Ilkka Kotilainen

# REALISM AND SIMULATOR SICKNESS IN A FIXED-BASE SHIP SIMULATOR

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# ABSTRACT

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The aim of this study was to examine simulator realism and effect of simulator sickness in a fixed-base ship simulator. The importance of the study is refelected on the usage of a simulator as a research or training tool where simulator realism and simulator sickness may have a significant effect on the results. Literature of previous research findings on simulator realism and validity evaluation as well as simulator sickness was reviewed.

The quasi-experimental study was conducted with convenience sampling and a counterbalanced within-subject design. Thirty-two participants steered a ship simulator in calm and storm weather conditions for five minutes in total. After the experiment, participants filled a closed type Likert questionnaire with questions on background demographics and statements of the simulator experience and Simulator Sickness Questionnaire (SSQ). The data was analyzed to find common explaining factors, associations as well as statistically significant differences of simulator realism and simulator sickness.

A positive correlation was found between experience of realism, enjoyment and interest components. Increase of enjoyment and interest was measured together with the increase of experienced realism. Participants indicated mild to severe symptoms of simulator sickness during the experiment. Components realism, interest as well as enjoyment and SSQ total score had no statistically significant associations with background variables of age, experience in real-world maritime or in computer games. Also experience of realism and SSQ total score had no statistically significant associations with calm and storm weather conditions.

Based on the results the fixed-base ship simulator was qualitatively evaluated as having a moderate physical and behavioral realism. Reliability of the experimental setup, internal consistency of the SSQ scale and validity of the extracted components are discussed as having a possible effect for the research results. Future research is encouraged with larger sample size with a study of user motivation of simulator usage, behavioral validity and simulator sickness with different simulator platforms and experimental designs.

Keywords: ship simulator, simulator sickness, experience of realism, behavioral realism, physical realism

# TIIVISTELMÄ

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Tämän tutkimuksen tavoite oli selvittää simulaattorin realismin kokemuksen ja simulaattorisairauden vaikutukset kiinteä-alustaisessa laivasimulaattorissa. Tutkimuksen motivaatio ja tärkeys tulevat simulaattorin realismin kokemuksen ja simulaattorisairauden mahdollisista vaikutuksista simulaattorin käyttöön tutkimus- ja koulutustarkoituksissa. Osana tutkimusta tehtiin kirjallisuuskatsaus aikaisempaan tutkimukseen simulaattorin realismista, validiteetista ja simulaattorisairaudesta.

Kvasi-eksperimentaalinen tutkimus toteutettiin vastabalansoidulla koehenkilöiden sisäisellä tutkimusasetelmalla. Kolmekymmentäkaksi sattumalta tutkimukseen saapunutta koehenkilöä ohjasi laivasimulaattoria tyynessä ja myrskyisessä sääolosuhteessa yhteensä viiden minuutin ajan. Kokeen jälkeen koehenkilöt täyttivät taustatietonsa sekä suljetun Likert-kyselyn, jossa esitettiin väitteitä laivasimulaattorin käyttökokemuksesta ja simulaattorisairaudesta. Tuloksista tutkittiin yhteisiä selittäviä tekijöitä, riippuvuuksia sekä tilastollista merkitsevyyttä simulaattorin realismikokemuksesta ja simulaattorisairaudesta.

Realismin sekä nautinto ja kiinnostus kokemusten väliltä löydettiin positiivinen korrelaatio. Koehenkilöiden ilmoittama lisääntynyt nautinto simulaattorissa ja kiinnostus simulaattoria kohtaan mitattiin yhdessä korkeamman realismin kokemuksen kanssa. Koehenkilöiden simulaattorisairausoireet vaihtelivat lievistä vaikeisiin simulaattorisairauskyselyn perusteella. Realismi, kiinnostus ja nautinto sekä simulaattorisairauskyselyn tulosten, että taustamuuttujien ikä, kokemus oikeanmaailman merenkulusta ja tietokonepelaamisesta väliltä ei löydetty tilastollisesti merkitseviä yhteyksiä. Myöskään sääolosuhteiden sekä realismikokemuksen ja simulaattorisairauden väliltä ei löydetty tilastollisesti merkitseviä yhteyksiä.

Tulosten laadullisen arvioinnin perusteella tutkimuksessa käytetyn kiinteäalustaisen laivasimulaattorin fyysisen ja käyttäytymisen realismin arvioidaan olevan kohtalaisella tasolla. Tutkimustulosten luotettavuudessa katsotaan olevan parannettavaa koeasetelman, simulaattorisairauskyselyn sisäisessä johdonmukaisuudessa ja komponenttien validiteetissa. Jatkotutkimukseen kannustetaan suuremmalla otannalla sekä tutkimuksella simulaattorikäyttäjien motivaatiosta. Lisäksi käyttäytymisen validiteettiin ja simulaattorisairauden tutkimiseen eri simulaattorialustoilla ja tutkimusasetelmilla.

Asiasanat: laivasimulaattori, simulaattorisairaus, realismi, käyttäytymisen realismi, fyysinen realismi

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# 1 INTRODUCTION

For most of us driving a bicycle or a car is a daily task, for some it's a profession, such as an airplane pilot, or a mix of profession and leisure, such as a maritime captain or a sailboat sailor. A common factor for the vehicle control task is the need of practice before we learn to master the vehicle or ship in the demanding environment, surrounded with variables such as other traffic, instruction and warning signs, signals and obstacles.

Carefully selected and defined practice sessions with hours of repetitions for beginner and professional drivers would enhance safety and knowledge of driving task. To build such a carefully planned practice session in real-world would require significant resources. In turn, new technology offers possibility to build such training environment in relatively low costs. A simulator is a tool that is built on computer hardware and software components to simulate the real-world environment and vehicle. Simulator enables safe training environment to rehearse even the most demanding driving scenarios repeatedly, further enhancing driver's vehicle control skills and insight of driving task.

Advance in microprocessor, computer generated imagery (CGI) and Information and Communications Technology (ICT) can be seen in simulator fidelity; simulators not only look physically like the real-world version but also function, act like, their real-world models (Allen, Hays & Buffardi, 1986). To gain the simulator benefits mentioned above, a real-world like practice environment needs to be created and the real-world experience must be transferred into the simulation and vice versa. The transfer of experience and its level of success is described using the term 'realism' (Blana, 1996). Research on simulator validity studies on how well the real-world environment measurements relate to the simulator as well as the human behavior transferability between these two environments, i.e. how realistic the simulator is.

Even advance in simulator fidelity and physical realism does not guarantee seamless practice environment as the simulator may come with an unpleasant surprise, a side effect, which can make you sick. The problem with simulators is motion sickness, referred as simulator sickness in simulator environment, which causes symptoms such as nausea, headache and even vomiting for the user handling the simulator (Kennedy, Lane, Berbaum and Lilienthal, 1993). Drivers attempt to learn a new maneuver turns into a physical illness, which may lead the user to dropout the exercise – an unwanted situation for the trainee but also for the trainer, researcher or application developer. Previous research on motion sickness has not found any single explaining factor for the symptoms and more research is needed (Brooks, Goodenough, Crisler, Klein, Alley, Koon, Logan, Ogle, Tyrell and Wills, 2010).

The aim of this thesis is to study experience of realism and effects of simulator sickness in a ship simulator environment. Simulator realism and simulator sickness may have a significant effect on the simulator usage and therefore the benefits of the study can be leveraged in better usage of a simulator as a research or training tool. Motivation is to study how well a fixed-based ship simulator, build in a conference area, is experienced by the users. Furthermore, the motivation is to advance simulator environment research to tackle simulator research related issues (such as simulator sickness). Positive user experience in a simulator may itself advance training and research possibilities. Knowledge on simulator environment is needed to turn the simulator training benefits to full advantage in the future.

The four main research questions presented and pre-hypothesis discussed:

1. Did the participants experience simulator sickness symptoms during the experiment?
    - Previous research suggests that motion sickness or simulator sickness in the simulator environment is experienced.
2. Are there any associations between the experience of realism, enjoyment and interest?
    - Experienced realism could be associated with increase of experienced enjoyment and interest towards the simulator.
3. Are there any associations between background variables and experience of realism, enjoyment, interest and simulator sickness?
    - Previous research indicates that e.g. age might affect the experience of simulator sickness.
4. Did the ship simulator's storm and calm weather conditions have effect on experienced realism and simulator sickness?
    - Different weather conditions may influence how real the simulator movement is felt, which again may induce simulator sickness.

First two chapters of the thesis present a literature review of past research and findings on simulator as a training tool, simulator realism and validity and simulator sickness.

Chapter four present the research method of the experimental design, equipment, analysis of the research questions and data analysis. Chapter five presents results. Finally following discussion and conclusions.

# 2 SIMULATOR AS A TOOL

First simulators offered a practice environment on modern technology such as airplane cockpits. Blana (1996) states that first driving simulators were developed during World War II for the need of military personnel tactical training. After the WWII the use of simulators found a new place in research.

Advance in computer technology and needs of the industry, such as automotive, and interest of research centers and universities gained a popular ground for simulators. Especially driving simulator research has gained popularity in recent decades as the computer hardware and software development has become more common and inexpensive.

A modern simulator is built on hardware and software components. Part of the simulator is a simulated environment and vehicle. Simulation is often referred as a Virtual Reality (VR) or simulated environment also known as Virtual Environment (VE) (Kolasinski, 1995). Simulation is created using computer generated graphic representation of the real-world environment. Simulation's computer processing is only one end of the simulator's functionality. Allen et al. (2011) list as processing output sensory feedback generation such as processing of visual image, sound, controls and motion. This Feedback is then extracted as visual, auditory, control and motion movements. In the end of the loop is the human operator in a cabin receiving the output and providing input for the simulation computer processing.

In this thesis simulator is referred as a tool which hardware usually comprises a computer as well as control and steering equipment that are used for navigation in the simulated environment. Software component includes a simulator software which builds the physical laws and computer-generated imagery for the simulator.

The following chapters introduce literature of a human operator and control task of a vehicle, simulator usage in training and research and simulator evaluation research.

## 2.1 Human operator and control task of a vehicle

One of the most complex task that we do in our lifetime requires perception, cognitive skills and motor functions all at the same time (Allen, Rosenthal & Cook, 2011); this task is the control and driving of vehicles in land, sea and air. Peters and Nilson (2007) list cognitive, perceptual and motor abilities as the functional abilities for the human in control of a vehicle steering task.

Simulator sensory feedback to visual, auditory, control and motion movements is received and controlled by the human operator of a vehicle. Human visual, auditory, proprioception and vestibular senses provide input for the vehicle in simulation computer processing. (Allen et al., 2011)

Several driving behavioural models such as Zero-risk, Risk homeostatis and Task-Capability Interface theories and models have been introduced to explain the complexity and behaviour of a driving task. These models are described more closely for example in Kotilainen (2014) thesis.

Driver behaviour tactical and strategical levels as well as control level are described by Michon (1985) after Janssen (1979): strategic level is general plans of the task with long time constant, manoeuvring or tactical level is controlled action patterns within seconds and control level is automatic action patterns within milliseconds.

## 2.2 Simulator in training and research

Benefits of simulator are safe practice environment, low operational costs, i.e. when compared to many modern vessel operational costs, possibility to practice specific tasks and situations repeatedly and extract feedback and data from these scenarios to train user. Finally, simulators offer a possibility to train large number of personnel, fast and efficiently, something that was beneficiary during WWII when modern war machinery was introduced.

In the era of Internet, modern simulator software such as games can be distributed for hundreds of thousands, even for millions of players. Such scalability offers new possibilities, not just for the limited number of personnel in specific military branch, but for every homemade driver, pilot, new consumer machinery user, traveler or even Sunday sailor.

TABLE 1 below present driver types or kind of usage for simulator by Espie, Gauriat and Duraz (2005). Espie et al. divide professionals for those whom driving is not the main occupation such a car tester. Another subgroup of professionals are those whom the simulator is a working tool used for a specific purpose, for example training course for professional drivers.

Table 1 Driving simulator usage by Espie, Gauriat and Duraz (2005).

| Kind of usage – Types of drivers | Vehicle design | Human factors | Training |
|---|---|---|---|
| 1. Professionals | | | |
| 1.a) With possibility of learning of the simulator | X | | |
| 1.b) With few possibility of learning of the simulator | | X | X |
| 2. Ordinary people | | X | X |

## 2.3 Simulator evaluation research

The concept of simulator can be described as a real-world representation. Simulator, unless intended otherwise, aims to generate an accurate environment with similar look and feel as the real-world physical environment, i.e. be as realistic as possible. Previous research in simulator evaluation, as reviewed in the following chapters, has been mostly done in a driving simulator environment.

Gemou and Bekiaris (2014) state that currently no methodological approach translates the driving simulator results in real traffic conditions accurately without being dependent on technical characteristics or the specific research hypotheses of each experiment.

Gemou and Bekiarris (2014) approach behavioral validity by discussing the concept of translating driving simulator results in real traffic conditions. Need for a framework is stressed and Riener (2010) referred as suggesting to either seek for high fidelity simulators or a conversion matrix/model that would provide each simulator fidelity level and correction for participating parameter.

Espie, Gauriat and Duraz (2005) divide driving simulator validation into two schools: intrinsic validation and validation by objectivity. The intrinsic validation compares the results extracted from the simulator and those obtained in real-world, e.g. acceleration, to prove that the simulator is valid (Reymond, Kemeny, Droulez & Berthoz, 2001). The validation of objectivity studies the driver's behavior or training as the object is the human and not the simulator as a tool. Behavioral study concerns on the task that the driver has executed and its transferability in the real-world. Validity is considered for a given situation and if it's equal to the actual real-world situation (Espie, Gauriat and Duraz, 2005). Case of training, a simulator is considered valid if the experiences can be transferred into the real-world driving (Espie, Gauriat & Duraz, 2005, referring to Dols, 2001).

### 2.3.1 Microworlds, transferability and validity with reliability

Kantowitz (2001) presents Brehmer & Döner (1993) view on microworlds, that are computer-generated complex artificial environments, dynamic and opaque, i.e. goal structure, operation in real-time and operator inference about the system. Kantowitz continues with Ehret et al. (2000) that there are three dimensions which have been identified for comparison of microworlds and other simulated task environments and real world: tractability, realism and engagement.

Tractability refers to how well the researcher can effectively use the simulated environment. Realism is described as matching experience in real and simulated worlds. Engagement refers to how naturally the users act in the simulated environment, i.e. level of behavior compared in the real world. Kantowitz (2011) notes that there are individual differences between perception of the real world and simulation, e.g. professional pilots and drivers.

To use the simulator effectively as a part of a research or training session, it is needed to ensure that the training and measurement results are transferable to the real-world setting and vice versa. Espie, Gauriat and Duraz (2005) state that simulator results transferability towards actual situations is crucial if we want to assess the credibility of the usage. Blana's (1996) research on driving simulator validation studies introduces evaluation in addition of transferability through reliability, validity and realism of the driving simulator.

Reliability can be described as how consistent results of each of the simulator's sub-systems gives, e.g. gas pedal input in the simulator. Validity on the other hand is about how well the driving simulator device is measuring what it's supposed to measure, e.g. on road acceleration and control task of forward moving vehicle. Simulator gas pedal input may be reliable by giving consistent results, but if the results are not correct, the simulator is not valid. (Blana, 1996)

### 2.3.2 Simulator physical and behavioral validity

Simulator physical validity is the internal criteria to evaluate simulator physical realism. Physical validity is often described as fidelity or how well the simulator looks and is physically like the real-world version (Allen, Hays & Buffardi, 1986). When physical validity is evaluated it is often indicated with a simulator fidelity level which is divided to three: low, moderate and high. Components defining the fidelity level can include for example an evaluation of moving base platform (fixed, limited or moving base), screen width (20–360 degrees) and resolution, sign legibility and night time visibility (poor, fair or good). (Caird & Horrey, 2011)

Simulator behavioural validity is the extent of the driving behaviours that are created in the simulator and transferred to the real-world setting. Behavioural validity is often described as how well the simulator functions or acts like the real-world version (Allen, Hays & Buffardi, 1986).

When driver behaviour and transferability of the driver behaviour to real-world are of interest, Blana (1996) suggests referring for internal and external validity criteria. Mullen, Charlton, Devlin and Bedard (2011) describe internal validity as the causal impact and confidence of an experimental treatment; external validity by the extent of the simulator results can be generalized driving on the road. Blana (1996) continues to recommend internal and external validity criteria to be used when investigating driver behaviour on tactical and strategic level.

### 2.3.3 Simulator absolute and relative validity

Results in driver performance and performance differences, according to Blana (1996), should refer for absolute and relative validity and to be used when investigating driving task on the control level as it's seen as less complex environment.

The absolute validity of a simulator is a criterion to evaluate simulator validity with quantitative methods. In case of absolute validity, the numerical values measured and extracted from the simulator and real-world are about equal in both systems.

The relative validity of a simulator is the criteria to evaluate simulator validity with qualitative methods. Relative validity is determined when there is a same order and direction of the differences between experimental simulator and real-world conditions.

## 2.4 Simulator realism

Manser (2011) defines realism as the degree to which testing environments represent real world. Blana (1996) highlights the importance of the realism evaluation, which is seen critical for the face validity of a simulator, i.e. experiment is effective in terms of its aim.

Realism elements in the vehicle construct, according to Manser (2011), should include vehicle dynamics of steering, acceleration and deceleration as well as highly functional vehicle cab. Realism elements in the simulator environment should include high-resolution images, wide field of view to promote an accurate sense of speed, driving scenarios and realistic traffic flow that are based on the comparable real-world scenarios.

In the following two chapters realism is discussed from the perspective of computer graphics, human perception and two dimensions of realism: physical and behavioral.

### 2.4.1 Realism and computer graphics in simulator

Vision is the most important sense for human and the simulator realism can be considered dependent on the visual environment generated by computer graphics. Granda, Davis, Inman & Molino (2011) state that computer graphics technology has pushed the simulator fidelity and realism forward.

Ferwerda (2003) in his research on computer graphics evaluation proposes a conceptual framework for image realism and tools to measure and assess image realism. Ferwerda continues to introduce Hagen's (1986) three varieties of realism in computer graphics: physical realism, photo-realism and functional realism. In Physical realism the image provides the same visual stimulation as the scene, photo-realism produces the same visual response as the scene and functional realism provides the same visual information as the scene. Ferwerda calls more research and collaboration between graphics and vision researchers.

Slater, Steed and Chrysanthou (2002) consider following of the term realism in computer graphics diving it to three, presented next in increasing order of difficulty. Geometric realism is a graphical object that has a close geometric resemblance to the real-world object that is being represented, behavioral realism is the emotional sense of real which is discussed more here in the following chapter and illumination realism considers illumination and reflections of light.

Slater et al. (2002) also take discussion in caricatures, impressionism, and iconic representations that are more an art like experience with visual cognitive models. Another aspect is the tension between realism and real-time in virtual environment. The human tendency to generalize reality from tiny samples of reality is a great news for simulator environment visual presentations, e.g. two dots in row and upward curved line below the dots create a picture that a human can resemble as a smiling face. However, to create such an environment, a real-time performance would be required – high enough frame rate (images per second) or Hertz (Hz) to create an illusion of real-time environment. Real-time performance has challenges when computational power is needed for the accurate modeling of the simulator.

FIGURE 1 below illustrates different realism levels of computer-generated ships; simple drawing of a ship and a 3D modeled ship compared to a real-world picture of a ship with realistic illuminations.

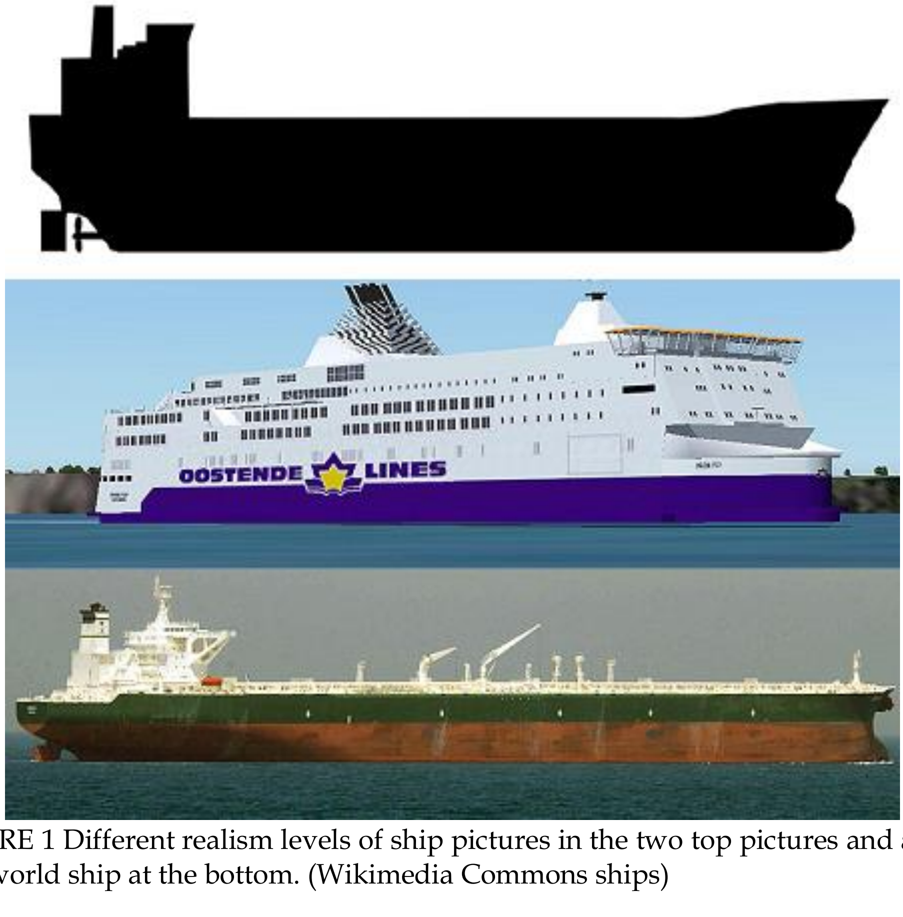


FIGURE 1 Different realism levels of ship pictures in the two top pictures and a picture of a real-world ship at the bottom. (Wikimedia Commons ships)

### 2.4.2 Physical and behavioral realism in simulator

Yin, Sun, Zhang, Liu, Ren, Zhang and Jin (2010) state that physical and behavioral realism of the simulator should be high enough to obtain an immersive feeling for the user. Blana (1996) reviews behavioral realism through questionnaires that are giving impression and opinions of the subjects' view on simulator.

Kumar, Etheredge and Boudreaux (2012) describe physical realism, and its improvement, in three different aspects: physical environment of the simulator, 3D objects as well as effects and perception. Realistic environment has greater ecological validity for the user in simulation interaction (Rizzo, Bowerly, Buckwalter, Klimchuck, Mitura & Parsons, 2006). For example, in a ship simulator, a realistic throttle and wheel as well as physically similar ship bridge as the real-world version. 3D objects and effects including real-world scenes, navigation areas, and wider perception for the user by using multi-display vision.

Behavioral realism and graphical objects are discussed by Slater et al. (2002) stating, that even simplification of an object, far from real and incorrect to physics, may arouse emotional state and seem realistic to an observer. Yin et al. (2010) note that motion system and higher motion prediction and visualization improve behavioral realism. Behavioral realism improvements (Kumar et al, 2012) include accurate motion prediction of objects. For example, in a ship simulator, all the possible factors such as vessel's physical properties and wave motion should be accurate as possible. Dynamic objects in the virtual environment should also have realistic physics. (Kumar et al, 2012)

Espie, Gauriat and Duraz (2005) whom consider the challenges and tricks that are producing the illusions of real-world sensations discuss simulator physical rendering limitations. Phenomena's such as acceleration and visualization are challenging, if not impossible, to reproduce in simulator environment. Tricks such as mobile platform for simulation movement and graphic engine, rendering and model development behind these are to render the simulator fidelity.

FIGURE 2 below demonstrates high physical realism. First in left is a model of a ship, second picture in right has a ship bridge partly constructed and multi-display vision systems. Behavioral realism improvements include motion platform in the left picture.


FIGURE 2 Left a ship simulator with a motion platform to improve behavioural realism. Right a ship bridge and multi-display vision system to improve physical realism of the simulator. (Wikimedia Commons US Navy)

# 3 FEELING SICK ON THE SIMULATED SEA

Previous chapter introduced simulator and its benefits when transferring real-life conditions in a simulated environment, methods used to evaluate simulator effectiveness in use and simulator realism driven by the technological advance.

Technological development has made possible creation of high-fidelity simulators that aim to represent real-world accurately as possible by sending sensorial cues for the human user such as visual, auditory, haptic, inertial, vestibular and neuromuscular (Aykent, Merienne, Guillet, Paillot & Kemeny, 2013). The very same cues that help the human user to drive and steer the simulator, affect the user of the simulation in a way that pose possible risk of sickness caused by the simulation.

Motion sickness (MS), syndrome known in the simulated environment as simulator sickness (SS), can be a threat to a research training scenario, cause research results reliability and validity issues and even lead participants to dropout from a study. In this chapter previous literature of SS is reviewed.

## 3.1 Motion sickness symptoms and theories

Kolasinski (1995) states that motion sickness and simulator sickness do have similar symptoms, but they are not the same thing. Although simulators with moving-base incorporate motion, this is not the case with fixed-base simulators, which may produce just as much symptoms as the previous. Many similarities of these two sicknesses and no exact cause of simulator sickness, simulator sickness literature necessarily includes references to motion sickness.

Motion sickness syndrome include symptoms such as nausea, sweating, salivation, apathy, fatigue, stomach awareness, disorientation, dizziness, incapacitation and even vomiting in most extreme cases. Physiological signs of cardiovascular, respiratory, gastrointestinal, biochemical and temperature regulation functions may also occur. Motion sickness symptoms in simulator studies are presented in TABLE 2 below. (Kennedy et al., 1993; Kennedy, Drexler & Kennedy, 2010)

Table 2 Simulator Sickness Questionnaire symptoms (Kennedy et al, 1993)

| Question number | SSQ Symptom (Kennedy et al. 1993) |
|---|---|
| 1 | General Discomfort |
| 2 | Fatigue |
| 3 | Headache |
| 4 | Eyestrain |
| 5 | Difficulty focusing |
| 6 | Increased salivation |
| 7 | Sweating |
| 8 | Nausea |
| 9 | Difficulty concentrating |
| 10 | Fullness of head |
| 11 | Blurred vision |
| 12 | Dizzy (eyes open) |
| 13 | Dizzy (eyes closed) |
| 14 | Vertigo |
| 15 | Stomach awareness |
| 16 | Burbing |

Motion sickness is reported to appear when environmental motion exists within frequencies ranges near 0.2 Hz (McCauley and Kennedy, 1976). Traditionally a ship in the sea is going in a motion frequency less than 1 Hz. Less than 0.2 Hz frequencies appear also in motion-based simulators. (Kennedy, Drexler & Kennedy, 2010)

Brooks et al. (2010) introduce the three most common theories, and fourth explaining theory, of motion sickness and simulator sickness. First, sensory conflict theory by Reason and Brand (1975) propose that between the motion that one sees, and the actual motion perceived there is a conflict within the vestibular system. Therefore, the detection of direction and acceleration of motion are the two main contributors. Second theory by Riccio and Stoffregen (1991) argue that MS occurs when a new motion environment is introduced, and one needs to adapt and learn to maintain a balance. Third theory is the eye movement theory where stimulation of eyes causes eye movement leading to tension in the eye muscles that stimulate the vagus nerve causing MS (Ebenholtz, 1992). Fourth evolutionary theory exists which explains the occurrence of MS by human species lack of adaption to new transport modes (Treisman, 1977); conflict in sensory information is interpret as there would be poison ingested in the body leading to vomiting reaction.

## 3.2 Simulator sickness research in ship simulators and maritime

Motion sickness mechanisms have been well explained, but research have advanced most in quantitative models predicting the severity of nausea and incidence of vomiting. In VR and simulator systems illusion of self-motion, poor eye collimation and lag between real motion and the corresponding update of the visual display can cause stimulus and SS. (Golding, 2006)

In addition of shipboard surveys, motion simulators have been used in laboratory studies to see the effects of the motion sickness in a ship, referred as seasickness. Simulator in addition to simulation models helps a passenger ship design stage. Designers of a ship must make sure that seakeeping qualities are well-suited and not causing seasickness among passengers. (Arribas & Pineiro, 2007)

Bos, MacKinnon and Patterson (2005) found in a motion platform ship simulator that simulator sickness was highest when the inside view was used, intermediate in the outside viewing condition and mildest in the blindfolded condition. They also found that simulator sickness had no effect on task performance in the experiment.

## 3.3 Individual differences in motion and simulator sickness

Park, Allen, Fiorentino, Rosenthal and Cook (2006) list factors that affect the SS severity: the simulator, the simulated task and the individual. Example of the simulator are motion platform, display and field-of-view. Simulated tasks have different exposure duration of the task and selected route with variety in wheel turning rate.

Individual factors in motion sickness are dependent on several factors such as gender, age, smells, gastric, psychological, and environmental (Aykent, Merienne, Guillet, Paillot & Kemeny, 2013). Cobb, Nichols, Ramsey & Wilson (1999) also lists time of exposure, illness, mental rotation ability and postural instability to play an important role when evaluating participant tendency to become sick. Cobb et al. (1999) and Park et al. (2006) refer to previous studies on experience in the simulation affecting the onset of SS.

Past research has found evidence that older adults are more prone to SS than younger (Roenker, Cissel, Ball, Wadley & Edwards, 2003). Yet mixed results provide only little empirical results to give strong support for the age effect (Rizzo, Sheffield, Stierman & Dawson, 2003). Park et al. (2006) found scenario completion and dropout rates with higher symptom incidence for older drivers (70-90 years old) than younger drivers (21-50 years old), especially older female drivers, using the Kennedy et al. (1993) Simulator Sickness Questionnaire. In turn there were no age effect found in the SSQ data. From the dropout group gender differences were not found, but then again found in the non-dropout group.

Arribas and Pineiro (2007) state people of all ages, genders and positions may get affected by seasickness at least once in their life time, referring to the work of Stevens and Parsons (2002) as well as Dobie (2000), whom found seasickness in navy vessels and crew performance. These results might not be surprising as the etymology of word nausea is the Greek word naus, which means ship.

## 3.4 Measuring simulator sickness – the Simulator Sickness Questionnaire (SSQ)

Main indicator methodology for motion sickness is self-report (Kennedy et al., 2010). Brooks et al. (2010) list two common surveys used for measuring of MS and SS: Motion Sickness Assessment Questionnaire (MSAQ) and the Simulator Sickness Questionnaire (SSQ) derived from the Motion Sickness Questionnaire (MSQ). Other measures are different postural tests or ataxia evaluation, such as stand-on-leg tests, heart rate measurement or predictive history questions (Kolasinski, 1995). Next a closer look is taken to SSQ which is widely referred and used in research.

Simulator Sickness Questionnaire has been formed based on the MSQ Exploratory Factor Analysis by Kennedy et al. (1993), whom studied principal factor analysis/varimax and hierarchical factor analysis (hierarchical rotation). Factor analysis results clustered sickness symptoms into three types: 1) nausea, 2) oculomotor and 3) disorientation (TABLE 3).

SSQ is used by creating a form which contains the 16 symptoms. Subject scoring the symptom form should be in their usual state of fitness. Each symptom is then scored with 4-point scale from 0 to 3 or none, slight, moderate and severe. After forming the three sub-scales of nausea, oculomotor and disorientation, an overall SSQ score is produced by a series of mathematical computations. (Kennedy et al., 1993; Brooks et al., 2010).

Kennedy et al. (1993) recommend that baseline scores would be obtained before any engineering changes to the simulators and then compared to the original. Overall simulator sickness total scores have no interpretive meaning, but a function of scale for easier comparison of the values. Kennedy et al. (1993) over 1100 observations total severity *Mean* = 9.8 and *SD* = 15.0.

| Question number | SSQ Symptom (Kennedy et al. 1993) |
|---|---|
| **Nausea** | |
| 1 | General Discomfort |
| 6 | Increased salivation |
| 7 | Sweating |
| 8 | Nausea |
| 9 | Difficulty concentrating |
| 15 | Stomach awareness |
| 16 | Burbing |
| **Oculomotor** | |
| 1 | General Discomfort |
| 2 | Fatigue |
| 3 | Headache |
| 4 | Eyestrain |
| 5 | Difficulty focusing |
| 9 | Difficulty concentrating |
| 11 | Blurred vision |
| **Disorientation** | |
| 5 | Difficulty focusing |
| 8 | Nausea |
| 10 | Fullness of head |
| 11 | Blurred vision |
| 12 | Dizzy (eyes open) |
| 13 | Dizzy (eyes closed) |

# 4 METHOD

## 4.1 Experimental design and participants

The quasi-experimental ship simulator study was conducted during a transport conference. Participants (*N* = 32) were taking part conference. Convenience sampling was gathered among the volunteers passing a conference stand. A within-subject counterbalanced design was used for the experiment as all the participants were tested under each of the treatment conditions.

First day at the exhibition arena was used for pilot testing. Research experiments were implemented in three days period: twelve on Tuesday (37%), eleven on Wednesday (34%) and nine on Thursday (28%).

The experiments were conducted during quiet hours when there were only few people crowding the stand. This way the participants were provided a better concentration as there was less external distraction from other people.

## 4.2 Procedure

Conference visitors passing the stand was asked if they would like to steer the boat simulator and if they would like to participate on a voluntary research. Research participation was not mandatory for simulator tryout. Each visitor was informed about the length of the experiment and about two-page questionnaire to be filled after the experiment.

After agreeing to participate each participant was asked if they felt normal and healthy. All participants were also given a float jacket to wear during the experiment, not so much to create authentic environment but more of a promotion of maritime safety.

Each participant steered the boat in two weather conditions each 2.5 minutes, overall time of 5 minutes: calm weather starting at the location of Suomenlinna harbor and in storm weather starting at Porkkalanselkä (FIGURE 3). By weather condition calm it is referred to a state of the sea where water surface is glassy or rippled and weather condition storm as slight to moderate wind waves with height 0.5 to 2.5 meters (WMO, 2017). The two weather conditions were counterbalanced and varied between subjects; for every other subject the storm or the calm weather was steered first.

FIGURE 3 Storm weather at Porkkalanselkä on left and calm weather at Suomenlinna on right.

After the boat ride participants were given a two-page questionnaire to fill out (explained more detail in the following chapter). After filling the questionnaire participants were praised for participating and asked if they had further questions. The experiment procedure handout used by the researcher during the experiments can be viewed at the APPENDIX 1.

## 4.3 Questionnaire

After a five-minute boat ride, participants were given two A4 pages closed type Likert questionnaire. Participants filled out their demographic information, simulator sickness symptoms and answered questions concerning the experience itself. The questionnaire is also critically analyzed by its structure and questions. The complete questionnaire can be viewed in APPENDIX 2.

Questionnaire was divided into four sections. First section gathered background information such as gender, age, nationality and profession. Former experience on a boat simulator was also asked on a four-point scale: never, once or twice, less than 10 times and more than 10 times. An estimation of real world maritime experience in years was also asked.

Second section of questions was the Simulator Sickness Questionnaire (SSQ) adapted originally by Kennedy, Lane, Berbaum and Lilienthal (1993). The SSQ questionnaire constructs from sixteen different questions about simulator sickness symptoms that are evaluated by the participant in four-point scale: none, slight, moderate and severe (APPENDIX 2 – Question 2.).

Third section included only one question on how often the participant played computer games. Evaluation was done on a five-point scale: never, a few times a year, a few times a month, a few times a week and almost every day.

Fourth and final question section was constructed on a five-point Likert scale: strongly disagree, disagree, neutral, agree and strongly agree. Participants were asked to evaluate and comment the following six statements: "I felt like being in a real boat", "I enjoyed the experience", "Transport and ship simulator games (such as Stormwind) help me to understand and practice real world situations", "The fact that the simulator is based on a real world setting (with existing maps and landscape) improved the experience", "The simulator enhanced my interest for Finnish transport and mobility" and finally "Steering the simulator made me more interested in travelling Finnish waterways."

## 4.4 Equipment

A Finnish maritime video game Stormwind, a boat simulator including realistic maps and environment of Finnish Southern coastline, was used at the experiment (Stormwind.fi). The Stormwind simulator exploits e.g. National Land Survey of Finland (Finn. Maanmittauslaitos, MML), Finnish Forest Research Institute (Finn. Metsäntutkimuslaitos, Metla) and Finnish Transport Agency open data on elevations, forests and maps. (Eteläaho, 2014; National Land Survey of Finland open data; Finnish Forest Research Institute open data; Finnish Transport Agency open data)

The simulator software was delivered by the Stormwind simulator developer. Final simulator setup including steering wheel and throttle quadrant. Builiding and testing was completed by the research team.

Simulator setup included a multi-screen world created by 2 x 4 Sharp PN-V601 60" LCD Monitors. Screens were installed landscape in such way that the two four screen video walls were in a 90-degree angle with each dimension being 2,672 meters x 1,508 meters and overall resolution of 3840 x 1080 pixels (Sharp World). Simulator software was run on one of the four screen video wall as the second wall only presented an informative text "Stormwind simulator - Open data".

Boat's controllers were built on a table by using a boat wheel attached to a Logitech MOMO Racing Force Feedback steering wheel. Boat's traveling speed was controlled by using Saitek Pro Flight throttle quadrant (on the right side of the participant). Steering wheel force feedback was enabled and only one axel hand throttle was operated during the experiment (FIGURE 4).


FIGURE 4 Stormwind simulator's dashboard view on the left and participant steering the simulator on the right.

Participants' horizontal distance from eye level to the screen was 2260 mm (89 inch), distance from eye level to screen corners was 2620 mm (103 inch) and viewing angle approximately 60 degrees (FIGURE 5).

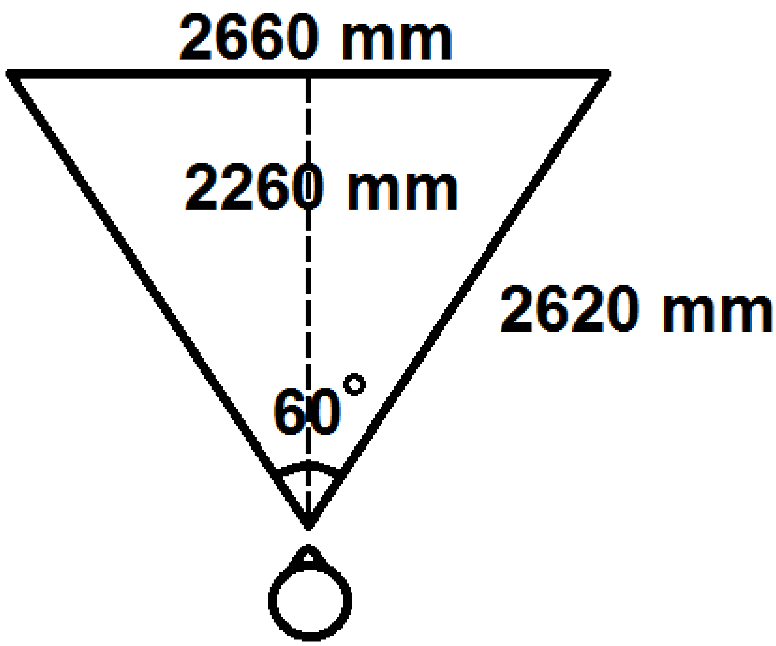


FIGURE 5 Participants distance from the screen and viewing angle

## 4.5 Data analysis

### 4.5.1 Statistical analysis

Data analysis included exploring of demographic information, finding common explaining components and factors as well as statistical hypothesis testing. IBM SPSS Statistics version 22 release 22.0.0.1 was used in the analysis.

First set of the data analysis is adopting the use of Simulator Sickness Questionnaire (SSQ) by Kennedy, Lane, Berbaum and Lilienthal (1993). Second data set comprise of the Likert-type scale questionnaire.

Principal Components Analysis (PCA) was used for a data reduction and to find common explaining factors from the data. PCA was applied for the simulator experience Likert scale question number four (chapter 4.3 'Questionnaire' and APPENDIX 2).

To study associations between the scale variables, a non-parametric Spearman correlation test was selected, as not all components were normally distributed. An independent-samples t-test and a non-parametric Mann-Whitney U-test were applied to determine whether there were statistically significant differences between the research groups that are analyzed and presented in detail at the chapter five results.

Data extracted in the results were analyzed for outliers – individual data values or measurement variability that is distant from other values. Because of the relatively small sample size, a decision was made to report data values identified as possible outliers, but not to remove any of these data points from the data set.

### 4.5.2 Simulator Sickness Questionnaire analysis

The Simulator Sickness Questionnaire (SSQ) scale scores for the three symptoms were calculated according to Kennedy et al. (1993) by multiplying the weight in each column, Nausea by 9.54, Oculomotor by 7.58 and Disorientation by 13.92 and summed. The SSQ total score was calculated by adding the scale scores and multiplying by 3.74.

Cronbach’s alpha was applied for the three individual symptom scores to test the questionnaires internal consistency. Symptom questions are presented in the chapter 3.4 'Measuring simulator sickness – the Simulator Sickness Questionnaire (SSQ)' TABLE 3 according to Kennedy et al. (1993). The reliability coefficient values of 0.7 or higher are considered good (DeVellis, 2003).

Since the SSQ is based on a specific set of symptom scores extracted using Factor Analysis by Kennedy et al. (1993), an Exploratory Factor Analysis is applied to the collected SSQ data to qualitatively evaluate the model’s reliability.

### 4.5.3 Research questions from the previous literature and hypothesis

Previous literature on behavioral realism and simulator realism was considered. The physical and behavioral realism of the simulator was described as an immersive feeling for the user by Yin et al. (2010). Further Blana (1996) describes behavioral realism through questionnaires that give impression and opinions of the subjects' view of the simulator. The research questions were outlined to study associations between enjoyment, interest and simulator sickness with the realism. Also, whether the background variables, such as an age (Aykent, Merienne, Guillet, Paillot & Kemeny, 2013), had an impact on realism, enjoyment, interest and simulator sickness.

The study's four main research questions are:

1. Did the participants experience simulator sickness symptoms during the experiment?
2. Are there any associations between the experience of realism, enjoyment and interest?
3. Are there any associations between background variables and experience of realism, enjoyment, interest and simulator sickness?
4. Did the ship simulator's storm and calm weather conditions have effect on experienced realism and simulator sickness?

Null hypothesis for the background variables are presented below. Detailed analysis of the background variables hypothesis for statistical evaluation are studied in the chapter 5 Results.

1. Did the participants experience simulator sickness symptoms during the experiment?
   a. $H_0$: there is no experienced simulator sickness in the studied ship simulator
   b. $H_A$: there is experienced simulator sickness in the studied ship simulator

2. Are there any associations between the experience of realism, enjoyment and interest?

Enjoyment:
   a. $H_0$: there is no association between the realism and enjoyment in the studied ship simulator
   b. $H_A$: There is an association between the realism and enjoyment in the studied ship simulator

Interest:
   a. $H_0$: there is no association between the realism and interest in the studied ship simulator
   b. $H_A$: There is an association between the realism and interest in the studied ship simulator

3. Are there any associations between background variables and experience of realism, enjoyment, interest and simulator sickness?

    a. $H_0$: There is no difference between 31 or under and 31 or over years old participants.
    b. $H_0$: There is no difference between participants who have experience and who have no experience on real world maritime.
    c. $H_0$: There is no difference between participants who play computer games frequently and those who don't play frequently.

    $H_A$ for the 3.a.-b. is that there is a difference.

4. Did the ship simulator's storm and calm weather conditions have effect on experienced realism and simulator sickness?

    Realism and weather condition:

    a. $H_0$: There is no difference on experience of realism between storm and calm weather
    b. $H_{A:}$ There is difference on experience of realism between storm and calm weather

    Simulator sickness and weather condition:

    a. $H_0$: There is no difference on experience of simulator sickness between storm and calm weather
    b. $H_{A:}$ There is difference on experience of simulator sickness between storm and calm weather

# 5 RESULTS

## 5.1 Demographic information

The thirty-two participants were aged between 23 and 63 years (*Mean* = 39.34; *Median* = 36.00; *SD* = 12.375) (FIGURE 6). Twenty-seven of the participants were males (84%) and five females (16%).

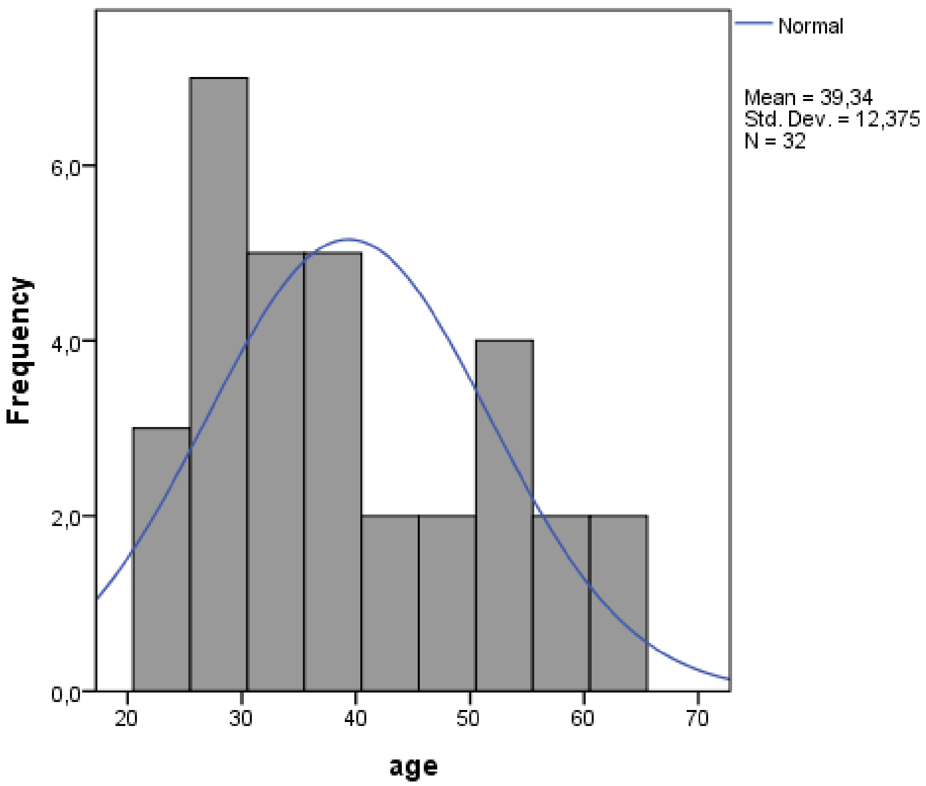


FIGURE 6 Participants' age distribution.

Eleven different nationalities participated in the study. Eighteen participants were from the host country Finland (56%). Other participants were in alphabetical order from Austria, Belgium, China, Estonia, France, Germany, Ireland, Italy, Netherlands and Spain.

When asked about profession eight participants (25%) responded being a researcher and another eight (25%) being an exhibition visitor / stand personnel. Officials' (government institution) were six participants (19%) as rest of the professions divided between student, representative of related businesses, decision makers, delegate of NGOs (non-governmental organization) and in the selection of "other".

Experience in real world maritime (sailing, boating or similar) in years was reported by seventeen (53%) of the thirty-two participants as fifteen (47%) of the participants reported no experience at all (FIGURE 7).

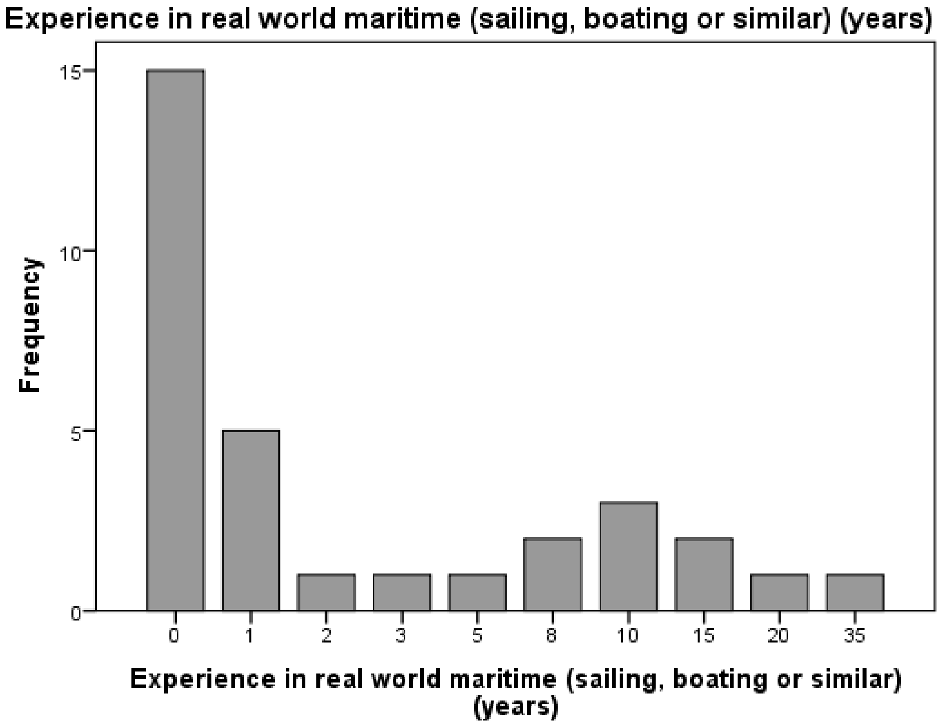


FIGURE 7 Participants' experience in real world maritime (sailing, boating or similar) (years).

Twenty-seven participants reported to have never played a similar boat simulator (84%), three participants (9%) once or twice and two (6%) less than 10 times (FIGURE 8).

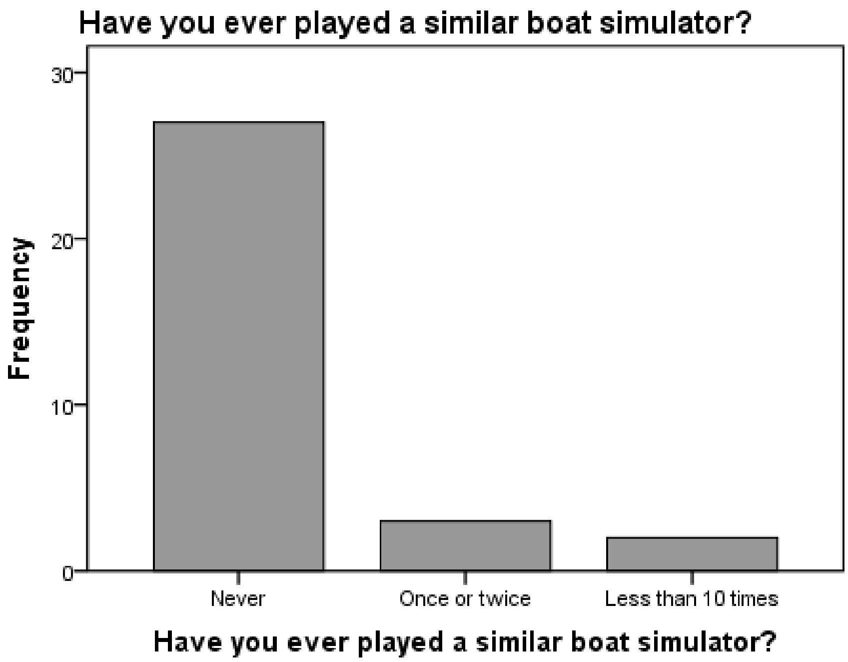


FIGURE 8 Have you ever played a similar boat simulator?

Twenty-eight participants reported to have played computer games (87%) as only four (13%) reported to have never played. Seventeen (53%) participants played a few times a year, five (16%) a few times a month and four (13%) a few times a week. Two participants did not answer the questions (6 %). (FIGURE 9).

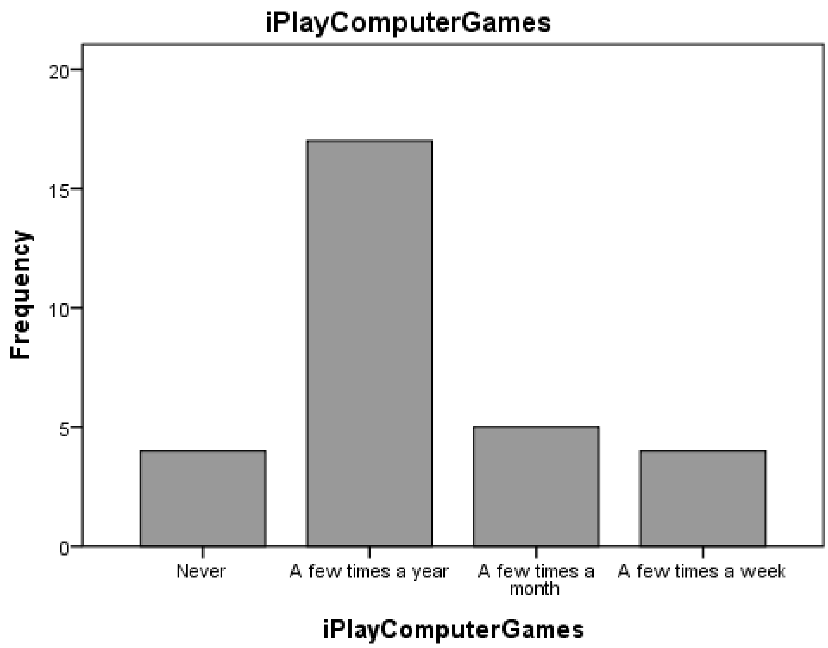


FIGURE 9 I play computer games

## 5.2 Simulator Sickness

### 5.2.1 Simulator Sickness Questionnaire Results

All thirty-two participants completed the experiment and filled the Simulator Sickness Questionnaire (SSQ). Null and alternative hypothesis for the research question 3. "Did the participants experience simulator sickness symptoms during the experiment?" were

a. $H_0$: there is no experienced simulator sickness in the studied ship simulator
b. $H_A$: there is experienced simulator sickness in the studied ship simulator

FIGURE 10 presents the total distribution of the SSQ total score amongst the participants. Ten of the participants reported no symptoms as the rest of the participants (69 %) reported mild to severe.

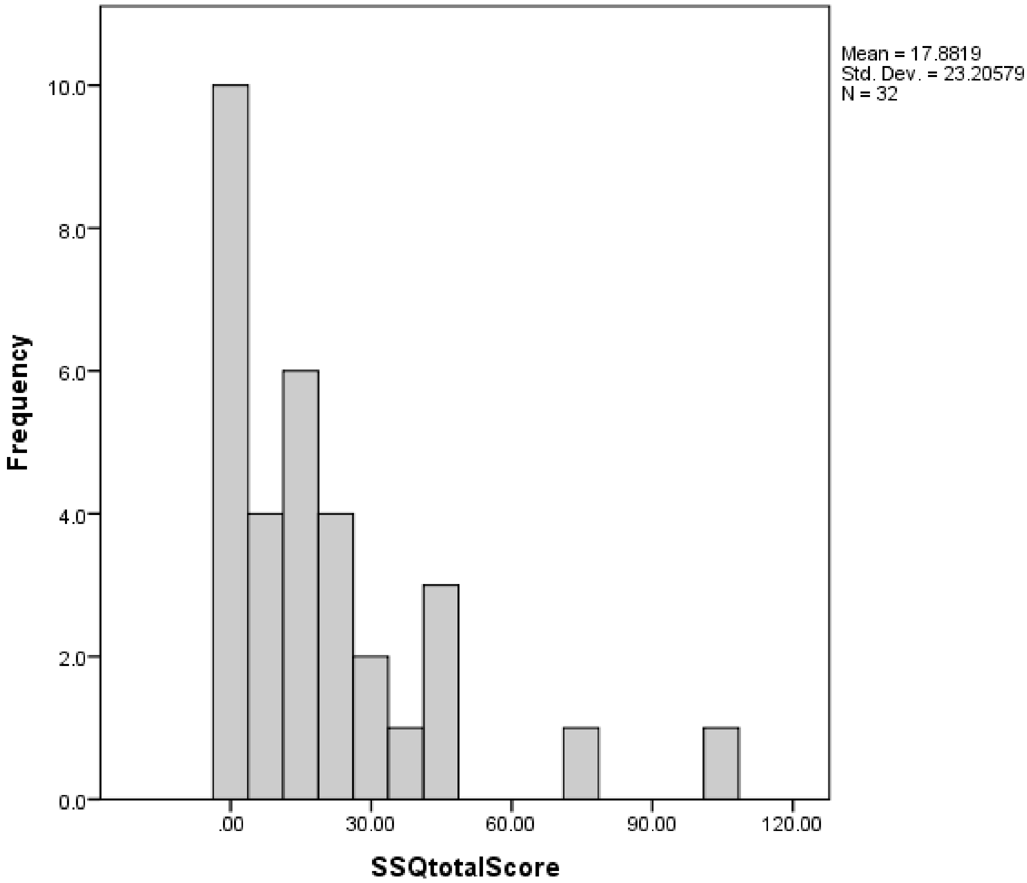


FIGURE 10 Total distribution of the SSQ total scores amongst the participants (N = 32).

Based on the results, the null hypothesis is rejected and alternative hypotheses "there is an indication on simulator sickness in the studied ship simulator" accepted.

### 5.2.2 SSQ Reliability Analysis

Reliability analysis was applied to test the internal consistency of each of the three symptom scores. FIGURE 11 presents the individual symptom scores of Nausea. Kennedy et al. (1993) nausea symptom score consisted of seven questions. The scale had a low level of internal consistency, as Cronbach's alpha of 0.588 was reported. It should be noted that the questions 7 (sweating, r = .177) and 9 (difficulty concentrating, r = .193) had a correlation of below 0.3 with the sum of all other items. The question 16 was removed as it had no variance.

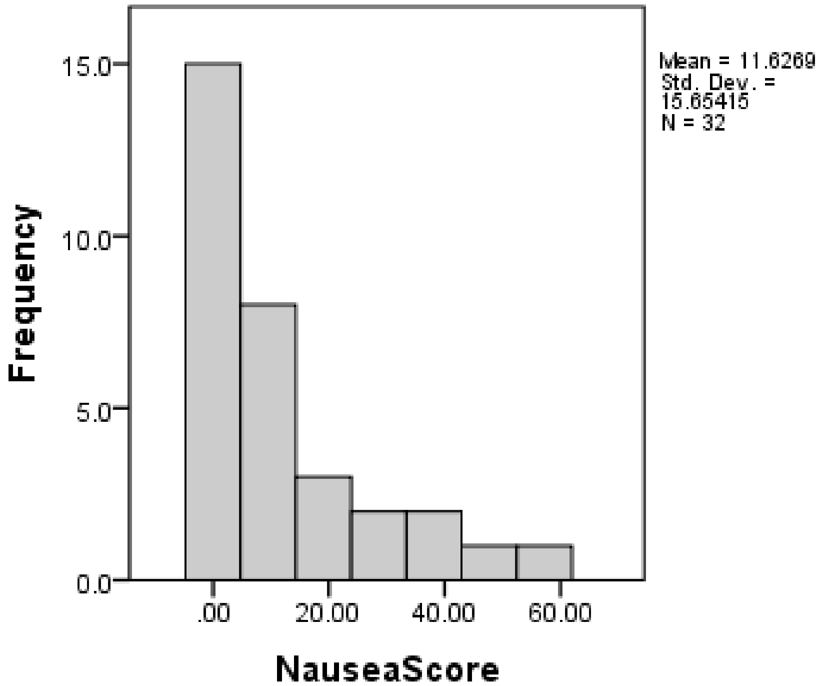


FIGURE 11 Nausea individual symptom scores (N = 32).

FIGURE 12 presents the individual symptom scores of Oculomotor that consisted of seven questions. The scale had a high level of internal consistency, as Cronbach's alpha of 0.744 was reported.

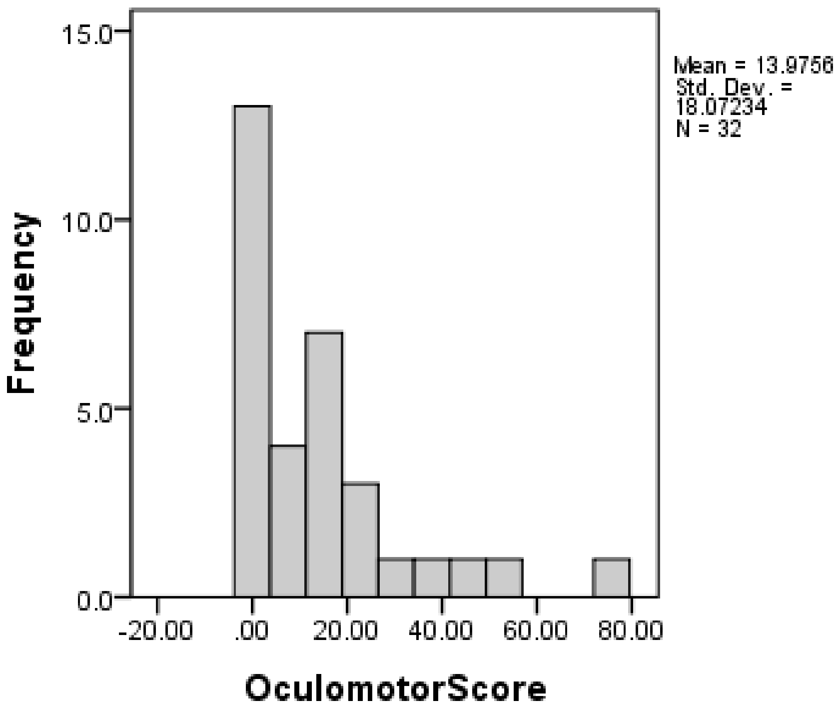


FIGURE 12 Oculomotor individual symptom scores (N = 32).

FIGURE 13 presents the individual symptom scores of Disorientation that consisted of seven questions. The scale had a high level of internal consistency, as Cronbach's alpha of 0.827 was reported. It should be noted that the question 5 (difficulty focusing, r = .152) had a correlation below 0.3 with the sum of all the other items.

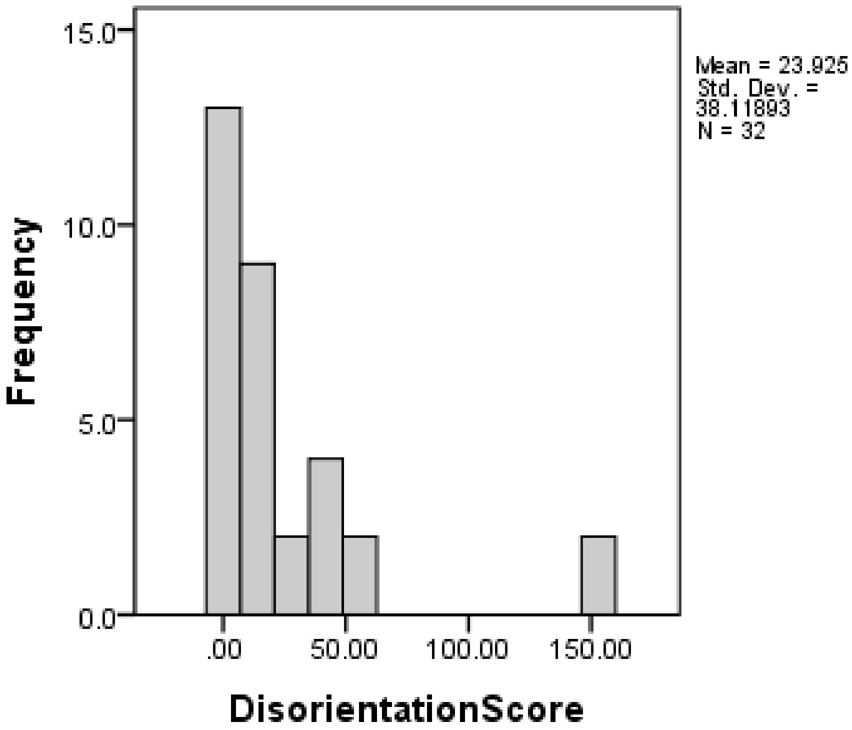


FIGURE 13 Disorientation individual symptom scores (N = 32).

### 5.2.3 SSQ Exploratory Factor Analysis – qualitative comparison to Kennedy et al. (1993)

Kennedy, Lane, Berbaum and Lilienthal (1993) identified clusters of symptoms named as Nausea, Oculomotor and Disorientation by utilizing two forms of factor analysis; principal factors analysis with normalized varimax rotation and hierarchical factor analysis method to extend the analysis of the rotated-factor matric and to extract a general factor.

A principal factor analysis varimax factors qualitative comparison was made between the Kennedy et al. (1993) symptom clusters and the symptom clusters extracted from the research's SSQ for estimation of the SSQ reliability. Factors are presented in TABLE 4 below.

Table 3 Simulator Sickness Questionnaire (SSQ) principal factors analysis factor loadings Kennedy, Lane, Berbaum and Lilienthal (1993) and the components extracted from the study. Grey colors markings indicate component factors.

| Question number | SSQ Symptom | SSQ Symptom (Kennedy et al. 1993) | | | Component | | |
|---|---|---|---|---|---|---|---|
| | | N | O | D | 1 | 2 | 3 |
| 1 | General Discomfort | .65 | .40 | .18 | .117 | **.527** | .252 |
| 2 | Fatigue | .15 | .54 | −.04 | **.649** | .044 | -.013 |
| 3 | Headache | .22 | .53 | .15 | .167 | **.605** | .132 |
| 4 | Eyestrain | .00 | .74 | .17 | .205 | **.672** | .042 |
| 5 | Difficulty focusing | −.01 | .61 | .43 | -.042 | **.580** | -.194 |
| 6 | Increased salivation | .53 | .21 | .13 | **.922** | .221 | -.061 |
| 7 | Sweating | .31 | .24 | .08 | -.052 | -.096 | **.569** |
| 8 | Nausea | .75 | .08 | .30 | **.674** | .064 | **.506** |
| 9 | Difficulty concentrating | .32 | .39 | .27 | .275 | **.654** | -.167 |
| 10 | Fullness of head | .12 | .17 | .37 | **.679** | **.391** | .237 |
| 11 | Blurred vision | .01 | .36 | .40 | **.750** | .243 | -.065 |
| 12 | Dizzy (eyes open) | .17 | .07 | .76 | **.908** | **.305** | -.163 |
| 13 | Dizzy (eyes closed) | .17 | .09 | .65 | **.733** | .152 | -.140 |
| 14 | Vertigo | .18 | .08 | .37 | **.317** | **.527** | .053 |
| 15 | Stomach awareness | .64 | .03 | .21 | -.115 | .195 | **.816** |
| 16 | Burping | .41 | .04 | .22 | – | – | – |

None of the factors were identical. When comparing similarities, the Kennedy et al. symptom factor Disorientation (D) was closest of being the study Component 1, including six same symptoms. Kennedy et al factor Oculomotor (O) included five same symptoms with the Component 2. Finally, study Component 3 which had only three symptoms, but all common with the factor Nausea (N). Kennedy et al. (1993) Nausea symptom 16 burping was left out from the analysis as it had zero variance.

## 5.3 Simulator experience

When asked whether participants felt like being in a real boat, sixteen (50%) participants agreed with the statement and two (6%) participants strongly agreed. Neutral answer was given by eight (25%) participants and six (19%) participants disagreed. (FIGURE 14)

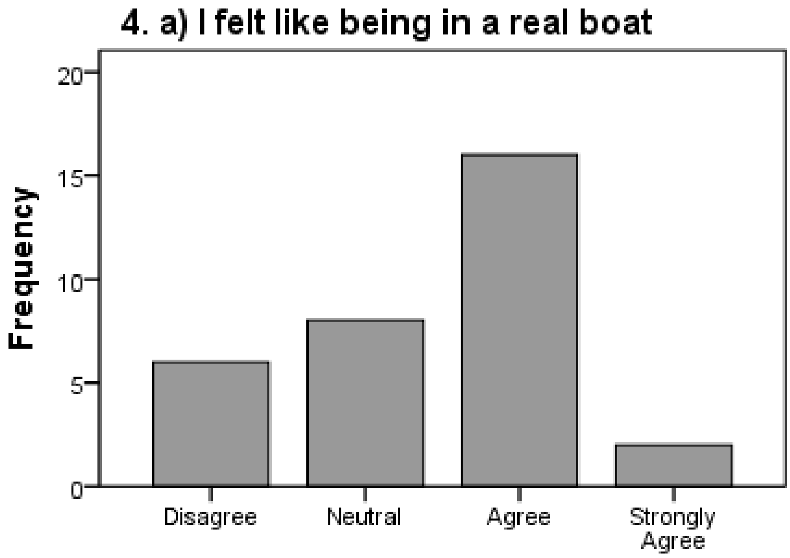


FIGURE 14 Question 4. a) I felt like being in a real boat.

Statement "I enjoyed the experience" had fifteen (47%) strongly agree and thirteen (41%) agree answers. Neutral was selected three (9%) times and disagree once (3%). (FIGURE 15)


FIGURE 15 Question 4. b) I enjoyed the experience.

Fifteen (47%) participants agreed and seven (22%) participants strongly agreed that "Transport and ship simulator games (such as Stormwind) help me to understand and practice real world situations." Nine (28%) participants indicated neutral and one (3%) participant disagreed. (FIGURE 16)


FIGURE 16 Question 4. c) Transport and ship simulator games (such as Stormwind) help me to understand and practice real world situations.

Next participants were questioned whether the fact that the simulator is based on a real-world setting (with existing maps and landscape) improved the experience. Thirteen (41%) participants strongly agreed and sixteen (50%) participants agreed with the statement. There were three (9%) neutral answers. (FIGURE 17)

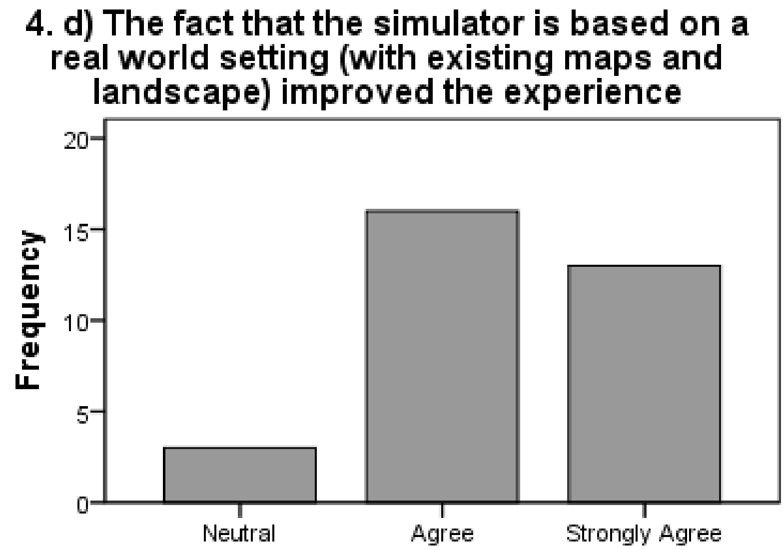


FIGURE 17 Question 4. d) The fact that the simulator is based on a real-world setting (with existing maps and landscape) improved the experience.

The simulator enhanced my interest for Finnish transport and mobility statement had five (16%) strongly agree and sixteen (50%) agree answers. Eleven (34%) neutral answers were given. (FIGURE 18)

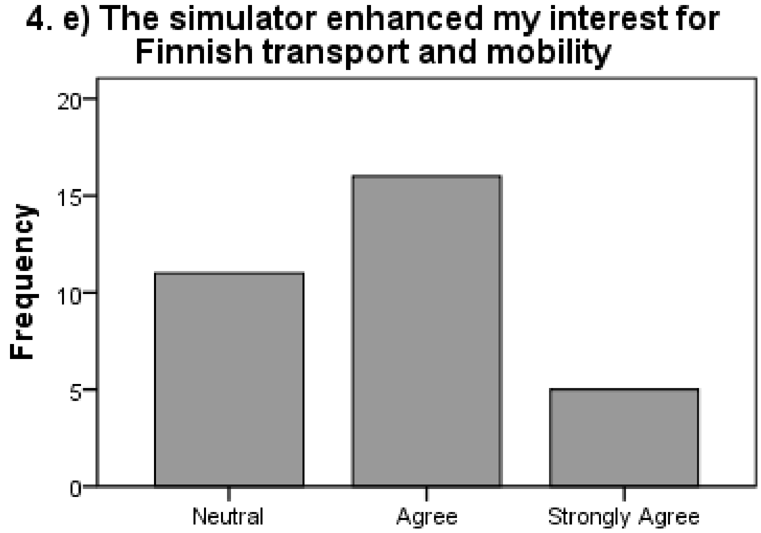


FIGURE 18 Question 4. e) The simulator enhanced my interest for Finnish transport and mobility.

When asked if steering the simulator made participants more interested in travelling Finnish waterways, eight (25%) participants strongly agreed and fourteen (44%) participants agreed with the statement. There were nine (28%) neutral answers and one (3%) that disagreed. (FIGURE 19)

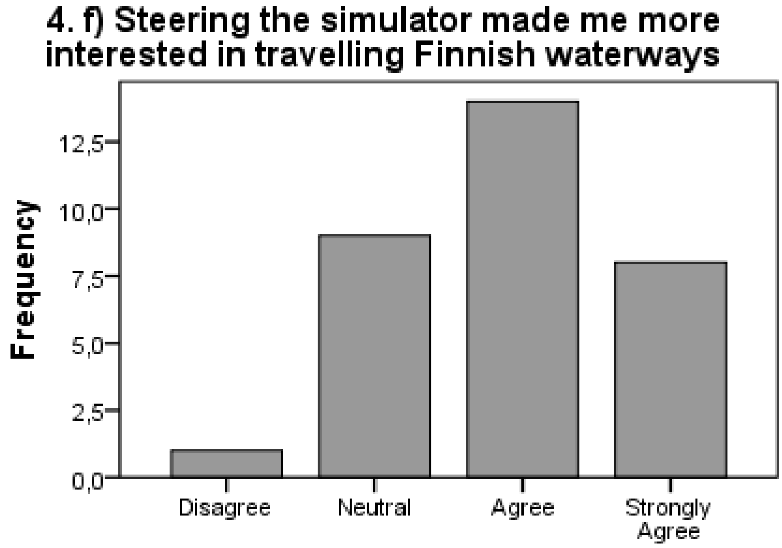


FIGURE 19 Question 4. f) Steering the simulator made me more interested in travelling Finnish waterways.

## 5.4 Exploring the variables

### 5.4.1 Principal Components Analysis

The six questions in the questionnaire's section four measured the conference visitors' interest, enjoyment and feeling of realism in the Stormwind boat simulator. Before the analysis a correlation matrix was created to test the PCA suitability. A Varimax orthogonal rotation was used for interpretability.

All variables had at least two correlations greater than 0.3. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.67. Individual KMO measures were all greater than 0.6 but below 0.8 except the question 4. e) which KMO measure was 0.595. These KMO results present sampling adequacy between mediocre to middling. Bartlett's test of sphericity was statistically significant ($p < 0.005$) and therefore the data most likely factorizable.

In the end PCA presented two components that had eigenvalues greater than one. In similar order, these components explained 45 % and 18% of the total variance and overall the two components explained 63 % of the total variance. The two components did not fully meet the interpretability criterion of simple structure as questions 4. c) and 4. d) loaded on both components. Component loadings and communalities of the rotated solution are presented in TABLE 5.

Table 4 Principal Component Analysis component loadings.

| Rotated Structure Matrix for PCA with Varimax Rotation of a two component questionnaire | | | |
|---|---|---|---|
| Items | Rotated Component Coefficients | | |
| | Component 1 | Component 2 | Communalities |
| 4. a) I felt like being in a real boat | **.885** | -.001 | .784 |
| 4. c) Transport and ship simulator games (such as Stormwind) help me to understand and practice real world situations | **.729** | .343 | .547 |
| 4. b) I enjoyed the experience | .712 | .201 | .648 |
| 4. e) The simulator enhanced my interest for Finnish transport and mobility | .043 | **.896** | .441 |
| 4. f) Steering the simulator made me more interested in travelling Finnish waterways | .205 | **.725** | .804 |
| 4. d) The fact that the simulator is based on a real world setting (with existing maps and landscape) improved the experience | **.430** | .507 | .568 |

The two components presented were visually inspected. A decision was made to name the component 1, consisting of the questions 4. a), 4. c) and 4. d), as experience of realism. These three questions described the sense of simulation realism. Similarly, the component 2 was created from questions 4. e) and 4. f) named as interest. These two questions described participants' interest on the simulation.

Question 4. d) loaded on both components 1 and 2. A decision was made to include the question on component 1 as the question is considered to relate better to simulation realism than interest. Question 4. b) "I enjoyed the experience" was purposely left out, although loaded with component one, as it is considered of being a third independent component: enjoyment.

Components loadings are market with gray background in the TABLE 5 above. Again, the simple structure was not fully met as the component 2 "interest" included only two variables for recommended three.

Osborne and Costello (2004) state that PCA sample size have been argued by statisticians, looking at total N or ratio of subject to items. Rule of thumb such as 3:1, 5:1 or 15:1 have been suggested and the ratio of subject to items in this research was 32 / 6 ≈ 5.3, which was considered sufficient.

### 5.4.2 Component's reliability – Cronbach's alpha

Before creating a component based on the PCA, a following step was to analyze the components coefficient of reliability, which was measured using the Cronbach's alpha.

Cronbach's alpha measures the internal consistency of the items. Reliability is considered of being acceptable with Cronbach's alpha values between 0.6 and 0.7 and good when greater than 0.7 (DeVellis, 2003).

Therefore, the component 1 titled as experience of realism, internal consistency is considered of being acceptable with Cronbach's alpha of 0.70 and the component 2 titled as interest same with Cronbach's alpha of 0.64.

### 5.4.3 Components of realism and interest

Two components were extracted based on the PCA. First, the component of experienced realism had $M$ = 2.88, $Mdn$ = 3.0 and $SD$ = 0.615. Variable was visually inspected as being approximately normally distributed (FIGURE 20).

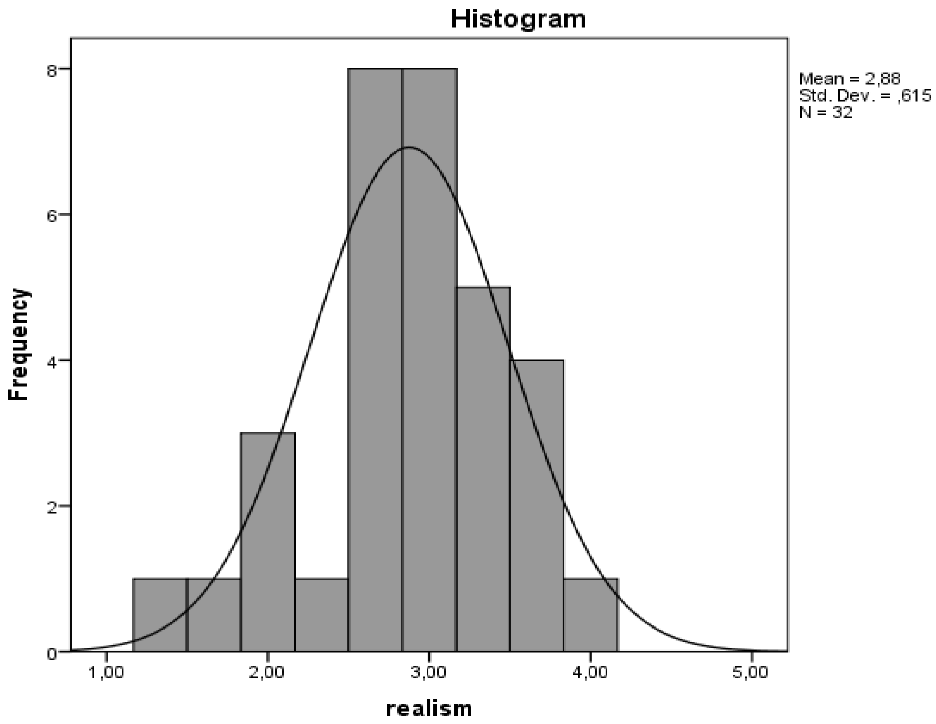


FIGURE 20 Component realism

Secondly, a component of experienced interest had *M* =2.86, *Mdn* = 3.0 and *SD* = 0.650. Variable was visually inspected as being close to normally distributed (FIGURE 21).

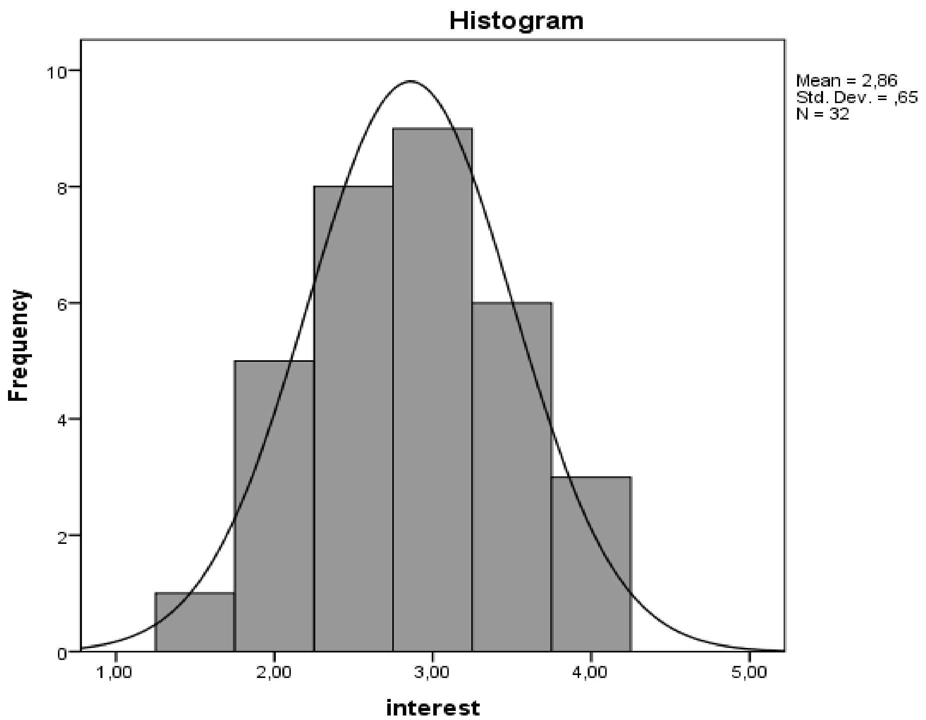


FIGURE 21 Component interest

## 5.5 Experienced realism associations on interest and enjoyment

Based on the findings in previous literature and after exploring the variables, three dependent scale variables were select for further analysis: components of interest, realism and enjoyment.

The variables distributions were visually inspected. Components interest and realism were approximately normally distributed (as presented in the chapter 5.4.3) but the variables enjoyment (chapter 5.4.1) was not. Therefore, a non-parametric Spearman correlation test was selected to research associations between the scale variables. The following null hypotheses are based on the research question two "Is there an association between the experience of realism and enjoyment and interest "?

Enjoyment:

c. $H_0$: there is no association between the realism and enjoyment in the studied ship simulator
d. $H_A$: There is an association between the realism and enjoyment in the studied ship simulator

Interest:

c. $H_0$: there is no association between the realism and interest in the studied ship simulator
d. $H_A$: There is an association between the realism and interest in the studied ship simulator

To run the Spearman correlation, scatter plots were created to visually inspect variables monotonic relationship. The following FIGURES 22 and 23 show mild monotonic relationship between the interest and enjoyment variables with the realism variable.

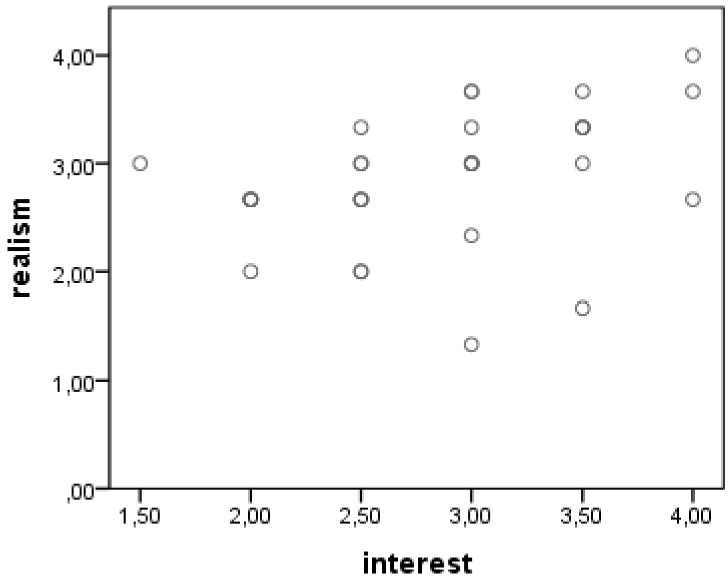


Figure 22 Scatter plot of realism and interest monotonic relationship

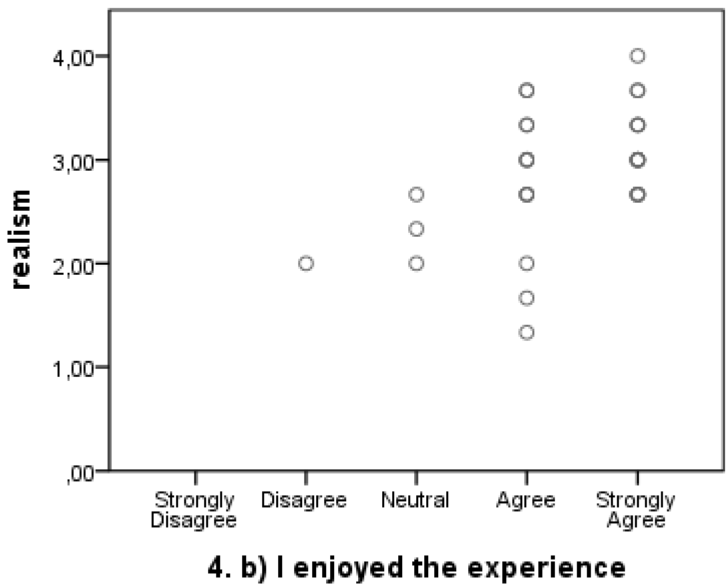


Figure 23 Scatter plot of realism and enjoyment monotonic relationship

Spearman results indicated moderate positive correlation between realism and enjoyment, $r_s = .451$, $p = .010$. Realism and interest also had a moderate positive correlation, $r_s = .473$, $p = .006$. Correlations are presented in TABLE 6.

Table 5 Spearman correlations of realism, enjoyment and interest.

| Spearman correlations of realism, enjoyment and interest | | | |
|---|---|---|---|
| | Realism | Enjoyment | Interest |
| Realism | 1.00 | **.451*** | **.473*** |
| Enjoyment | **.451*** | 1.00 | .289 |
| Interest | **.473*** | .289 | 1.00 |

* Correlation is significant at the 0.01 level (2-tailed), *N* = 32

Based on the results, the null hypothesis of variables realism and enjoyment is rejected, and alternative hypotheses accepted. Variables realism and interest null hypothesis is also rejected, and alternative hypothesis accepted.

## 5.6 Effects of background variables on simulator realism, interest, enjoyment and SSQ total score

The third research question of the study was

3. Are there any associations between background variables and experience of realism, enjoyment and interest?

The four dependent variables of realism, interest, enjoyment and SSQ total score and background variables of gender, age, nationality profession and experience on boat simulators, real world maritime and computer game experience were analyzed for possible explore on statistical associations.

First, background variables gender and experience on boat simulators were left out of the analysis as there were only five female participants and five participants with experience on boat simulators. Five participants per group were considered too low for statistically sound results. Background variables profession and nationality were also left out of the analysis; references or previous results were not found in the literature review for these variables.

Secondly, the three independent background variables were selected for further analysis: age, experience in real world maritime and experience in computer games.

Age was selected to find whether difference in age would affect perceived experience in the simulator, for example, Kantowitz (2011) notes the individual differences in perception of real-world and simulation. Also, previous research has suggested that older adults are more prone to simulator sickness than younger (Roenker et al., 2003) as others have found only little empirical results for the age effect (Rizzo et al., 2003). Participant group did not include older adults (age > 60) and therefore the group was divided evenly for two groups, under and over 31 years old.

Experience in real world maritime and experience in computer games variables are both studied for the transferability of the experience, i.e. by comparing participants with real-world experience in maritime and computer games and their experienced transferability in simulator and real-world (Espie, Gauriat & Duraz, 2005). Participants with different experience may also have a different tenstion between realism and real-time in virtual environment and ecological validity for the realistic environment (Slater et al., 2002; Rizzo et al., 2006).

Variables were analyzed by their scale type (nominal, ordinal or continuous), then divided into two nominal groups (between-subject) and finally a null hypothesis was created for each of the variables. This analysis is presented in the TABLE 7 below.

Table 6 Background variable analysis and null hypothesis

| Background variable analysis and null hypotheses | | | |
|---|---|---|---|
| **Independent variable** | **Variable and variable scale (type)** | **Variable values by group (type nominal, between subject)** | **Null hypothesis ($H_0$)** |
| **Age** | Years (continuous) | Group 1:<br>Under 32 years old<br>Group 2:<br>32 or over years old | There is no difference between 31 or under and 31 or over years old participants. |
| **Experience in real world maritime (sailing, boating or similar) (years)** | Years (continuous) | Group 1 (value 0):<br>no experience<br>Group 2 (years):<br>have experience | There is no difference between participants who have experience and who have no experience on real world maritime. |
| **Computer game experience** | Never; a few times a year; a few times a month; a few times a week; almost every day (ordinal) | Group 1 (values 0 to 1):<br>does not play or only few times a year<br>Group 2 (values 1 to 4):<br>plays frequently | There is no difference between participants who play computer games frequently and those who don't play frequently. |

Thirdly, to explore differences between the groups, appropriate statistical tests were selected for each variable. The four dependent variables were analyzed together with the independent variables. The independent variables were all nominal as being divided into two groups.

Dependent variables realism and interest, components extracted using the PCA, were considered as continuous variables. Therefore independent-samples t-test was selected for nominal independent variables of two groups and continuous dependent variables of realism and interest.

Based on the qualitative analysis of the continuous dependent variable SSQ total score (FIGURE 10 in chapter 5.2.1), the variable was not normally distributed and therefore non-parametric Mann-Whitney U-test was selected.

Dependent variable enjoyment being one of the questions in the questionnaire was considered as an ordinal type of variable. Therefore, a non-parametric Mann-Whitney U-test was selected.

### 5.6.1 Age

Age groups of under 32 years old (*N* = 11) and 32 or over 32 years old (*N* = 21) boxplots were visually inspected for outliers. Realism and age data included one possible outlier in the under 32 years old group (*Mean* = 2.9; *Median* = 3.0; *SD* = 0.65) which was greater than 1.5 box-lengths from the edge of the box. The outlier was left in the data as not considered affecting the analysis. Group of over 32 years (*Mean* = 2.6; *Median* = 3.0; *SD* = 0.61) had no outliers. (FIGURE 24)

Interest and age groups of under 32 years old (*Mean* = 2.9; *Median* = 3.0; *SD* = 0.58) and over 32 years old (*Mean* = 2.8; *Median* = 3.0; *SD* = 0.70) data had no outliers (FIGURE 25).

SSQ total score and age groups of under 32 years old (*Mean* = 23.1; *Median* = 14.7; *SD* = 28.5) had two outliers and over 32 years old (*Mean* = 15.1; *Median* = 7.5; *SD* = 20.2) data had one outlier (FIGURE 26). The first group two outliers that were 1.5 box lengths from the edge of the box were considered not affecting the results and left in the data. Also, the outlier in group under 32 years old that was more than 3 times lengths from the box edge was decided to be kept for the same reason.

Variable enjoyment and age groups of under 32 years old (*Mean* = 3.6; *Median* = 4.0; *SD* = 0.52) had no outliers and over 32 years old (*Mean* = 3.2; *Median* = 3.0; *SD* = 0.87) data had one outlier that was kept in the data as considered not affecting the results (FIGURE 27).

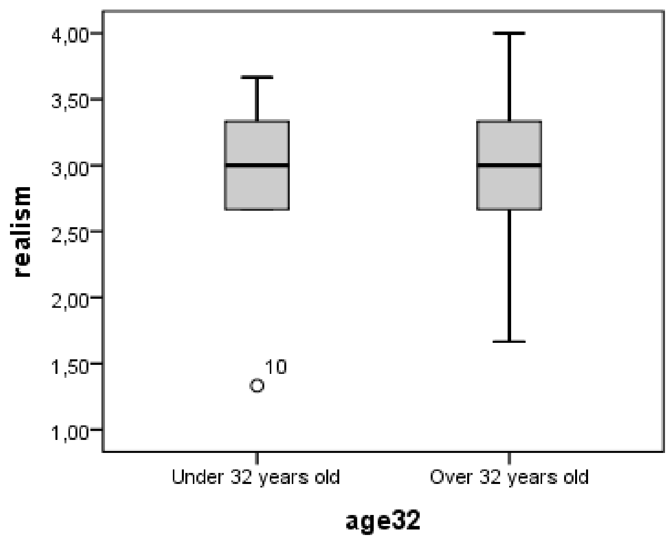


Figure 24 Boxplot of age groups and realism

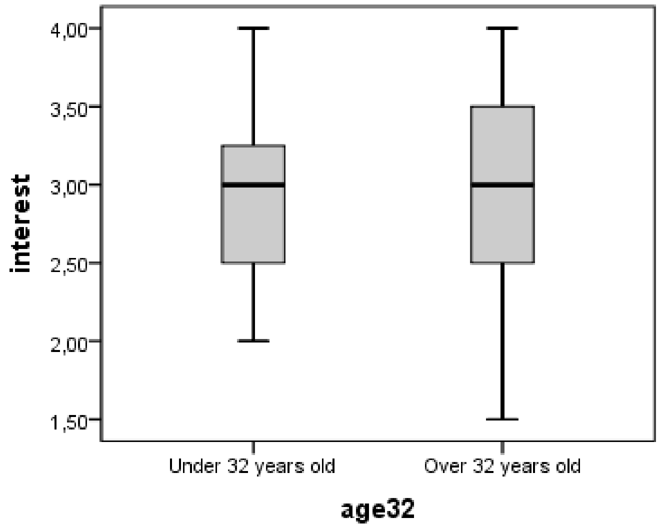


Figure 25 Boxplot of age groups and interest

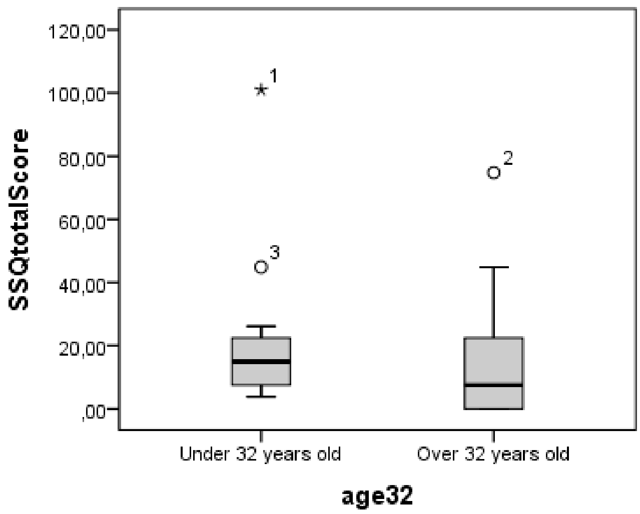


Figure 26 Boxplot of age groups and SSQ total score

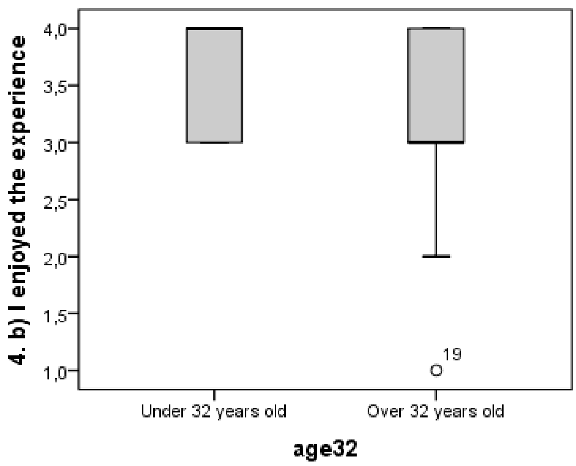


Figure 27 Boxplot of age groups and enjoyment

An independent samples t-test was run to test if there was a difference on how the simulation realism was perceived between age groups under 32 and 32 or over 32 years of old participants. Levene's test for equality of variances indicated that there was homogeneity of variances ($p$ = .902). There was not a statistically significant difference between the age groups, $t(30)$ = .223, $p$ = .825. The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

An independent samples t-test was run to test if there was a difference on variable interest between the two age groups. Levene's test for equality of variances indicated that there was homogeneity of variances ($p$ = .422). There was not a statistically significant difference between the age groups, $t(30)$ = .308, $p$ = .760. The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

A non-parametric Mann-Whitney U-test was run to test if there was a difference in the SSQ total score between the age groups of under 32 (*Median* = 14.7) and 32 or over 32 years of old (*Median* = 7.5). Median SSQ total score was not statistically significantly different between the age groups, $U$ = 82.5, $z$ = -1.332, $p$ = .183 (asymptonic p-value). The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

A non-parametric Mann-Whitney U-test was run to test if there was a difference in the enjoyment between the age groups of under 32 (*Median* = 4.0) and 32 or over 32 years of old (*Median* = 3.0). Median enjoyment was not statistically significantly different between the age groups, $U$ = 92.0, $z$ = -1.023, $p$ = .306. The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

### 5.6.2 Experience in real world maritime

Experience groups "no experience in real world maritime" (no experience) ($N$ = 15) and "experience in real world maritime" (experienced) ($N$ = 17) boxplots were visually inspected for outliers. There were no outliers in the realism and real world experience group of no experience (*Mean* = 2.9; *Median* = 2.7; *SD* = 0.55) but the experienced group (*Mean* = 2.8; *Median* = 3.0; *SD* = 0.68) included one outlier. The outlier was 1.5 box lengths apart from the edge of the box and therefore a decision was made to keep the outlier in the data set. (FIGURE 28)

Interest and real world experience group no experience (*Mean* = 2.8; *Median* = 2.5; *SD* = 0.68) had no outliers. Group experienced (*Mean* = 2.9; *Median* = 3.0; *SD* = 0.63) had three outliers as shown in the FIGURE 29. The three outliers were all one and a half box length away from the edge of the box. All three outliers were kept.

SSQ total score and real world experience group no experience (*Mean* = 20.7; *Median* = 11.2; *SD* = 29.78) had two outliers that were decided to be kept in the data. Group experienced (*Mean* = 15.4; *Median* = 11.2; *SD* = 15.91) had no outliers. (FIGURE 30)

Variable enjoyment and real world experience group no experience (*Mean* = 3.4; *Median* = 4.0; *SD* = 0.74) had no outliers. Group experienced (*Mean* = 3.2;

*Median* = 3.0; *SD* = 0.83) had one outlier. The outlier was one and a half box length from the edge of the box and therefore decided to be kept in the data. (FIGURE 31)

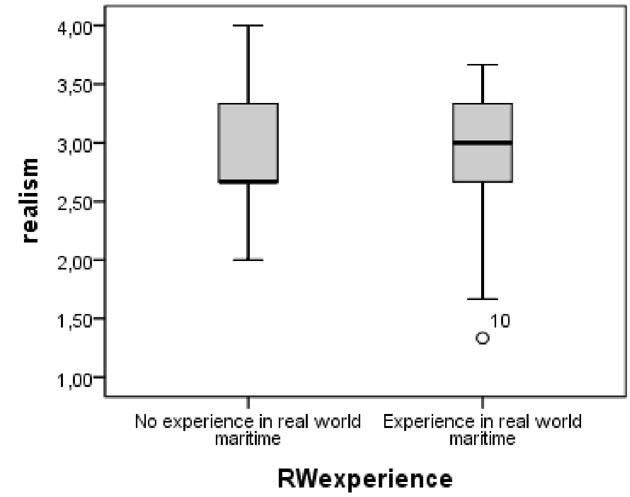


Figure 28 Boxplot of real-world experience groups and realism

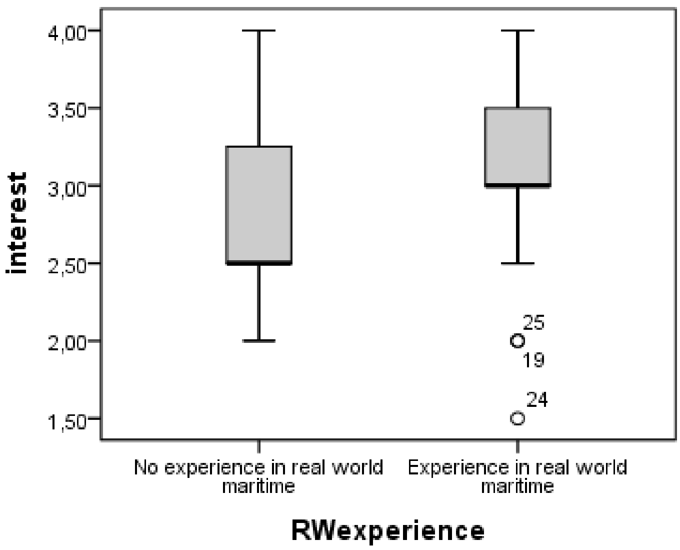


Figure 29 Boxplot of real-world experience groups and interest

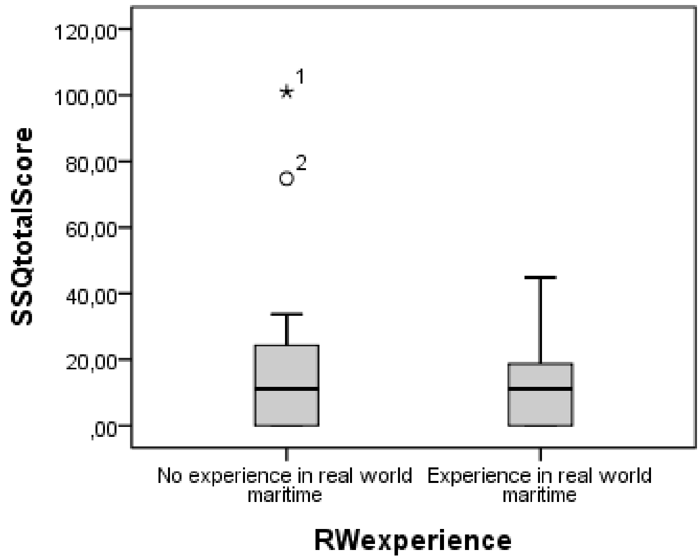


Figure 30 Boxplot of real-world experience groups and SSQ total score

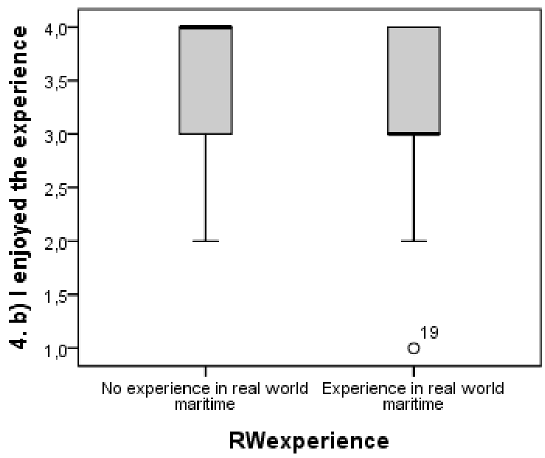


Figure 31 Boxplot of real-world experience groups and enjoyment

An independent samples t-test was run to test if there was a difference on how the simulation realism was perceived between the experience groups of no experience and experienced in real world maritime. Levene's test for equality of variances indicated that there was homogeneity of variances ($p$ = .562). There was not a statistically significant difference between the experience groups, $t$(30) = .307, $p$ = .761. The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

An independent samples t-test was run to test if there was a difference on how the simulation interest was perceived between the experience groups of no experience and experienced in real world maritime. Levene's test for equality of variances indicated that there was homogeneity of variances ($p$ = .438). There was not a statistically significant difference between the experience groups, $t$(30) =

-.752, $p$ = .458. The null hypothesis was sustained as there were no statistically significant findings ($p > .05$).

A non-parametric Mann-Whitney U-test was run to test if there was a difference in the SSQ total score between the experience groups of no experience (*Median = 11.2*) and experienced (*Median* = 11.2). Median SSQ total score was not statistically significantly different between the experience groups, $U$ = 127.5, $z$ = .000, $p$ = 1.0. The null hypothesis was sustained as there were no statistically significant findings ($p > .05$).

A non-parametric Mann-Whitney U-test was run to test if there was a difference in the enjoyment between the no experience (*Median* = 4.0) and experienced (*Median* = 3.0). Median enjoyment was not statistically significantly different between the experience groups, $U$ = 114.0, $z$ = -.560, $p$ = .628. The null hypothesis was sustained as there were no statistically significant findings ($p > .05$).

### 5.6.3 Experience on computer games

Based on participants estimation on computer game experience, groups "never or few times" (a year) ($N$ = 21) and "play computer games actively" (a few times a month or more often) ($N$ = 9) boxplots were visually inspected for outliers.

Variable realism computer players group "never of few times" (*Mean* = 2.8; *Median* = 3.0; *SD* = 0.56) had five outliers in total. Two of the outliers had values greater than the mean value and were one and a half of length from the edge of the box. Three of the outliers had values below an average and one of the values was more than three times lengths from the box edge. The outliers were kept in the data. Group "play computer games actively" (*Mean* = 3.0; *Median* = 3.3; *SD* = 0.79) had no outliers. (FIGURE 32)

Variable interest and computer playing groups "never of few times a week" (*Mean* = 2.9; *Median* = 3.0; *SD* = 0.70) and "play computer games actively" (*Mean* = 3.1; *Median* = 3.0; *SD* = 0.58) had no outliers as presented in the FIGURE 33.

SSQ total score had one outlier in group "never or few times" (*Mean* = 23.0; *Median* = 15.0; *SD* = 26.43). Outlier was 1.5 times from the edge of the box. The outliers were kept in the data. Group "play computer games actively" (*Mean* = 6.2; *Median* = 3.7; *SD* = 8.77) had no outliers. (FIGURE 34)

Variable enjoyment computer players group "never or few times" (*Mean* = 3.1; *Median* = 3.0; *SD* = 0.85) had one outlier that was 1.5 length from the edge of the box. The outlier was sustained in the data. Group "play computer games actively" (*Mean* = 3.6; *Median* = 4.0; *SD* = 0.53) had no outliers. (FIGURE 35)

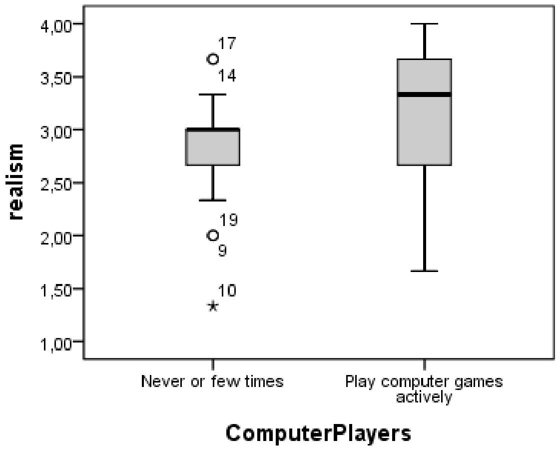


Figure 32 Boxplot of computer games groups and realism

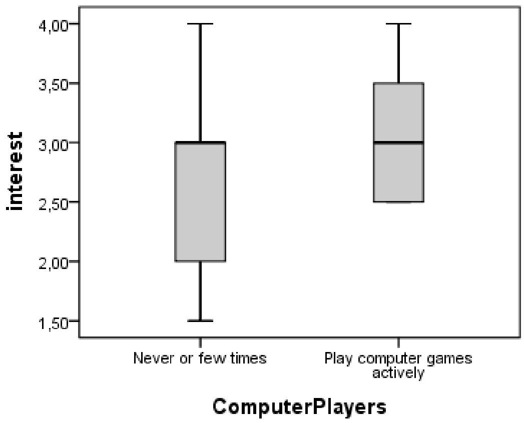


Figure 33 Boxplot of computer games groups and interest

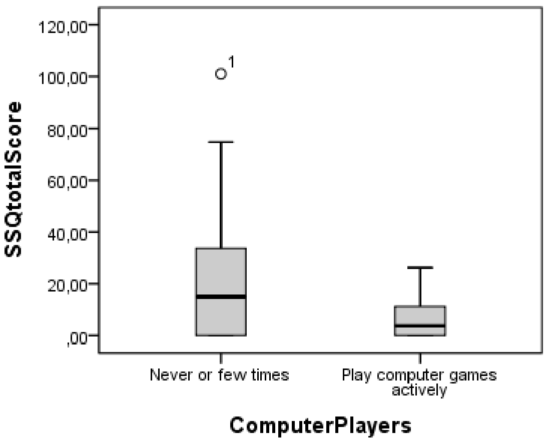


Figure 34 Boxplot of computer games groups and SSQ total score

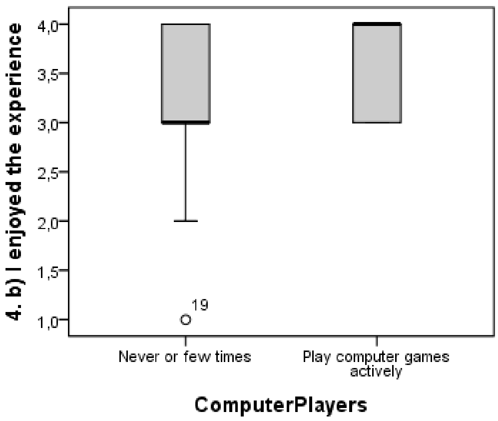


Figure 35 Boxplot of computer games groups and enjoyment

An independent samples t-test was run to test if there was a difference on how the simulation realism was perceived between the computer playing experience groups of never or few times (a year) and play computer games actively. Levene's test for equality of variances indicated that there was homogeneity of variances ($p$ = .191). There was not a statistically significant difference between the computer playing experience groups, $t$(28) = -.897, $p$ = .377. The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

An independent samples t-test was run to test if there was a difference on how the simulation interest was perceived between the computer playing experience groups. Levene's test for equality of variances indicated that there was homogeneity of variances ($p$ = .596). There was not a statistically significant difference between the experience groups, $t$(28) = -1.013, $p$ = .320. The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

A non-parametric Mann-Whitney U-test was run to test if there was a difference in the SSQ total score between the computer playing experience groups of never or few times (a year) (*Median = 15.0*) and play computer games actively (*Median* = 3.7). Median SSQ total score was not statistically significantly different between the computer playing experience groups, $U$ = 54.0, $z$ = -.1.871, $p$ = .070. The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

A non-parametric Mann-Whitney U-test was run to test if there was a difference in the enjoyment between the computer playing groups of never or few times (a year) (*Median* = 3.0) and play computer games actively (*Median* = 4.0). Median enjoyment was not statistically significantly different between the computer playing experience groups, $U$ = 119.0, $z$ = 1.212, $p$ = .283. The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

## 5.7 Effect of simulated weather conditions on experience of realism and simulator sickness

Participants steered the ship simulator in two different weather conditions: storm and calm weather. The within-subject experimental setup was counterbalanced in a way that each randomly selected participant started from either from the storm or calm weather. Research question four:

Did the ship simulator's storm and calm weather conditions have effect on experienced realism and simulator sickness?

Realism and weather condition:

c. $H_0$: There is no difference on experience of realism between storm and calm weather
d. $H_{A:}$ There is difference on experience of realism between storm and calm weather

Simulator sickness and weather condition:

c. $H_0$: There is no difference on experience of simulator sickness between storm and calm weather
d. $H_{A:}$ There is difference on experience of simulator sickness between storm and calm weather

Independent variable weather included two different groups of treatment that were counter-balanced between subjects: storm and calm weather. Dependent variables of realism and SSQ total score were considered being continuous variables. Independent-samples t-test was chosen for analysis of realism and weather. A non-parametric Mann-Whitney U-test was selected for analysis of SSQ total score and weather conditions as the SSQ score was not normally distributed (see chapter 5.2.1, FIGURE 10).

### 5.7.1 Realism and weather conditions

Realism groups of calm ($N$ = 17) and storm weather ($N$ = 15) boxplots were visually inspected for outliers. Realism and calm weather data (*Mean = 2.9*; *Median* = 3.0; *SD* = 0.62) included one possible outlier in which was greater than 1.5 box-lengths from the edge of the box. Group of storm weather (*Mean* = 2.8; *Median* = 3.0; *SD* = 0.63) had two outliers. The outliers were left in the data as not considered affecting the analysis. (FIGURE 36)

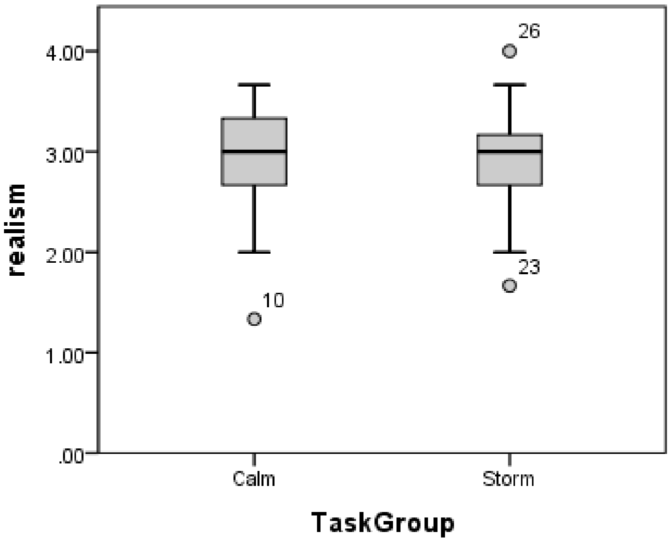


Figure 36 Boxplot of calm and storm weather groups and realism

An independent samples t-test was run to test if there was a difference on how the simulation realism was perceived between weather groups of calm and storm. Levene's test for equality of variances indicated that there was homogeneity of variances ($p$ = .950). There was not a statistically significant difference between the age groups, $t(30)$ = .260, $p$ = .797. The null hypothesis was sustained as there were no statistically significant findings ($p$ > .05).

### 5.7.2 SSQ total score and weather conditions

SSQ total score and calm weather (*Mean* = 19.6; *Median* = 15.0; *SD* = 20.4) as well as storm weather (*Mean* = 16.0; *Median* = 3.7; *SD* = 26.6) data had both one outlier (FIGURE 37). The two outliers were considered not affecting the results and therefore left in the data.

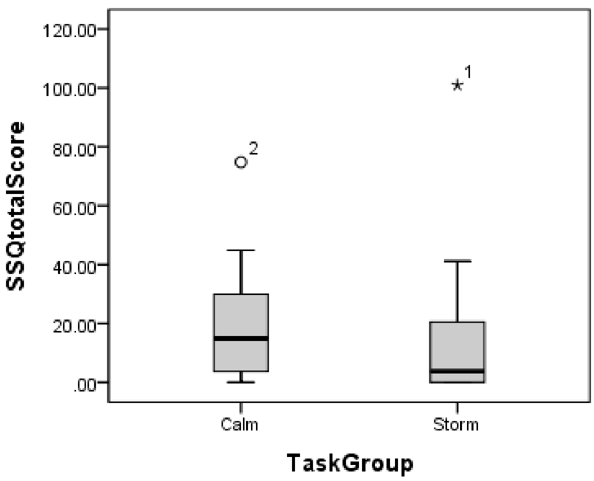


Figure 37 Boxplot of calm and storm weather groups and SSQ total score

A non-parametric Mann-Whitney U-test was run to test if there was a difference in the SSQ total score between the calm (*Median* = 15.0) and storm weather (*Median* = 3.7) groups. Median SSQ total score was not statistically significantly different between the weather groups, $U = 101.0$, $z = -1.018$, $p = .309$ (asymptonic p-value). The null hypothesis was sustained as there were no statistically significant findings ($p > .05$).

# 6 DISCUSSION

## 6.1 Results analyzed based on previous literature

A qualitative analysis of physical realism was conducted for the ship simulator used in the study. Physical realism is also seen related to simulator physical validity as it is described as how well the simulator looks and is physically like the real-world version (Allen, Hays & Buffardi, 1986). Physical realism of the simulator is overall considered as moderate when using the three level evaluation levels of low, moderate and high (Caird & Horrey, 2011). In detail, the physical realism is evaluated according to Kumar, Etheredge and Boudreaux (2012): the simulator physical environment with the steering wheel and throttle quadrant is considered low as there are no real ship parts such as ship's bridge. 3D objects as well as effects which are software components (Stormwind simulator software) are considered high. Perception is considered moderate as there was multi-display vision with a screen width of 2660 mm (105 inch) and viewing angle approximately 60 degrees.

Behavioral realism is assessed moderate in qualitative analysis of the results. Statistically significant association between realism and user enjoyment and interest, again indicating positive perceived simulator behavioral realism. Simulator's behavioral realism analysis based on previous literature indicate, that the lack of motion system, simulator in the study being a fixed based simulator, might have affected the user experience on realism (Yin et al., 2010). Although the Stormwind simulator's software's high-level motion prediction of the simulator environment objects and realistic physics (Kumar et al., 2012) together with photo-realistic computer graphics (Ferwerda, 2003), might enhance the experience.

Previous research in simulator sickness has found mixed results on background variable effect of age (Rizzo, Sheffield, Stierman & Dawson, 2003). The findings of Park et al. (2006) on dropout rates with higher symptoms incidence were for drivers over 70 years old. There was no over 70 years of old participants in this study. Participant in the study had a median age of 36 ($SD$ = 12.4) and 31 years younger and older were statistically reviewed with no significant findings. Past research has had findings of all ages, genders and positions getting affected by motion sickness (Arribas & Pineiro, 2007). Similar findings were made as no effect on background variables were measured. The study results of a simulator sickness in such an extent, mild to moderate, may have been induced by the large wide screen displays and the visual cue of motion in the screen combined with lack of real motion due to fixed base simulator. Previous findings of Bos, MacKinnon and Patterson (2005) in a motion platform ship simulator indicate, that simulator sickness was highest when the inside view of the ship was used. In this study the front part of the ship was visible, but view was not completely inside the ship. Another explaining factor might be the simulator tasks and especially the task of storm weather. High storm weather waves might have created a stronger experience of up and down motion for the participant. Cobb, Nichols, Ramsey & Wilson (1999) indicate time of exposure to have impact on SS experience. Storm scenario in this study was only half of the time during the experiment and even then, only 2.5 minutes.

## 6.2 Research reliability

Sample size (N = 32) of the study was small. A larger sample size could help to review the results. Twenty-seven participants reported to have never played a similar boat simulator (84 %) and therefore it can be said, that the research results represent participants' first experience on boat simulators. The quasi-experimental study design left questions whether participant sampling could have affected the results, e.g. a more controlled age groups.

The PCA had two notifiable elements impairing the results. First, one of the PCA's two components, interest, did not fully meet the interpretability criterion as it included only two variables of the three required. Secondly, simple structure was not met as two questions loaded on both components. Therefore, the component 2 "interest" qualification and its validity should be reviewed.

The study's evaluation of simulator sickness was measured using the Kennedy et al. (1993) Simulator Sickness Questionnaire (SSQ). The following consideration are made of the SSQ results reliability. The nausea scale had a low level of internal consistency. The SSQ reliability was evaluated qualitatively by using the Exploratory Factor Analysis (EFA). There were some similarities between two of the factors (Oculomotor and Disorientation) but not between all three components. EFA is mainly for finding common factors and confirmatory factor analysis would be required to statistically verify and evaluate the method and SSQ factors.

Finally, as the study was conducted in an open environment, although in quiet times, there is a possibility of participant distraction of external events. It is also questioned, whether the steering tasks that led the participants' free hands to explore the sea around them, could have produced difference in individual results. Also, Kennedy et al. (1993) recommend the use of a baseline score when using the SSQ: before and after the experiment measurements of SS, this was not implemented in this study.

## 6.3 Future research

This study began with an introduction of the simulator benefits in research and training. Here a future research topic is discussed on the simulator usage perspective, then secondly, on behavioral research perspective and thirdly, considering findings on simulator sickness.

Future research of simulator usage on professional and ordinary drivers', as divided by Espie et al. (2005), is needed. Study of the microworlds (Kantowitz, 2011) on engagement and as in this study, components of enjoyment and interest of using the simulator, i.e. an internal motivation to have fun and play with the simulators. Research of these factors may bring more insight on simulator behavioral realism. Professional and ordinary drivers' or sailors' have specific goals of using the simulator, but some of these include enjoyment and interest factors of having fun when completing tasks of the steering or driving task. Simulators are not anymore a rare explicit research or training tool, but available for every home user.

In this study, a behavioural realism was evaluated, but further research of realism should be supplemented with simulator behavioural validity research by comparing the real-world and simulator environment results and their transferability to the real-world setting. This could be supported with further research and data for simulator absolute and relative validity research.

Finally, research to reduce simulator sickness symptoms is required. In this study an experimental design with only 5 minutes of simulator time induced symptoms. Research of different experimental setups, physical realism settings, task procedures and experiment task times are encouraged. For example, how fixed-based simulator differs to a motion-based simulator as McCauley and Kennedy (1976) reported motion sickness to appear when environmental motion exists within frequencies ranges near 0.2 Hz. A frequency of which Kennedy, Drexler & Kennedy (2010) have reported in motion-based simulators.

# 7 CONCLUSIONS

A quasi-experimental ship simulator study was conducted with a convenience sampling and counterbalanced within-subject design. The study was participated by thirty-two (N = 32) volunteers taking part in a conference. Participants were aged between 23 and 63 years (*Mean* = 39.3; *Median* = 36.0; *SD* = 12.4). Twenty-seven of the participants were males (84%) and five females (16%). Seventeen (53%) of the participants reported previous experience in real world maritime (sailing, boating or similar). Twenty-seven participants reported to have never played a similar boat simulator (84%). Seventeen (53%) of the participants played computer games few times a year.

A fixed-base ship simulator was steered by the participants in two conditions of calm and storm weather, overall of 5 minutes by each of the participants. A questionnaire was assessed to measure participants' experiences on simulator realism and simulator sickness. A Principal Components Analysis (PCA) was conducted and components experience of realism and interest extracted as well as third component enjoyment selected. Simulator sickness was analyzed using the Kennedy et al. (1993) Simulator Sickness Questionnaire (SSQ) and factor SSQ total score was extracted.

First of the four main research questions was as follow: did the participants experience simulator sickness symptoms during the experiment? Of the participants steering the simulator (N = 32), twenty-two (69%) reported simulator sickness symptoms when measured using the Kennedy et al. (1993) SSQ (*Mean* = 17.9; *SD* = 23.2). When comparing to the scale results of the Kennedy et al. (1993) studies (N = +1100; *Mean* = 9.8; *SD* = 15.0), participants in this ship simulator research did experience mild to severe simulator sickness.

Second research question was as follow: Are there any associations between the experience of realism, enjoyment and interest? A Spearman's rank-order correlation indicated relationship between components realism and enjoyment as well as realism and interest. Increased experience on realism was associated with an increase on enjoyment and interest. Realism and enjoyment had a moderate correlation, $r_s(30) = .451$, p = .010, similarly as did the realism and interest, $r_s(30) = .473$, p = .006.

Third research question was as follow: Are there any associations between background variables and experience of realism, enjoyment, interest and simulator sickness? Realism, enjoyment, interest and simulator sickness had no associations with the background variables of age, experience in real world maritime (sailing, boating or similar) (years) and computer game experience ($p > .05$) .

Fourth research question was as follow: Did the ship simulator's storm and calm weather conditions have effect on experienced realism and simulator sickness? Calm and storm weather counter-balancing and experience of realism ($t(30) = .260$, $p = .797$) and as SSQ total score ($U = 101.0$, $z = -1.018$, $p = .309$) had no statistically significant associations.

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# APPENDIX 1 - EXPERIMENT PROCEDURE

## Stormwind Simulator – Experiment procedure

### 1) Before experiment

- Get people to fun and important research experience!
- Voluntary!
- Restart the game to a defined level (counterbalancing)
- Life jacket ready!

### 2) When participant(s) arrives in the simulator - Instructions:

- NOTE: reevaluate the experiment if mobile phone rings or if there is a distraction (e.g. conversation)
- Short overview of the purpose of the experiment:
    - "The purpose of the research is to study people's opinions and feelings when using the simulator."
- SCENARIOS (NOTE: counterbalancing!):
    - "You will be first sailing in a beautiful weather near Suomenlinna (old maritime fortress) for 2.5 min.
    - Second round will be sailing in the Porkkalanselkä (west from Helsinki) in a storm for 2.5 min"
- "There is a short questionnaire with FOUR questions to be answered after the simulation."
- "The research is completely anonymous and individual people cannot be identified from the reported results."
- "You can stop the experiment and leave anytime you want."

### 3) At the end

- Return the questionnaire!
- Thank and present A-Sanomat
- Note down if any problems.
- Good job! ☺

# APPENDIX 2 - QUESTIONNAIRE

**Please answer the following FOUR questions.**

**1. Background information**

a) Gender: Female Male b) Age: ______ c) Nationality: ____________________

d) Have you ever played a similar boat simulator?

| Never | Once or twice | Less than 10 times | More than 10 times |
|---|---|---|---|

e) Experience in real world maritime (sailing, boating or similar) (years): ______

f) Profession

| | |
|---|---|
| a) Researcher<br>b) Decision-maker<br>c) Delegate of NGOs<br>(non-governmental organisation)<br>d) Representative of related businesses | e) Official (government institution)<br>f) Student<br>g) Journalist / Media<br>h) Exhibition Visitor / Stand Personel<br>i) Other ____________________ |

**2. Simulator Sickness Questionnaire - Please circle how much each symptom below is affecting you right now.**

| | | | | |
|---|---|---|---|---|
| 1) General discomfort | None | Slight | Moderate | Severe |
| 2) Fatigue | None | Slight | Moderate | Severe |
| 3) Headache | None | Slight | Moderate | Severe |
| 4) Eyestrain | None | Slight | Moderate | Severe |
| 5) Difficulty focusing | None | Slight | Moderate | Severe |
| 6) Increased salivation | None | Slight | Moderate | Severe |
| 7) Sweating | None | Slight | Moderate | Severe |
| 8) Nausea | None | Slight | Moderate | Severe |
| 9) Difficulty concentrating | None | Slight | Moderate | Severe |
| 10) Fullness of the head | None | Slight | Moderate | Severe |
| 11) Blurred vision | None | Slight | Moderate | Severe |
| 12) Dizziness with eyes open | None | Slight | Moderate | Severe |
| 13) Dizziness with eyes closed | None | Slight | Moderate | Severe |
| 14) Vertigo | None | Slight | Moderate | Severe |
| 15) Stomach awareness | None | Slight | Moderate | Severe |
| 16) Burbing | None | Slight | Moderate | Severe |

**3. I play computer games**

| Never | A few times a year | A few times a month | A few times a week | Almost every day |
|---|---|---|---|---|

**4. Please evaluate and comment the following statements.**

a) I felt like being in a real boat.

Strongly Disagree — Disagree — Neutral — Agree — Strongly Agree

b) I enjoyed the experience.

Strongly Disagree — Disagree — Neutral — Agree — Strongly Agree

c) Transport and ship simulator games (such as Stormwind) help me to understand and practice real world situations.

Strongly Disagree — Disagree — Neutral — Agree — Strongly Agree

d) The fact that the simulator is based on a real world setting (with existing maps and landscape) improved the experience.

Strongly Disagree — Disagree — Neutral — Agree — Strongly Agree

e) The simulator enhanced my interest for Finnish transport and mobility.

Strongly Disagree — Disagree — Neutral — Agree — Strongly Agree

f) Steering the simulator made me more interested in travelling Finnish waterways.

Strongly Disagree — Disagree — Neutral — Agree — Strongly Agree

The participants cannot be identified from the reported results. Please contact us if you have further questions.

Thank you for participating and have a nice summer!