# Evaluation of a Virtual Reality System for Ship Handling Simulations

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Abstract: The assessment of virtual reality ship handling simulators is extremely important to guide the research in the field, since the prolonged use can affect both the performance and the experience of users. Here, we evaluate a ship simulator based on two different visualization setups: a non-immersive system based on standard monitors, and an immersive system that uses a virtual reality head mounted display. We did an experimental session of manoeuvring tasks performed by 20 volunteers, specifically students of a naval academy. To evaluate the system, we analyzed three different aspects: performances, level of cybersickness and sense of presence. The results show that: (i) expert users are able to follow the predefined path in a quite accurate manner; (ii) both systems do not introduce anxiety, stress or particular undesired effects, and the use of immersive virtual reality itself does not explain the increase of user malaise state; (iii) immersive virtual reality systems allow users to feel more involved and present in the simulation scenario.

## 1 INTRODUCTION

Ship handling simulators have always taken advantages from computer-based environments representing a replica of the real world, in which the ship is operating. Such a kind of systems can be used for both design assessment and for training purposes (Varela et al., 2015; Varela and Soares, 2015; Benedict et al., 2014). New technologies and, in particular, immersive virtual reality (VR) head mounted displays (HMDs) give the users the possibility of interacting in synthetic environments for more realistic experiences, which are a key aspect in the context of the Industry 4.0 and of the factories of the future.

The goal of the current study is the assessment of a new VR technological system for ship handling simulation, developed in the context of the project MIT - Leadership Tecnologica [1]: the prolonged use of this type of systems might produce on users different negative effects related both to a decrease of performances and an increase of sickness. The considered ship handling simulator is a simulation framework designed with different targets on mind: training, virtual prototyping and virtual test bed. Major strengths of the framework are the high detailed real-time physical behavior reproduction of any type of ships (from small boat to big ships) and a powerful visualization system using up to date gaming technologies for the best cost effective virtual reality environment available nowadays.

In this article, we present the results of the assessment of the described ship handling simulator: we carried out an experimental session lead on students of the Genoa naval academy, by testing how the operator can feel using different types of immersive experience during navigation activities. In particular, the aim of this work is the evaluation and comparison of different technological solutions and techniques for the implementation of an interactive virtual reality system: on the one hand, a traditional simulation system, composed of a monitor for visualization; on the other hand, a virtual reality system constituted by a HMD for VR (the Oculus Rift). Interaction is done through the physical reproduction of a ship command panel, which, in the first case, is completely visible to the user, while, in the second case, has to be substituted by a schematic virtual representation in the virtual

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environment and synchronized with it.

The paper is organized as follows: in Section 2 we briefly discuss the state of the art, in the field of VR based simulation; in Section 3 we describe some technical aspects of the considered setups and the experimental procedure we have followed. In Section 4 we present and discuss the obtained results, and in Section 5 we conclude and discuss the further developments and implication of our research.

## 2 STATE OF ART

In this Section, we will discuss the state-of-the art concerning the main factors analyzed in the paper: *cybersickness* and *sense of presence*.

In the last decade, virtual reality has had a widespread success, especially after the release of cost effective devices, such as the Oculus Rift, the Playstation VR and the HTC Vive. The domains of application are disparate but one of the most important still remains training and education. However, *cybersickness*, defined as a state of malaise and unpleasant side effects associated to use of immersive simulations, is still a common problem, affecting 60-80 % of the users, and it is a potential issue for the broader adoption of these technologies, although its minor, short term health risk (Nesbitt et al., 2017). Typically *cybersickness* varies between individuals but common symptoms are nausea, eyestrain, dizziness, apathy, sleepiness, disorientation, fatigue and general discomfort. It can occur immediately after training or even up to 5-12 hours later (Munafo et al., 2017; Kim et al., 2005). It is also worth noting that this state of malaise can also cause cognitive impairment and negatively affect user's performance while accomplishing a task (Nesbitt et al., 2017).

Causes of *cybersickness* are still over debate, but three prominent theories are: poison theory (Bouchard et al., 2011), postural instability theory (Riccio and Stoffregen, 1991) and sensory conflict theory (Reason and Brand, 1975)). In particular, the latter thesis suggests that the mismatch of vestibular and visual sensory systems could cause sickness, due to the absence of inertial displacement and could explain why higher Visually Induced Motion Sickness(VIMS) levels were reported in passive exploration compared to active exploration of virtual environment (Sharples et al., 2008).

Factors influencing *cybersickness* include individual, device and task differences (McGill et al., 2017; Nesbitt et al., 2017; Davis et al., 2015; Davis et al., 2014).

*Cybersickness* can be quantify using both subjective and objective measures, which were listed by (Keshavarz and Hecht, 2011; Nesbitt et al., 2017). Subjective scales of evaluation include susceptibility questionnaires (Motion Sickness Susceptibility Questionnaire (Gianaros et al., 2001), Reason and Brands Motion Sickness Susceptibility Questionnaire (Reason and Brand, 1975)), online reports, usually composed by a symptom or question that participants are asked to rate multiple time during the simulation in order to detect runtime onset, course, severity and trend of VIMS (Fast MS Scale (Keshavarz and Hecht, 2011), Misery Scale Index (Bos et al., 2010), Short Symptom Checklist (Nichols et al., 1997)) and standard questionnaires usually filled in before and after the trial, where user is asked to rate the severity level of different symptoms (Simulator Sickness Questionnaire (Kennedy et al., 1993), Motion Sickness Assessment Questionnaire (Gianaros et al., 2001), Pensacola Motion Sickness Questionnaire (Lawson and Mead, 1998), Nausea Profile(Muth et al., 1996)). Objective measures, instead, include physiological measurements, some of which have been proven to be correlated with VIMS (Davis et al., 2015). (Nalivaiko et al., 2015) studied the effect of *motion sickness* on thermoregulation, using provocative visual stimuli (immersion into the virtual reality simulating rides on a rollercoaster). They found out that, during immersion, there is an initial phase of vasoconstriction, due to a defense response associated with arousing effects of the simulated ride, followed by a vasodilation, related to *cybersickness*. Vasodilatation causes heat loss through sweating, an increase of skin conductance, skin warming and tachycardia, which is related to the activity of the sympathetic nervous system, as a defensive reaction against the sensation of nausea (Ohyama et al., 2007). An other study conducted by (Kim et al., 2005) demonstrated a significant positive correlation of *cybersickness* severity with gastric tachyarrhythmia, increase of eyeblink rate and EEG delta wave and decrease of heart period. Finally, also analysis of sway and center of pressure (COP) could be informative (Munafo et al., 2017; Aldaba et al., 2017). In fact body sway differs between participants who report motion sickness and those who do not.

Another important aspect to be considered is *sense of presence* or *spatial presence*, which is defined as the psychological state where virtual experiences and computer-generated environments feel authentic rather than the actual physical locale, or, in other words, the sense of "being physically there" (Sheridan, 1992). Unlike *immersion*, which depends essentially on the type of technology used and can be objectively described, *sense of presence* is primarily subjective and is linked to the user experience. In particular, some theories asses that *spatial presence* is determined by how efficiently we mentally process the spatial relations within the environment (Wirth et al., 2007). So, persons able to process spatial arrangements effectively will find it easier to create a "mental model" of the spatial environment, thus they will experience a higher *sense of presence*. Authors in (Coxon et al., 2016) proved that self-reports of imagery are positively correlated with reports of *spatial presence*, but *spatial presence* itself is not related to performance.

Although, its subjective nature, however, other factors influence *spatial presence* (Usoh et al., 2000): the degree of interaction user has with the virtual environment, as the presence of the player in the virtual world implicitly implies his ability to act in it and interact with it; the proper implementation of an action-effect loop; the high resolution of information displayed, in a manner that it does not indicate the existence of the display; the consistency of the displayed information across different sensory modalities; the presence of a first person avatar, as a self-representation of the user in the virtual world, which should be similar in appearance or functionality to the individuals body.

Standard questionnaire commonly used to measure *sense of presence* are the IGroup Presence Questionnaire (Regenbrecht and Schubert, 2002), the Presence Questionnaire (Witmer and Singer, 1998) and the Slater, Usoh and Steed (SUS) Questionnaire (Slater et al., 1998; Usoh et al., 1999).

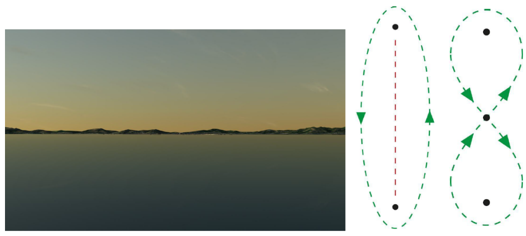
# 3 MATERIAL AND METHODS

Here, we describe how the software application has been designed, the two different hardware solutions taken into account and the parameters defined in order to evaluate the two different setups.

## 3.1 Software

The simulation system is conceived as a gamification of a ship handling experience. Gamification is a process consisting in the introduction of techniques, methods and strategies typical of entertainment world in educational contexts, which, otherwise, would be deficient in induced interactivity. This way, users are encouraged to familiarize with a new experience bypassing the specific physical interface and constraints, due to a lack of knowledge or experience.

When the application starts, both with the monitor and the VR setup, participant finds himself on a boat offshore, some kilometers far from the coast. Scenario, shown in Figure 1a, is inspired to actually existing coastal areas, a surface of about 50 km x 50 km around Genoa harbour, taken from a 3D graphics database. Rendering is not detailed in order to avoid to distract the user with an excess of visual information, while maintaining a good level of involvement, determined by the recognition of familiar scenes.



(a) (b) (c)

Figure 1: (a) Scenario of the simulation. (b) Ellipse and (c) Eight paths.

User has to steer the ship following one of the predefined paths: the Ellipse and the Eight path (see Figure 1b-c). The Ellipse path is the simplest one, in fact it is composed of two curves and two long linear parts. The Eight path, instead, is more complex because of the frequent changes in direction. This implies a greater freedom of movement and a higher probability of losing the original route. Moreover, participants are required to have a better spatial mapping and control over the ship, being aware of its turning rate, i.e. time and space required to veer.

The path is fixed and visible to the user as a route just above the sea. Moreover, in order to improve spatial awareness and spatial mapping, a canvas showing the path with directional arrow and user tracked position is shown on the top lateral portion of the display.

Weather conditions are an additional feature of the system: in fact, in the Eight path simulation, sea is calm and plain, while in the elliptic path simulation, sea is more rough, in order to counterbalance the simplicity of the route.

Finally, participants have to accomplish the task with two different ships: a patrol boat and a coastguard, afterwards referred to as fast and slow boat, respectively. The patrol boat is a small light vessel (15 m long and 20 t of weight), that can reach 50 n of speed. The coastguard, instead, is a larger ship (20 m long and 50 t of weight) that can reach a maximum speed of 20 n. The aesthetics and the operating mechanisms of these two ships have been modeled and implemented as faithfully as possible.

### 3.2 Hardware

Two different setups have been designed and implemented: a traditional simulation non-immersive virtual reality system, based on 3 standard monitors, and an immersive VR system, based on a HMD. In both cases, interaction is done through the physical reproduction of a ship command panel, so people can drive ships rolling a real rudder and moving the accelerator knobs, one for the right engine and one for the left engine. In the first case, the command panel is completely visible to the user, while, in the second case, it has to be substituted by a schematic representation in the virtual environment, a slider showing rudder rotation, and synchronized with it.

In the monitor setup, three 27 inch monitors are disposed vertically side by side, in order to mimic the view from the ship command bridge. The user is required to wear a safety helmet, with a HTC Vive tracker attached on it, for the purpose of tracking his position and rotation. In the VR setup, instead, monitors are substituted with a HMD, the Oculus Rift. In this case, there is no need for external tracking, as the Oculus provides its own tracking system.

### 3.3 Parameters

As the goal of our work is evaluating the two different visualization solutions, we defined and measured different parameters considering three main aspects: participant performance; *cybersickness* and comfort in general; *sense of presence*.

**Performance.** Performance is considered as the ability of the user to follow the proposed paths, so boat latitude and longitude are recorded during the experimental session.

**Cybersickness and Comfort.** Avoiding *cybersickness* is a crucial point, as it can negatively affect users performance or even generate repulsion towards the system itself. For this reason we have decided to quantify it by using both subjective valuations, i.e. the Simulator Sickness Questionnaire (SSQ), and objective parameters, i.e. physiological measurements. The SSQ is an instrument commonly used to quantify this state of malaise. It is composed by 16 questions in a 4-points Likert scale evaluating three main aspects: Nausea, Oculomotor disorders and Disorientation. This questionnaire is usually submitted before and after the exposure to a simulation system in order to obtain a differential measure of induced discomfort.

Skin conductance, i.e. the continuous variations of the electrical characteristics of the skin caused by variations of the sweating, and heart rate are, instead, physiological parameters strictly linked to the emotional and mental state of the user: variations of these two parameters from the baseline could be a consequence of stress, fatigue, excitement or *cybersickness*.

We decided to use the Mindfield eSense Skin Response sensors, to measure skin conductance, and Scosche Rhythm armband, for heart rate. The first sensor is connected to a smartphone Galaxy S4 by wire and uses a proprietary software to record and send 5 samples/second, while the second sensor is connected to the same phone via Bluetooth and exploits the BLE Heart Rate Monitor software in order to memorize and send 1 sample/second.

**Sense of Presence.** In order to quantify *sense of presence* we decided to use the Igroup Presence Questionnaire (IPQ), which is one of the standard questionnaire currently available for measuring presence. It is composed of 13 7-points Likert scale questions evaluating three different aspects: the Spatial Presence, defined as the sense of being physically present in the virtual environment; the Involvement, intended both as attention during the interaction with the virtual world and as perceived involvement; the Experienced Realism, which measures the perceived realism of the VR experience. An additional question rates the *sense of presence* from the original definition on (Slater et al., 1994).

Moreover, user rotation and position are recorded during the test, in order to evaluate the tendency of people to explore the surrounding environment and interact with it in a natural way.

### 3.4 Procedure

In this work, we consider three different independent variables: boat type, visualisaton modality and path shape. Considering the two first variables we use a repeated measure experimental design, as all participants accomplish the task both with the slow and fast vessel with either the monitor and the HMD. While considering the latter parameter, we adopt a between group experimental design, half of the participant use the Ellipse route and half the Eight one, in order to understand the influence of the task on the choice of the setup.

Experimental procedure has been defined after a set of trial acquisitions, during which it has been noticed that people could not accomplish the task when they started with the immersive virtual reality simulation. So the order of execution is fixed: participants start with the monitor simulation and the slow boat (Monitor Slow), then the fast boat (Monitor Fast); after this, they wear the Oculus Rift and accomplish the task in the immersive virtual environment with the slow (HMD Slow) and fast (HMD Fast) vessel. Each trial lasts 5 minutes.

A brief introductory tutorial phase precedes the use of a new hardware setup. Guided by the experimenter, users start familiarizing with the interface and visualization system and try driving the ship for 1 minute. In this phase, we do not acquire any data.

The procedure, therefore, is fixed and well defined. Prior to the experiment execution, the experimenter explains participant the modality and the purpose of the test, the different tasks, the setup and the instrumentation used. Then subjects have to sign a written consent and the privacy policy. Participants are told that they could interrupt the experiment whenever they wanted.

After this, they have to fill in an anonymous module giving personal information, like their age, their genre, if they have already participated in studies concerning simulation and/or VR environments, if they have ever used immersive virtual reality systems and if they have ever driven a boat and which kind of boat.

Afterward, the experimenter attaches the different sensors to the participant (Scosche Rhythm armband and Mindfield eSense Skin Response sensors) and give him an armband for the smartphone. Sensor choice and position have been thought in order not to interfere with participants movements or cause discomfort, reducing *sense of presence*.

Next, participant is asked to fill in the first SSQ (SSQ Pre) and, once finished, he accomplishes the four tasks. After each trial, he has to complete a separate SSQ, in order to monitor his state of malaise from time to time.

Finally, volunteers are asked to fill in an IPQ for each trial accomplished.

The experiment has a total duration of 45 minutes, 20 minutes of which for simulation.

### 3.5 Participants

Data recorded have been collected on a sample of 20 volunteer healthy male subjects aged between 20 and 24 years (21.8 $\pm$1.1 years). They had normal or corrected to normal vision. The majority of participants were naive towards Virtual Reality (74 %), while 5 % had already took part to experiments involving VR systems. All of them were expert boat drivers (see Table 1), in fact they were students from the Genoa naval academy, so they were familiar both with the command panel and the task. On one side, we wanted to evaluate the reaction of experts to specific stressors; on the other hand, we wanted to understand their propensity to use VR technologies, which could be perceived more as a game than a serious tool for learning.

Table 1: Boats usually driven by participants.

| Kind of boat | Number of people |
|---|---|
| Fast smaller than 15 m | 8 |
| Fast longer than 15 m | 2 |
| Slow smaller than 40 m | 3 |
| Slow longer than 40 m | 2 |
| None | 4 |

## 4 RESULTS

In this section, we present results obtained from the analysis of head rotations, trajectories and physiological measurements (skin conductance and heart rate), considered as quantitative parameters, and of the Simulator Sickness and IGroup Presence Questionnaire, referred to as qualitative parameters, as they highlight users opinions and impressions. As stated before, participants were expert boat drivers taught to be impassible and not to move their head or body while driving. Data referred to head movements, though, are not informative and have been excluded from further analysis.

### 4.1 Analysis of Trajectories

The latitude and longitude of the virtual boat during task execution have been recorded and organized based on the ship velocity, the system used for simulation and the path. In general, as shown in Figure 2, participants trajectories seems to be quiet accurate and the original path shape is easily identifiable, especially concerning the Eight path data.

### 4.2 Skin Conductance

During the experimental session skin conductance was recorded as a measure of change in participant emotional state and well-being. Samples were analyzed firstly considering the kind of trial (Monitor Slow, Monitor Fast, HMD Slow, HMD Fast) and secondly taking into account both the kind of trial and the path (Ellipse or Eight).

Results obtained from the first analysis are shown in Figure 3. In the monitor case, in general, skin conductance is stable and constant, even if slightly higher in the trial with the faster ship, probably because of the greater difficulty of the task; whereas in the HMD case, it initially fast decreases and then settles around

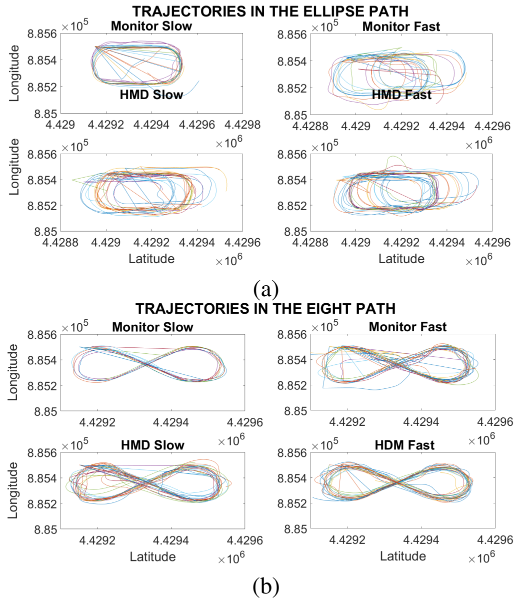



Figure 2: Trajectories of all participants who performed the task with the Ellipse path (a) and Eight path (b). Results are divided based on the simulator system used (monitor or HMD) and boat velocity (slow and fast).

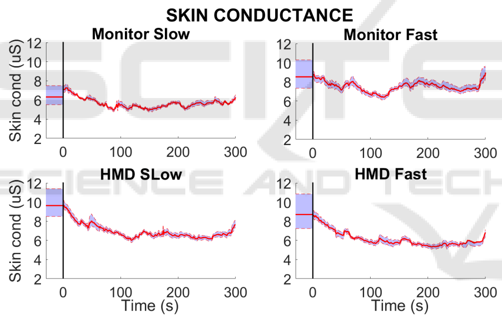



Figure 3: Average skin conductance based on the trial.

a stable value, similar to the one recorded during the simulation with the monitor. This descending trend at the beginning of the trial, can be associated to the fact that the majority of subjects have never tried VR before, so they could be particularly anxious or excited at first. However, when they realize that the task consists in an activity they are used to, skin conductance decreases.

Also the results obtained, considering the two paths separately, confirm the trend highlighted above (Figure 4). Moreover, skin conductance in the Monitor Fast trial is in average the highest one in both cases, maybe because participants face for the first time the fast task and still have little confidence with the setup, hardware and software. This effect, however, is attenuated in the following trials.

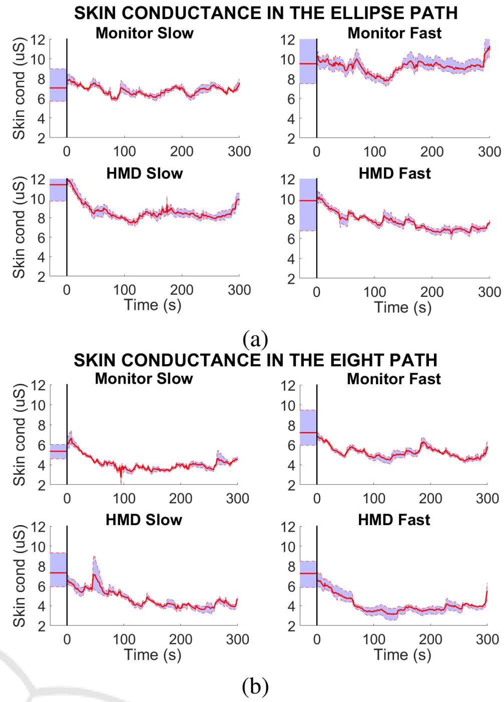



Figure 4: Average skin conductance considering the trial and the path: Ellipse (a) or Eight (b).

## 4.3 Heart Rate

Heart rate is a physiological parameter strictly linked to users' emotional, mental and physical state, like skin conductance. Heart rate was recorded during each experimental session and samples were analyzed firstly considering the kind of trial and secondly taking into account both the kind of trial and the path.

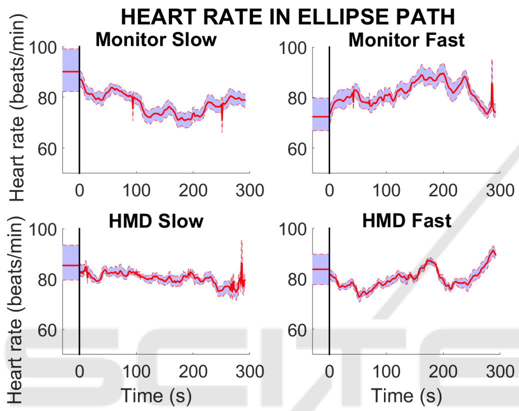
Figure 5 shows that heart rate is, in general, regular and comparable in the four trials. Slightly higher value in the fast trials, both with the monitor and the HMD, are probably caused by the difficulty of the task and can indicate a higher level of involvement. So, both hardware systems do not introduce particular emotional states that could compromise performances and interfere with learning.

Also data organized accordingly to the path, confirm previous considerations. In particular, the absence of elevated heart rate values (around 100 beat/min) excludes the presence of *cybersickness* and could indicate that participants have perceived the simulations as natural experiences, comparable to real life driving experiences.

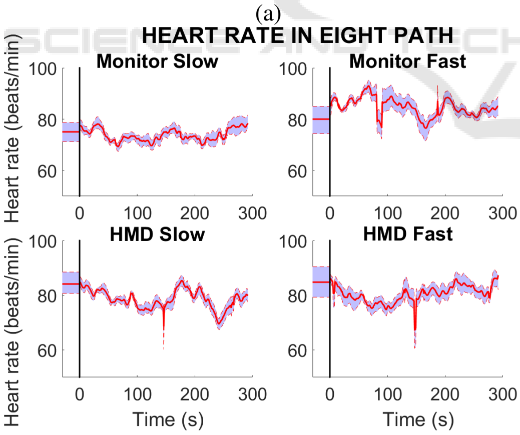
## 4.4 Cybersickness Questionnaire

If physiological measurements can be considered objective quantitative parameters for the evaluation of


Figure 5: Average heart rate based on the trial.



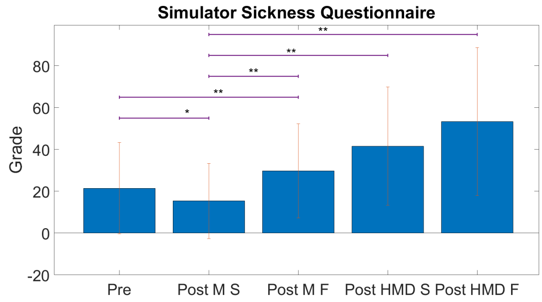

(a)



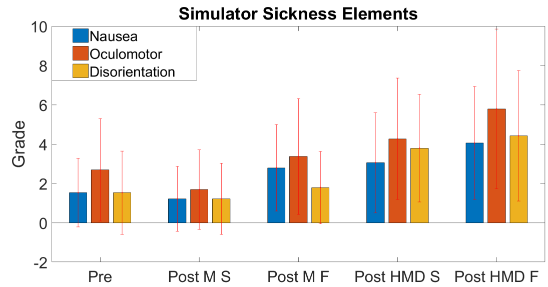

(b)

Figure 6: Average heart rate considering the trial and the path: Ellipse (a) or Eight (b).

the reaction of participants to different simulator systems, SSQ represents a more subjective and qualitative solution. Each participant submitted five questionnaires, one at the beginning of the experimental session and one after each trial. We collected answers given by all the volunteer subjects and analyzed them, firstly, considering the kind of trial and, secondly, taking into account also the path.




(a)




(b)

Figure 7: SSQ results of the five questionnaires submitted. (a) Total grade. (b) Results divided in the three subcategories of the SSQ (Nausea, Oculomotor and Disorientation). M = monitor, HDM = head mounted display, S = slow, F = fast. * p-value<0.05 e ** p-value<0.02.

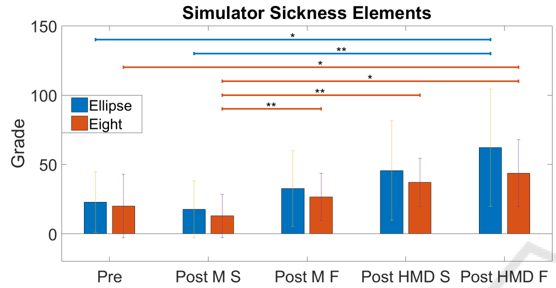
Figure 7a shows an increase in the *cybersickness* final values between consecutive trials. It is worth noting, however, that trial had fix order of execution (monitor first and HMD second), so the worst grade in HMD trials could be due also to fatigue. We performed a between group Wilcox test, in order to evaluate if the increment of *cybersickness* is statistically significant. Figure 7a highlights that differences between results obtained in the Pre questionnaire and in the two questionnaires referred to the monitor and those referred to the Monitor Slow trial and all the following experiments are statistically significant. This suggests that *cybersickness* can be caused either by the hardware system and by the boat velocity.

If we consider separately the three major symptoms of *cybersickness* (Nausea, Oculomotor e Disorientation), in general, they tend to increase during the experimental session, in particular Oculomotor grades, which is consistent with results found in the literature. Wilcox test performed between group, points out that results obtained with the total grade can be extended to the three subcategories (Table 2).

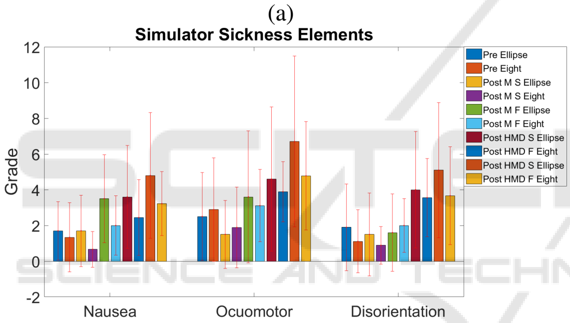
The analysis on SSQ questionnaire grades referred to the Ellipse and Eight paths, shown in Figure 8, confirms results previously described. *Cybersickness* is higher in the trial with elliptic path, probably because

Table 2: P-value obtained making a between group Wilcox test and comparing Nausea (N), Oculomotor (O) and Disorientation (D) grades in the five questionnaires.

| | N | O | D |
|---|---|---|---|
| Pre-Post HMD S | | | 0.0030 |
| Pre-Post HMD F | 0.0029 | 0.0119 | 0.0059 |
| Post L S-Post M F | 0.0111 | 0.0438 | |
| Post M S-Post HMD S | 0.0123 | 0.0032 | 0.0004 |
| Post M S-Post HMD F | 0.0006 | 0.0009 | 0.0026 |
| Post M F-Post HMD S | | | 0.0147 |
| Post M F-Post HMD F | | 0.0475 | 0.0124 |




(a)




(b)

Figure 8: SSQ results of the five questionnaires submitted organized considering the path. (a) Total grade. (b) Results divided in the three subcategory of the SSQ (Nausea, Oculomotor and Disorientation). M = monitor, HDM = head mounted display, S = slow, F = fast. * p-value<0.05 e ** p-value<0.02.

the sea was more rough than in the simulation with the Eight path. The worst sickness value, so, could depend on a combined influence of sea conditions, kind of hardware used (immersive or non-immersive) and ship velocity. In other words, the use of the HMD alone does not explain the increase of malaise. For this reasons further analysis are required.

A Wilcox test was performed in order to determine the statistical significance of these results. In particular, in the between groups analysis the null hypothesis was never rejected, while the within group analysis revealed interesting correlations shown in Figure 8a. In the elliptic path case, the differences between the total values of sickness in the Monitor Slow trial and in the HMD Fast trial are statistically significant (p<0.02), as the differences between the initial and final total grades (p<0.05). While in the Eight path case, only the results obtained in the first and final questionnaire (p<0.05) and in the trial with the monitor and the slow ship and the following tests are statistically significant(p<0.02). Therefore, in the first case, the factors majorly influencing sickness seem to be the boat velocity and the hardware used for simulation, with the HMD negatively affecting participants well-being. Whereas, in the second case, the velocity of the boat plays a fundamental role: curved and irregular trajectories and sudden direction changes, notwithstanding, cause malaise more easily than regular linear path.

These consideration are confirmed by the evaluation of the three major symptoms of *cybersickness*.

## 4.5 IGroup Presence Questionnaire

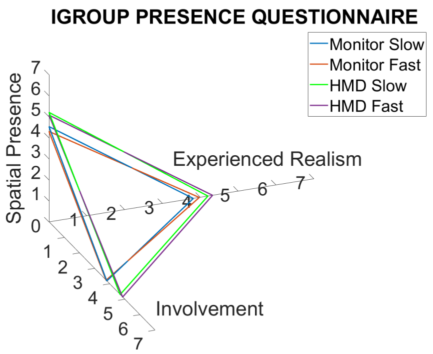
The IP Questionnaire is a subjective measure of the *sense of presence* perceived by users. At the end of the experimental session, participants were asked to fill in four IPQs, one for each trial they had accomplished. Again data collected have been analyzed, firstly, considering the kind of trial and, secondly, taking into account also the path.

The rates given to the three subscales that compose the questionnaire (Figure 9a) are better for the HMD, indicating a higher *sense of presence*. Moreover, the trials with the fast boat have less Spatial Presence but greater Experienced Realism if compared to the trials with the slow ship, maybe because of the realism and response speed of the vessel to user's commands.

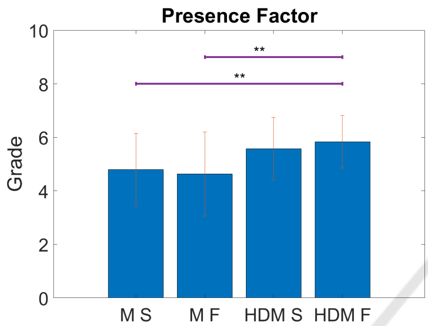
A between group Wilcox test was performed and only the difference of Involvement and Spatial Presence parameters in the monitor and HMD trials has been found to be statistically significant. This means that the use of the Oculus Rift allows the user to feel more involved and present in the virtual simulated environment.

If we consider the Presence Factor (Figure 9b), trials with the HMD obtained better results and this difference is statistically significant: in particular, the average grade in the Monitor Slow and Fast trials with the HMD Fast.

Figure 10a and Table 3 show results organized based on the path shape. Differences between monitor and HMD are more evident in the Eight case than in the Ellipse case, where there is a clear distinction of grades only for Involvements. In fact, in the elliptic path only the difference between Monitor Fast and HMD Slow and Fast for Involvement is statistically significant (p<0.05). In the Eight path, instead, the




(a)




(b)

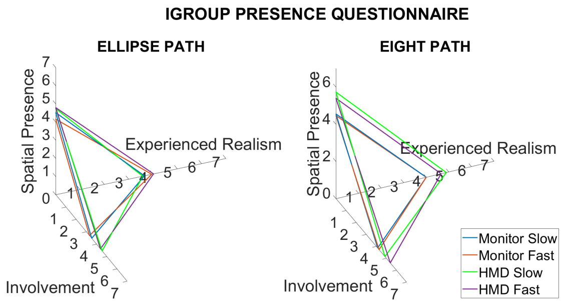
Figure 9: IPQ results of the four questionnaires submitted organized considering the trial. (a) Results divided based on the three evaluation subscales. (b) Mean of grades of the Presence Factor. M = monitor, HDM = head mounted display, S = slow, F = fast. * p-value<0.05 e ** p-value<0.02.

Table 3: P-value obtained making a within group Wilcox test and comparing Spatial Presence (SP), Involvement (I) and Experienced Realism (ER) grades in the four questionnaires considering the two path separately (Ellipse and Eight). Cross refers to the between group Wilcox test, made comparing Ellipse path trials and Eight path trials.

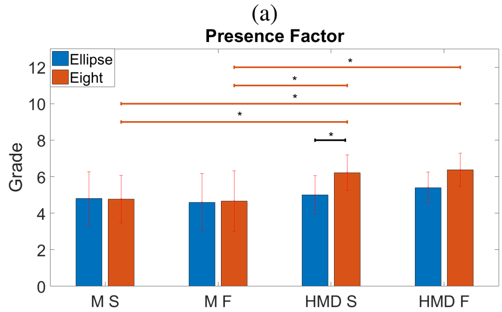
| | | SP | I | ER |
|---|---|---|---|---|
| Ellipse | M F-HMD S | | 0.0254 | |
| | M F-HMD F | | 0.0409 | |
| Eight | M S-HMD S | 0.0030 | | |
| | M S-HMD F | 0.0427 | | |
| | M F-HMD S | 0.0110 | | |
| | M F-HMD F | 0.0472 | | |
| Cross | HMD S-HMD S | 0.0178 | | 0.0261 |

differences in Spatial Presence between monitor and headset are statistically significant.

The Presence Factor shown in Figure 10b is better with the HMD in both paths. This trend is more evident in the Eight path case, were results are also statistically significant. All these data confirm an actual increasing of *sense of presence* in VR.




(a)




(b)

Figure 10: IPQ results of the four questionnaires submitted organized considering the trial and the path. (a) Results divided based on the three evaluation subscales. (b) Mean of grades of the Presence Factor. M = monitor, HDM = head mounted display, S = slow, F = fast. * p-value<0.05 e ** p-value<0.02.



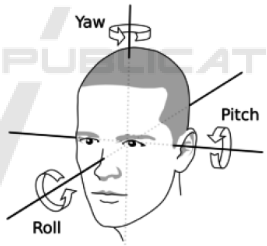
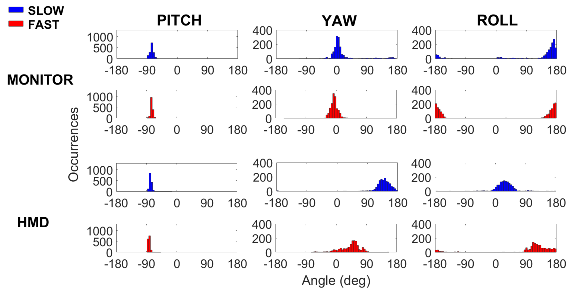



Figure 11: Head rotation angles schema: Yaw is the rotation around the vertical axis (y), Pitch is the rotation around lateral axis (x) and Roll is the rotation around the sagittal axis (z). Axis are referred to Unity coordinates system.

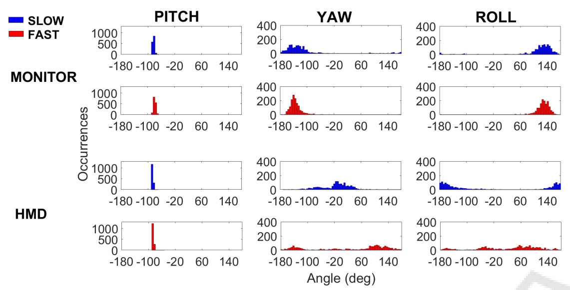
## 4.6 Head Rotation Analysis

Head rotation angles (Figure 11) describe the tendency of people to turn their head and explore the scenario in order to collect information for task execution. It is worth noting, however, that this tendency is subjective: people can be more or less prone to explore the virtual environment. So the following considerations have a relative value.

We extracted head rotation angles and calculated their histogram, in order to highlights users' preferential head rotation angle and distribution across the trial.




(a)




(b)

Figure 12: Non normalized histograms of Pitch, Yaw and Roll head rotation angles of participant 1 (a), who did the trial with the Ellipse path, and participant 2, who did the trial with the Eight path (b). Results are divided based on the system used (monitor or HMD) and the boat velocity (slow or fast).

Figure 12 shows results referred to two participants who accomplished the task with Ellipse (a) and Eight (b) paths both using the monitor and the Oculus Rift. Considering each subject, in the monitor case, we can notice that rotations are scattered around a central value, which corresponds to the initial head rotation when the application starts and the user looks at the horizon in front of him; in the HMD case, instead, especially in the Eight path, participants tended to turn their head more, in order to receive more information from the surrounding environment and better follow the path. This is due to the higher difficulty of the task, in fact the Eight path has more changes in direction while the elliptic one can be considered quite linear. This trend is even more evident in the trial with the fast boat.

## 5 CONCLUSIONS

A simulation system for the training of boat pilots have been tested by expert users. Two versions of the simulation application have been implemented: the first making use of a monitor (non-immersive) while the second uses VR technologies (immersive). The interface is composed of the model of a boat command panel, so the driving experience is as natural as possible and user can sail simply turning the rudder and using the accelerator knobs. The task is simple, participants are required to steer two different boats, a slow one and a fast one, and follow two paths, one having the shape of an Ellipse and the other of an Eight. Both vessel speed and path shape modulate the difficulty of the task, i.e. the trial with elliptic path and slow ship is the easiest one, while the trial with Eight path and fast ship is the most difficult.

In this paper, we present preliminary results obtained from the analysis of quantitative (head rotations, trajectories and physiological measurements, i.e. skin conductance and heart rate) and qualitative (SSQ and IPQ) parameters recorded during the experimental sessions. The main goal of our study is evaluating the two setups (immersive and non-immersive) in order to understand which one is better for the purpose of training. In particular, we analyze three different aspects: the performances, e.g. user's ability to follow the path; the comfort and naturalness of the experience, in terms of physiological measurements and level of *cybersickness*; the *sense of presence*, using both a subjective questionnaire and tracked head movements.

- **Analysis of Performances.** Boat latitude and longitude recorded during the experimental session, show that expert drivers are able to follow the predefined path in a quite accurate manner. This evaluation, however, is qualitative and coarse and could be substituted in future by the calculation of the actual accuracy between participants and real path. This parameter could be also used as a runtime feedback given to users in order to make them aware of their actual performances and encourage improvements.
- **Comfort and Naturalness of the Experience.** Considering the physiological measurements, both skin conductance and heart rate remain constant and stable in the four trials. They are slightly higher in the fast vessel tests, probably because of the difficulty of the task. This suggest that both systems (monitor and Oculus Rift) do not introduce anxiety, stress or particular emotional or malaise states that could compromise performances and, eventually, learning of new skills. Moreover, this could indicate that participants have perceived simulations as natural experiences, comparable to the real one.

  Finally, answers given to the SSQ highlight an increase of *cybersickness*, especially in the virtual reality setup. There is a general increment of Nausea, Disorientation and Oculomotor parameters, even if the last one is the most preponderant.

Considering the two paths separately, in the Ellipse case, *cybersickness* seems worst, probably because in this simulations sea was more rough. So sickness depends on a combine action of game settings (calm or rough sea), hardware setup (immersive or non-immersive) and speed of the boat. In other words, the use of VR itself does not explain the increase of user malaise state.

- **Sense of Presence.** *Sense of presence* rates are higher for VR simulations. Moreover, the trials with the fast ship have a lower Spatial Presence but a higher Experienced Realism with respect to trials with the slow vessel. This is probably due to the better realism and response speed of the fast ship. Furthermore, there is a statistically significant difference between the Presence Factor in immersive and non-immersive simulations. All these results demonstrate that the use of VR systems allows user to feel more involved and present in the virtual scenario.

  Head rotation angles represent an objective measurement of the degree of the interaction of the user with the virtual scenario. This evaluation, though, is subjective, in fact people can be more or less prone to explore the virtual world surrounding them. Considering each participant separately, we can notice that head rotations are actually more limited in the monitor case, scattered around a central value, which is the initial head rotation when the application starts. While in the HMD case, in general, people have a greater propensity to turn their head, especially in the Eight path with the fast boat, probably because the higher difficulty of the task leads them to collect more information from the environment, for example the development of the path curvature.

In conclusion, this preliminary work highlighted that the two setups have been proven to be equivalent: in terms of performances there are no differences and while monitor simulation system causes less *cybersickness*, VR setup allows a better *sense of presence*. Further acquisitions, on non expert drivers or senior drivers, are required in order to better understand the usability of the system on a large scale and its actual usefulness in providing long term learning of new skills.

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## REFERENCES

Aldaba, C. N., White, P. J., Byagowi, A., and Moussavi, Z. (2017). Virtual reality body motion induced navigational controllers and their effects on simulator sickness and pathfinding. In *Engineering in Medicine and Biology Society (EMBC), 2017 39th Annual International Conference of the IEEE*, pages 4175–4178. IEEE.

Benedict, K., Kirchhoff, M., Gluch, M., Fischer, S., Schaub, M., Baldauf, M., and Klaes, S. (2014). Simulation augmented manoeuvring design and monitoring-a new method for advanced ship handling. *TransNav, International Journal on Marine Navigation and Safety od Sea Transportation*, 8(1).

Bos, J. E., de Vries, S. C., van Emmerik, M. L., and Groen, E. L. (2010). The effect of internal and external fields of view on visually induced motion sickness. *Applied ergonomics*, 41(4):516–521.

Bouchard, S., Robillard, G., Renaud, P., and Bernier, F. (2011). Exploring new dimensions in the assessment of virtual reality induced side effects. *Journal of computer and information technology*, 1(3):20–32.

Coxon, M., Kelly, N., and Page, S. (2016). Individual differences in virtual reality: Are spatial presence and spatial ability linked? *Virtual Reality*, 20(4):203–212.

Davis, S., Nesbitt, K., and Nalivaiko, E. (2014). A systematic review of cybersickness. In *Proceedings of the 2014 Conference on Interactive Entertainment*, pages 1–9. ACM.

Davis, S., Nesbitt, K., and Nalivaiko, E. (2015). Comparing the onset of cybersickness using the Oculus Rift and two virtual roller coasters. In *Proceedings of the 11th Australasian Conference on Interactive Entertainment (IE 2015)*, volume 27, page 30.

Gianaros, P. J., Muth, E. R., Mordkoff, J. T., Levine, M. E., and Stern, R. M. (2001). A questionnaire for the assessment of the multiple dimensions of motion sickness. *Aviation, space, and environmental medicine*, 72(2):115.

Kennedy, R. S., Lane, N. E., Berbaum, K. S., and Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology*, 3(3):203–220.

Keshavarz, B. and Hecht, H. (2011). Validating an efficient method to quantify motion sickness. *Human factors*, 53(4):415–426.

Kim, Y. Y., Kim, H. J., Kim, E. N., Ko, H. D., and Kim, H. T. (2005). Characteristic changes in the physiological components of cybersickness. *Psychophysiology*, 42(5):616–625.

Lawson, B. and Mead, A. (1998). The sopite syndrome revisited: drowsiness and mood changes during real or apparent motion. *Acta astronautica*, 43(3-6):181–192.

McGill, M., Ng, A., and Brewster, S. (2017). I am the passenger: How visual motion cues can influence sickness for in-car VR. In *Proceedings of the 2017 chi conference on human factors in computing systems*, pages 5655–5668. ACM.

Munafo, J., Diedrick, M., and Stoffregen, T. A. (2017). The virtual reality head-mounted display Oculus Rift induces motion sickness and is sexist in its effects. *Experimental brain research*, 235(3):889–901.

Muth, E. R., Stern, R. M., Thayer, J. F., and Koch, K. L. (1996). Assessment of the multiple dimensions of nausea: the nausea profile (NP). *Journal of psychosomatic research*, 40(5):511–520.

Nalivaiko, E., Davis, S. L., Blackmore, K. L., Vakulin, A., and Nesbitt, K. V. (2015). Cybersickness provoked by head-mounted display affects cutaneous vascular tone, heart rate and reaction time. *Physiology & behavior*, 151:583–590.

Nesbitt, K., Davis, S., Blackmore, K., and Nalivaiko, E. (2017). Correlating reaction time and nausea measures with traditional measures of cybersickness. *Displays*, 48:1–8.

Nichols, S., Cobb, S., and Wilson, J. R. (1997). Health and safety implications of virtual environments: Measurement issues. *Presence: Teleoperators & Virtual Environments*, 6(6):667–675.

Ohyama, S., Nishiike, S., Watanabe, H., Matsuoka, K., Akizuki, H., Takeda, N., and Harada, T. (2007). Autonomic responses during motion sickness induced by virtual reality. *Auris Nasus Larynx*, 34(3):303–306.

Reason, J. T. and Brand, J. J. (1975). *Motion sickness.* Academic press.

Regenbrecht, H. and Schubert, T. (2002). Real and illusory interactions enhance presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, 11(4):425–434.

Riccio, G. E. and Stoffregen, T. A. (1991). An ecological theory of motion sickness and postural instability. *Ecological psychology*, 3(3):195–240.

Sharples, S., Cobb, S., Moody, A., and Wilson, J. R. (2008). Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems. *Displays*, 29(2):58–69.

Sheridan, T. B. (1992). Musings on telepresence and virtual presence. *Presence: Teleoperators & Virtual Environments*, 1(1):120–126.

Slater, M., McCarthy, J., and Maringelli, F. (1998). The influence of body movement on subjective presence in virtual environments. *Human Factors*, 40(3):469–477.

Slater, M., Usoh, M., and Steed, A. (1994). Depth of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, 3(2):130–144.

Usoh, M., Arthur, K., Whitton, M. C., Bastos, R., Steed, A., Slater, M., and Brooks Jr, F. P. (1999). Walking¿ walking-in-place¿ flying, in virtual environments. In *Proceedings of the 26th annual conference on Computer graphics and interactive techniques*, pages 359–364. ACM Press/Addison-Wesley Publishing Co.

Usoh, M., Catena, E., Arman, S., and Slater, M. (2000). Using presence questionnaires in reality. *Presence: Teleoperators & Virtual Environments*, 9(5):497–503.

Varela, J. and Soares, C. G. (2015). Interactive 3d desktop ship simulator for testing and training offloading manoeuvres. *Applied Ocean Research*, 51:367 – 380.

Varela, J. M., Rodrigues, J., and Soares, C. G. (2015). 3D simulation of ship motions to support the planning of rescue operations on damaged ships. *Procedia Computer Science*, 51:2397–2405.

Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C., Schramm, H., Saari, T., Laarni, J., Ravaja, N., Gouveia, F. R., et al. (2007). A process model of the formation of spatial presence experiences. *Media psychology*, 9(3):493–525.

Witmer, B. G. and Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence*, 7(3):225–240.