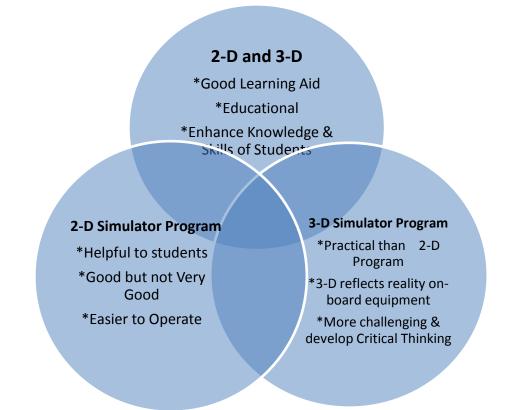
**2-D and 3-D**

*Good Learning Aid

*Educational

*Enhance Knowledge & Skills of Students

**2-D Simulator Program**

*Helpful to students

*Good but not Very Good

*Easier to Operate

**3-D Simulator Program**

*Practical than   2-D Program

*3-D reflects reality on-board equipment

*More challenging & develop Critical Thinking

**Figure 2 Summary of the views/insights of the nautical (BSMT) and marine engineering (BSMar-E) students towards 3D and 2D simulator programs**

# 9. CONCLUSIONS AND RECOMMENDATIONS

The key issue in successful application of state-of-the-art simulator programs is the instruction to ensure that simulation serves its purpose. The primary aim of any simulator experience is to create a certain level of skills performance among students. In summary, this study has the following conclusions:

The 2D and 3D simulator programs are good learning aids which are helpful to marine engineering students. Sustaining the marine engineering students' "competent skill" in performing the different tasks in simulator is needed and should be enhanced.

These simulator programs are very useful to the students to familiarize with the different parts of the machinery and equipment on-board. It is also stated that technology has been apparent in this regard as it has reached a threshold where virtual or simulated approaches can meet or exceed the learning outcomes of expository (teacher-centered) approaches.

The implications found here suggest that the simulator should consist, more than anything else, of a set of updated and upgraded computer software and hardware to address the observations and comments of the students.

In this regard, the following are recommended:
(1) The findings of this study revealed that 2D and 3D simulator programs effectively enhanced the mastery of desired skills of the marine engineering students at JBLFMU-Molo, Iloilo City. Most of the students preferred the 3D simulator program, therefore, the administration should look into the advantages of the 3D simulator program to maximize the applicability of the program. More studies of this kind must be considered to further validate the results of this investigation.
(2) The lack of computers of the 3D simulator program must be addressed through a careful and periodic assessment of the simulation rooms where these courses will be conducted.

# 10. ACKNOWLEDGEMENTS

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# The Development of a Shiphandling Assessment Tool (SAT): A Methodology and an Integrated Approach to Assess Manoeuvring Expertise in a Full Mission Bridge Simulator

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While adopted in the maritime industry computer based assessment (CBA) has mainly been deployed to support multiple choice questionnaires (MCQ) or very basic desktop simulations.CBA is principally used for basic screenings at initial stages of personnel selection processes or for Certificate of Competency issuing purposes. The rudimentary efforts to use CBA, even when coupled with oral examinations remain insufficient to assess shiphandling competence due to the complexity of the tasks and responsibilities involved. Nor has a commonly accepted, validated and standardised tool been developed to assess shiphandling. This paper describes the development of a methodology able to obtain the assessment of shiphandlers' outcomes while performing manoeuvres in a Full Mission Bridge Simulator. Variables and parameters used for the assessment are introduced and described even though, due to the limited space available for this paper, no results could be provided and discussed. It is believed that the approach herein presented, could pave the way for an assessment tool in the maritime transport which covers performance, physiological and cognitive measurements. The main aim of the research was to show how it was possible to collect objective measures able to discriminate among different levels of performance in a group of participants as an averaged result. Those results are thought to be valuable in terms of port operations risk assessments, new ports and infrastructure developments, and shiphandlers assessment and training.

**Keywords**: shiphandling, assessment, expertise, behavioural variables, simulator, heart rate variability, Nasa TLX, Shiphandling Assessment Tool, seafarers, marine pilots.

## Introduction

The contemporary maritime industry, compared to any other sector, can be considered perhaps the most globalised labour market in the world [1], with labour force drawn from an unrivalled number of different countries. Even though the maritime industry has established a set of internationally recognised and accepted standards for seafarer training and certification (STCW) [2],many differences can be found in the modalities through which such certifications are issued, endorsed and renewed worldwide. In addition, regardless of the type of approach adopted by each single Nation, a considerable variation in assessing standards [3] within each Country has been noticed, making it very difficult for employers to rely upon seafarer licences as an indication of seafarer competence, skill, or knowledge [4]. Several challenges remain to seafarer education and training [5] [6]. One of those challenges is that there is still the need to identify a commonly accepted and standardized way to assess shiphandling competency and performance. One of the increasingly important options is computer based assessments (CBA). Today, CBA, as adopted by the maritime industry seems to mainly rely on multiple choice questionnaires or simple desktop simulations. Those tools are mainly used to provide an unsophisticated screening during the initial stages of personnel selections or for Certificate of Competency issuing purposes [7]. Assessing shiphandling competency through oral examinations or multiple choices tests, when merchant vessels can reach displacements of hundreds of thousands of tons and when a simple accident can lead to disastrous consequences, is inadequate and high risk. This is increasingly appreciated, for example, by Marine Pilot Companies that have to make considerable investments before the necessary assessment and training period for a newly recruited trainee pilot can be considered completed and satisfactory. Nevertheless, simulators offer a potential solution. Simulators have significantly improved in the last few years. They are at a point where they

have proven their value in different fields of application within the transport industry, for example to simulate logistic dynamics and volumes before a port is even built [8], to improve training for airline pilots [9] as well as for train drivers [10].

The aim of this paper is to introduce an assessment methodology that, when taking into account several objectively measurable variables, can assesses participants' levels of "Shiphandling Expertise" [11]. This methodology will be tested using a Full Mission Bridge Simulator that directly replicates applied practice in a real world environment. Data collected and processed include Simulator data [12], but also Electrocardiogram signals (ECG) [13], eye movement and fixations [14] [15], manoeuvring plans [16] [17], interviews, briefings, debriefings and Nasa TLX form completion [18]. The methodology attempts to better depict the complexity underlying shiphandling in a port environment [19] [20], considering the human element with regards to the safety, accuracy and efficacy of ship conduction, evaluating correlations between physiological variables [21], behavioural markers and performance outcomes. More specifically, the Shiphandling Assessment Tool (SAT) collects and processes variables capable to show how effectively shiphandlers perform, while dealing with Bridge applications and equipment, such as an Electronic Chart Display and Information System (ECDIS), Integrated Navigation Systems (INS), radars, navigation aids, different natural and weather conditions, static and dynamic characteristics of vessel manoeuvrability [22], environmental and infrastructural constraints [23].
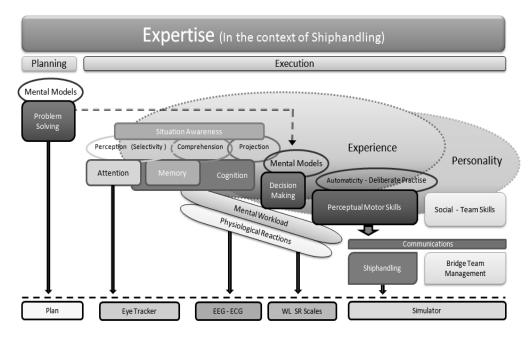


**Figure 1 – Model of Shiphandling Expertise adopted in SAT**

The figure above illustrates how Shiphandling Expertise can be related to different and consolidated theoretical constructs. Experts involved in planning activities are profitably capable to forecast future developments [24], evaluating initial conditions and structuring them into more accurate and realistic mental models. Mental models have been succinctly defined as "mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future states" [25]. In our case, mental models will derive from the capability of the shiphandler to understand the terms and the specificities of each proposed manoeuvre, predicting the implications and providing with a suitable plan. Mental Models are exploited to explain, interact and direct problem solving, working as a guide [26] or as a map [27]. Shiphandler's attention is then directed, guided by the mental model adopted, performing a slim and efficient filtering of available stimuli. Such filtering activity, despite carrying the risk of omitting relevant data, is nevertheless necessary whenever large amount of information is available. Perceived elements are so integrated in a meaningful ensemble and confronted with pertinent contents retained in memory structures. Elements gathered from reality will confirm or not if the mental model adopted is correct. "Testing against reality" is a clear reference to a continuously maintained state of situational

awareness [28] through the exploitation of the underlying cognitive processes of perception, comprehension and projection. Based on the outcome derived from the comparison between the maintained situation awareness and the adopted mental model, shiphandlers will take their decisions regarding actions deemed to be required. In the context of this assessment methodology, decision making specifically refers to the naturalistic paradigm where expertise is evaluated in its naturalistic context [29] [30] [31] [32] [33] [34]. The execution is the practical translation of shiphandlers' decisions into competent behaviours, identified by specific motor and communication skills relevant to the context of shiphandling. Perceiving, understanding, recalling and comparing with previous experiences, analysing, projecting, then acting with precision and effectiveness and then reassessing the outcome, put a certain "burden" on the shoulders of shiphandlers involved. This "burden" is what has been referred as mental workload (with its correlated physiological reactions). Despite the interest in the topic for the last few decades [35], there is still no universally accepted definition of mental workload [36]. Mental workload is a multidisciplinary concept and has long been recognized as an important element of human performance in complex systems [37]. The optimization of mental workload has shown to reduce human error, improve system safety, increase productivity and increase operator satisfaction [38]. Csikszentmihalyi, for example, identifies the "Flow" [39] as a state that is reached when a highly skilled individual is fully involved in a in a highly challenging activity. Mental workload could be seen as an indirect measure strictly related to such involvement. Mental workload arises due to a combination of the task demands and the resources that a particular individual has available [40]. The mental workload of a task can be seen as the level of attentional resources required to meet both objective and subjective performance criteria, which may be mediated by task demands, external support and past experience [41]. Subjective mental workload has been defined as the subject's direct estimate or comparative judgment of the mental or cognitive workload experienced at a given moment [42]. Since workload cannot be directly observed, overt measurements of psychological and physiological variables are gathered and used for inference [43]. At the bottom of the figure are reported, for each previously mentioned psychological construct, relevant variables that are collected in this assessment methodology and that will be extensively described in the next paragraphs. Personality traits as well as social skills and bridge team interactions could not be investigated due to the lack of a bridge team in the experimental setting. Experience is considered homogeneous for this particular study, after having evaluated interviews conducted with participants coming from the same group of Pilots. Results so obtained through the use of SAT are thought to be able to address immediate Industry's selection and training needs. Such results can also be used to identify areas of improvement for human machine interfaces [44], communications and operational procedures, influencing Industry's practises at a technical, operational, and regulatory level [45] [2].

## Methodology

The assessment is divided into two phases. During the first phase (Phase 1), participants are required to complete the planning of the manoeuvres that will be conducted, later on, in the in the Simulator. The second phase (Phase 2) consists in the observation and the whole data collection and processing during and after the execution in a Full Mission Bridge Simulator of the previously planned manoeuvres.

### Phase 1 –Planning

For the trial research study, conducted to test the assessment methodology, the first phase included the planning of four different manoeuvres. Each manoeuvre included the whole process necessary to transfer the ship from a defined initial position to the berth, within constrained port waters, with the use of own and/or external means of propulsion (tugs, when allowed). Even if all the shiphandlers were required to start each manoeuvre in the same position, they were able to choose their initial speed. These manoeuvres were chosen to test one of the aims of the research; to investigate the notion that "shiphandlers expertise "is bounded", or in other words, related to shiphandlers local knowledge of the port where they normally operate. So, for those four manoeuvres, two were the ports chosen as scenario. The first port was the shiphandlers' home port, while the second port was a virtual port (only present in the Simulator database), not representing any real existing port, so as to avoid any

possibility of previous manoeuvring experience the subjects may possess. For each port or scenario two levels of difficulty for the manoeuvres were presented: one easier and one more difficult. The level of difficulty was based on differences between the two manoeuvres in terms of spatial constraints, environmental conditions, vessel's manoeuvrability characteristics, number of tugs available, traffic present and communications required. It has to be noted that the manoeuvres were also coupled across the scenarios: i.e. the easy manoeuvres (as well as the difficult manoeuvres) were as much as possible comparable for several characteristics, such as: vessel hydrodynamic characteristics and limitations in manoeuvrability; distances to be covered from the starting position till the berth; spatial constraints due to infrastructures, natural conformation, presence of other vessels moored or at anchor, available depth of water; environmental forces acting on the vessel (wind, current, etc); Availability of Tugs; interactions with other ships' traffic; or radio communications with a local Port Authority – VTS. The manoeuvres where specifically chosen to represent a condition very similar to an ordinary job, regularly carried out in their daily activities, by the Pilots involved in the trial study (e.g. easy manoeuvre in Port of Brisbane). The other manoeuvres where designed as departures from this initial "normal" condition along two dimensions: the difficulty and the port. Difficulty was enhanced introducing / increasing parameters such as forces involved (wind and current, tug use), dimensions, weather conditions, and such like, and setting them up just above the operational maximum limits adopted in the Port of Brisbane. The use of a different port—even if the manoeuvres were designed to have extremely similar spatial constraints—was introduced to investigate the effect loss of familiarity had on a Pilot's outcomes. Despite of the specific manoeuvres chosen for the trial study and herein described, it can be understood how other type of manoeuvres can be chosen and standardized, in order to be profitably adopted for more focussed assessing purposes.

### *Navigational Charts and the Detailed Manoeuvre Plan*

Phase 1 requires participants provide an extensive explanation regarding how they would perform the manoeuvre in the Simulator. In order to create and to obtain the record of such explanation in a numerical form a Detailed Manoeuvre Plan (DMP) table is compiled by each participant for each manoeuvre prior to performing this manoeuvre on the Simulator. This table can be seen as a more detailed version of the routine passage plan that normally is discussed between Pilots and Ship Masters before a ships enters into a port to be moored at a specific berth [16].The compilation of the mentioned table is obtained through a face to face exchange between the shiphandler and the instructor. The initial material provided by the instructor to the shiphandlers includes also a facsimile of port navigational charts at the appropriate scale for each manoeuvre. On these charts the initial and the final positions of the ship are indicated, specifying which side of the ship is required to be alongside at the end of the manoeuvre. At the beginning of the face to face exchange between the instructor and the shiphandler, only the chart and a brief explanation about the manoeuvre are provided (initial position, position of the berth, side to go alongside to). Shiphandlers are invited to ask all the questions they deem necessary to complete the planning. All the questions are collected in order to evaluate the elements considered by the shiphandlers. There are no limitation whatsoever to the amount, specificity or topic of the questions. All the shiphandlers then receive only the list of the answers relative to their questions. Shiphandlers are allowed to require additional information at any time during Phase 1 until, in their opinion, the information is enough to allow them to proficiently complete the planning task.

For this planning task the shiphandlers are required to sketch ship's movements using the previously mentioned charts, identifying any associated elements of interest with some precision. More specifically shiphandlers are asked to complete their intended Detailed Manoeuvre Plan showing, for example: the sequential positions of the vessel (using waypoints), the speed profile, the use of ship's propulsion (main propulsion, thrusters), and external forces (tugs). Shiphandlers have also to describe how they would better exploit ship's sensors (radar and ECDIS information, gyro and magnetic compass, logs..) and account for environmental and hydrodynamic forces acting on the vessels (wind, current, tide, bottom and bank effects..). All the plans are collected before all the manoeuvres can take place in the simulator. As prepared prior to the simulation these plans form a comparative basis for assessing outcomes measures generated from the completed simulation experience. Such measures include the execution of each manoeuvre. In fact a Full Mission Bridge Simulator can record in real

time and with a high degree of accuracy at several samples per second, all the previous mentioned parameters being studied.

## Phase 2 – Execution

For the purpose of the initial trial study, the Maritime Safety Queensland, Full Mission Bridge Simulator in Brisbane was used (Smartship® Simulator www.smartshipaustralia.com.au). This Simulator included advanced features such as a 16m diameter screen with 360 degree field of view (FOV). In addition, the Bridge was fully equipped with original bridge consoles featuring real navigation equipment and, in particular, NACOS 65-5 (a command and control, Integrated Navigational System) by SAM Electronics. Simulator software and hardware are provided by FORCE Technology® (www.forcetechnology.com), Denmark. A Full Mission Bridges, classified as Class A (NAV) according to the standards issued by DNV [46], should be adopted to carry out the here proposed methodology. Those standards require that such Simulator should be capable of simulating a total shipboard bridge operation situation, including the capability for advanced manoeuvring in restricted waterways.

### At the Simulator - Execution of the Manoeuvres

Before starting the manoeuvres previously planned, shiphandlers are fitted with the equipment necessary to record their physiological variables. Once the electrocardiogram and eye tracker equipment is tested, shiphandlers are required to perform a very simple mooring manoeuvre with a vessel different from those used in the experimental runs. This first manoeuvre is used as a familiarization run in order to have the shiphandlers acquainted with the bridge environment and the navigation equipment available. After this familiarization run, the remaining manoeuvres that were previously planned in Phase 1, are used as "hot runs", so all the data of interest is recorded. Before each manoeuvre, the relevant Detailed Manoeuvring Plan (compiled in Phase 1) is reviewed with the instructor in order to evaluate any possible doubt or additional question. A video recording, where the shiphandler goes through the plan with the instructor, is finally captured. Before the simulation is started an initial physiological baseline recording is carried out. After few minutes of baseline recording the simulation is started, allowing the shiphandler to execute the manoeuvre. During the manoeuvre there are no interruptions or suggestions by the instructor who is generally acting as the ship's Master or, when required by the specific context, as the member of the bridge team more suitable to interact with the shiphandler at that time. Immediately on completion of the manoeuvre once the simulation is stopped, another physiological baseline is recorded. At the end of the final baseline recording a NASA TLX Questionnaire is completed by the shiphandler. For each run or manoeuvre a debriefing is carried out and video recorded, in order to take note of any comment or consideration formulated by the shiphandler with reference to the just completed exercise. Each manoeuvre requires to complete a mooring using the side of the ship opposite to the position of the berth at the beginning of the manoeuvre (i.e. if the berth is on the starboard side of the ship at the beginning of the manoeuvre, then the manoeuvre would require to go alongside with the port side of the ship). This implies that for each manoeuvre the ship has to swing (rotate 180 degrees) before she can be moored. For this reason, it is possible for each manoeuvre to identify 3 main sections: the "approach" (from the initial position until the start of the swing), the "swing" (from the start of the operations necessary to induce the swing until the rotation is completed and stabilized), the "closing" (from the end of the swing, as previously defined, until a defined certain distance from the berth).

### Recording and Processing of Physiological Parameters:

One of the tools used by the assessment methodology is a continuous recording of physiological variables in the least obtrusive possible way. For the entire duration of each manoeuvre and for an initial and subsequent baseline period of at least 5 minutes a continuous recording of the physiological variables is conducted. Those measurements are thought to provide an insight of the shiphandlers level of involvement or difficulty subjectively experienced, helping to better understand end evaluate correlations with following performance outcomes. Only portable, wireless and sufficiently comfortable recording devices are chosen.

For the recording of the Electrocardiogram, a Smartex® Wearable Wellness System® was used (www.smartex.it). This system, among other variables, is able to collect a full electrocardiogram (sampling frequency of 250 samples per second).From the raw ECG signals, the Heart Rate Variability (HRV) is then analysed. HRV is known as a non invasive technique to measure cardiovascular autonomic regulation [47]. It expresses the balance of the regulation of the sympathetic and parasympathetic nervous systems. HRV has been extensively exploited to study the association between psychological processes and physiological reactions [48]. The LF/HF ratio is an important parameter derived from the study of the power spectral density (PSD) of the inter beat intervals signal (IBI) in the Low Frequencies (LF – from 0.04 to 0.15 Hertz) and in the High Frequencies (HF – from 0.15 to 0.40 Hertz) [49]. LF power component is connected with the nervous system sympathetic activity while the HF power component is more connected with the parasympathetic system [50]. Elevated values in the LF are associated with high work stress [51], resulting in higher scores in the LF/HF ratio. The strong correlation between Heart Rate Variability and Stress has been extensively documented in the literature [52]. For the purposes of this paper, we define "stress" as the transition from a calm state into an excited state, through the activation of the sympathetic system [53], considering as "stressors", excessive intellectual, emotional and perceptual stimuli [54]. The measurements of LF/HF ratio and the Heart Rate are specifically chosen for the assessment methodology described in this article, due to their sensitivity to work related stressors [51, 55].

To test eye movements, ASL® Mobile Eye XG® (www.asleyetracking.com) eye tracking goggles are used. The Eye Tracker goggles have a front HD camera that records what is in front of the subject, a second infra red camera is pointed towards the subject right eye and records the pupil movement. This system is then able merge the two channels, providing the gaze position through a red cross overlaid on the video recorded by the front camera. Audio is also recorded. The video and audio recordings obtained from the Eye tracker are reviewed and categorized using INTERACT® software (www.mangold-international.com). The video coding is conducted using a set of labels, hierarchically organized, to identify specific elements that the shiphandler observes in the simulated environment. For example, these labels identify elements that could be observed in the port environment such as beacons or leads, or elements that could be observed on the Bridge such as instruments, indicators and equipment. Due to the long time necessary to complete the manual coding for the whole duration of the manoeuvres, a sampling strategy is applied in order to obtain the video coding from specific parts of the manoeuvre. A total duration of 20 minutes of video coding is obtained for each manoeuvre, considering 4 different sections of 5 continuous minutes. The section's location in each manoeuvre is dictated by the following criteria:

| Approach | | | Swing | | | Closing | | |
|---|---|---|---|---|---|---|---|---|
| Video Coding | GAP | Video Coding | GAP | Video Coding | GAP | GAP | Video Coding | GAP |

**Table 1 – Locations of video coded sections in each manoeuvre**

Each coded section has always a minimum duration of five minutes (unless the whole duration of that specific manoeuvring phase is less). In the swing and in the closing section the video coding is always placed in the middle of the identified window, while for the Approach section, it is placed at the very beginning and at the end, finishing with the limit of the swing section. Gaps, of course, have to vary accordingly, depending on the duration of the different manoeuvre sections. Video Coding provides statistics regarding shiphandlers gaze distribution, in terms of frequency and duration, on different elements, for each section of the manoeuvre. From such data, it is possible then to infer what sources of information are preferred by shiphandlers, in order to maintain and develop (or not) their situational awareness [56].

Those statistics can be profitably compared with performance outcomes (as described in the following paragraph) in order to provide correlations between shiphandlers screening behaviours and performance results obtained [57]. Exploiting the same software application (INTERACT®) it is also possible to code the audio tracks, this time for the entire duration of each manoeuvre. Labels used for coding, identify different type of communications adopted on the Bridge. To provide an example,

these communications could be strictly "orders" originated by the shiphandlers to execute specific adjustments on ship's propulsion settings or rudder, or radio communications with other vessels present in the exercises. The aim of the audio coding is to quantify the volume and quality of communications. Thinking aloud reports (Walker 2004) in the form of situation and intentions sharing with the rest of the Bridge (acted by the instructor), are also considered and quantified. While the actual measurement will be described in the next paragraph, audio coding can also provide insight into the mental workload experienced by the shiphandler through the use of ordinal ratings on a self assessment scale.

### Recording and Processing of Self Reported Mental Workload

Measurement of mental workload reflects the enumeration of mental processes which occur during performing a task [58]. One of the methods used in research to assess subjective mental workload is the adoption of self assessment techniques. Self assessment scales present some disadvantages: they can tend to be situation specific and may fail to take into account the individual's learning, experience, natural ability and changes in emotional state, they also might reveal little in terms of the brain mechanism involved in task performance [58]. Nevertheless, self assessment scales are relatively easy to administer and interpret and they do not require extensive training or equipment [42]. In light of all those considerations, for the purpose of this Assessment Methodology, two Mental Workload measurements are adopted.

One of them is the National Aeronautics and Space Administration-Task Load Index (NASA-TLX). NASA-TLX [18] is a multidimensional scale for which the overall mental workload is a function of 6 subscales: 1. Mental Demand (MI), 2. Physical Demand (PD), 3. Temporal Demand (TD), 4. Own Performance (OP), 5. Effort (EF), 6. Frustration Level (FR). At the end of each manoeuvre a NASA TLX form, in a Microsoft® Excel® electronic format, was completed by the shiphandlers.

The second self assessment Workload measurement is obtained through the audio coding. The audio recording is exploited to obtain the level of involvement or Workload experienced by the shiphandler during the entire execution of the manoeuvre. Before the manoeuvres are started shiphandlers are instructed about the use of a self assessment scale, which they will have to refer to, to verbally report their level of "involvement or workload". The scale provided (and always kept in shiphandlers' sight), reports 7 different levels of "exercise difficulty", meaning the personal level of workload experienced or effort necessary, in order to be able to manage the situation at the time of the question. Level 7 was indicated as the level where the situation was felt so demanding, that was just about to be out of hand; level 6 was a challenging situation that required the complete attention of the shiphandler, working at almost 100% of his capabilities; level 5 was a situation requiring more attention than normal, but not felt as critical as level 6; level 4 wanted to depict a normal level of involvement where the shiphandler could feel perfectly capable to achieve the desired outcome with a necessary but comfortable level of effort (routinely operation); level 3 was an easy condition offering no specific challenge, with required effort below the average; level 2 was a very comfortable, almost effortless situation; level 1 indicated a situation of "complete boredom", with very little or no involvement. The shiphandler, during the execution of the manoeuvre, is briefly reminded (every two minutes circa), with a quick question asked by the instructor (i.e. "How do you feel?"), to simply report a number according to the scale above described. The results so obtained, with reference to the whole manoeuvre using the NASA TLX, and within each manoeuvre using the self reporting scale, can be compared with the physiological measurements, as described in the previous paragraphs.

### Recording and Processing of Technical parameters provided by the Simulator

The simulator was principally used to gather data more related to technical aspects. For the purposes of the assessment methodology introduced in this paper, the technical performance results are obtained evaluating the difference between the data initially estimated and provided by the shiphandlers in the DMP and the actual measurements recorded by the simulator during the execution of the manoeuvres. More specifically, it is considered: the distance from the intended track and the effective ship track recorded by the simulator (Cross Track Distance); the difference between the intended speed over the ground and recorded speed; the difference between the intended use of power and the recorded power for main engine, thrusters and tugs. The calculation of the results for any of the above parameters is

performed for each participant and for each manoeuvre (within each section). In particular, participants are assessed and ranked, based on their capability to minimize the parameters above mentioned.

## Conclusions

This paper describes the development of an assessment methodology to objectively evaluate groups and/ or individuals' shiphandling capabilities in a Full mission Bridge Simulator. Given the complexity and the broadness of the concept defined as "Shiphandling Expertise" in this paper, several different objective measurements are isolated to permit assessors to empirically quantify different levels of a Shiphandler's "expert performance". Those measurements take into account shiphandlers' planning and forecasting capabilities through the compilation of a Detailed Manoeuvre Plan. Such plan can be seen as a more advanced version of the currently used "Pilot Master Exchange Briefing". The obvious difference with the latter is that the proposed DMP provides a more stringent and quantifiable way to report the information required, to allow an objective comparison between planned action and execution.

Another element considered by the methodology, is the amount and type of information that the planner requests in order to forecast the manoeuvre. Such information can be used to support an inference about shiphandling related knowledge and experience. Independent and unobtrusive self reporting and physiological variables are also proposed as subjective and objective measurements of experienced stress / workload. Those measurements are thought to provide an insight of the shiphandlers level of involvement or difficulty subjectively experienced, helping to better understand end evaluate correlations with following performance outcomes. Those variables are triangulated with an overall subjective assessment of the manoeuvre, obtained from the administration of a NASA TLX form. Behavioural variables (obtained from eye trackers audio and video recordings) are considered in order to identify and objectively measure working strategies adopted. The measurement and the quantification of specific overt behaviours and screening strategies can identify those that prove to be more efficient and effective. Several performance variables were proposed as concurring measurements able to objectively evaluate different levels of technical shiphandling capabilities. Those measurements can offer the opportunity to trainers and instructors to better understand and evaluate individual performance, allowing, for example, improvements in training techniques.

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