Eindhoven University of Technology

HTI Design Track A

Course project report

Stabilight

Using intelligent lighting against motion sickness

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Preface

Could interactive light help to negate motion sickness effects? In this two month project we investigated the issue with the main focus on sea sickness in the context of cabins on board of a ship. This document reports on the methodology employed, analyses and results. We discuss the potential of interactive light in this area and outline the requirements for such appliances. This project is supervised by and performed within the Human-Technology Interaction sub department, aiming to investigate the relation between human experiences and technology. The project was initiated by OPENLIGHT, the program line of the Intelligent Lighting Institute which investigates innovative light concepts from both societal and technological perspectives.

We would like to thank our supervisors, Wijnand Ijsselsteijn and Yvonne de Kort, and Rombout Frieling and Tim Ebbers of OPENLIGHT, Jelte Bos of TNO for his expertise, and the people at Stena Line and DFDS Seaways for the opportunity to spend time there and to learn from their views, and finally all participants in the interviews and experiments.

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Summary

This HTI Design Track A report investigates one particular role that dynamic and intelligent application of lighting can take towards improving human experiences, namely the reduction of nauseous feelings people may experience onboard large vessels. This project has taken a first step towards answering the question how intelligent lighting could help to negate perceptual conflict effects. Although the idea can be translated to various other ways of using lighting it was decided using a projection on a surface inside a windowless cabin is the most valuable way to investigate the issue. The rationale is that due to the sense of movement but lack of congruent visual stimuli (as there is no outside view) motion sickness is prevalent. Several research methodologies have been employed:

- Literature study and expert interview to review the scientific state of the art.
- Focus group interview with people to reveal personal experiences and implications of motion sickness for those who are sensitive to motion sickness.
- Experiment using a simple motion simulator to gather qualitative feedback on a mid-fi prototype.
- Interviews at two ferry companies to integrate their experiences and perspectives.

Based on the scientific evidence found it can be concluded that there is support for the general idea of using dynamic lighting to negate motion sickness in closed environments. Because this conclusion already answers whether lighting can help this project has taken a more explorative direction towards understanding human attitudes towards motion sickness. From the interviews and tests performed it emerges that personal experiences are more diverse than may commonly be assumed, plus motion sickness can pose clear practical and social limitations for those who suffer. Viewing a projected sea vista or looking outside through a window may have negative effects due to the apparent realization that one is at sea and susceptible to seasickness. This finding is contradictory to scientific evidence and therefore surprising. It illustrates the value one should give to experiential measures for a (partially) subjective experience such as motion sickness.

The initial focus of this project on a dynamic lighting solution within an windowless cabin may have merit but less so than originally expected. When people do get sick the cabins are seen as part of the solution by ferry employees and not, as assumed, part of the problem. It is therefore suggested to reconsider the focus from cabins to public spaces onboard where people actually spend most of their time. We suggest that a field test is performed to assess the true merit of the Stabilight concept in an appropriate context. A gap in the current knowledge is how ferry passengers actually experience the trip and how they value the impact of motion sickness. We recommend that this important knowledge is taken into account during future projects to cross-validate our findings. The findings so far have resulted in a separate requirements document laying out the necessities for future designs.

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1. Introduction

This report investigates one particular role that dynamic and intelligent application of lighting can take towards improving human experiences, namely the reduction of nauseous feelings people may experience onboard large vessels. Such motion sickness can seriously reduce an otherwise pleasant trip. According to personal communication with ferry staff members about one in every twenty passengers experience seasickness, although this number can vary due to the weather and the type of vessel. Even among experienced seafaring crews motion sickness can hinder the ability to perform. While such loss of performance due to motion sickness is the topic of a wide range of scientific investigation, most of it focuses on quantifiable human factors such as task performance (e.g. in military settings). This project investigates motion sickness from the perspective of human wellbeing.

In general motion sickness can be described as a perceptual conflict. In a cabin onboard a ship people may feel motion but they do not see this apparent movement. The two perceptual sources are in conflict, giving rise to a situation which needs be resolved in order to make sense of the world. A possible interpretation for our brains is to conclude that one of the senses is at fault compared to the 'right' reference percept. In return this faulty sensory behavior could be interpreted as a result of bad ingestion, such as intake of poisonous food. This evolutionary interpretation by Treisman (1977) provides a link with the nauseous sensations and one's desire to relieve the stomach.

Although a large part of the population is susceptible to motion sickness, there is variation in the effects individuals may experience. Reasons for this may relate to coping abilities and personal experience (a.o. Benson, in Pandoff & Burr, 2002). The relation between coping ability, experience and nausea proneness suggests that motion sickness is a subjective experience rather than a purely biological issue. This means that alternatives to a purely medical approach could also be effective. The idea that this experience is subjective means there could be opportunities to ameliorate the experience by using dynamic lighting.

1.1 The Stabilight project

This project, named Stabilight, has been initiated by OPENLIGHT, the design-driven program line of the Intelligent Lighting Institute (ILI) of this university. This specific project is performed within the Human-Technology Interaction sub department, linked to ILI. The overall project goal is to investigate the use of dynamic, intelligent lighting to negate motion sickness effects. This in turn is expected to reduce negative experiences of people suffering from motion-induced nausea. Finding such applications for interactive, intelligent lighting can potentially widen the application of lighting beyond illumination.

1.1.1 This project

Within this HTI Design Track A project a first start has been made towards investigating the current experience with motion sickness. Seasickness is one of the most salient cases of motion sickness and was therefore chosen as the scene for this endeavor into positive experiential capabilities of interactive light. Specifically, this project has focused on motion sickness aboard large vessels in which people are able to retreat into cabins for the night. The rationale is that due to the sense of movement but lack of congruent visual stimuli (as there may be no outside view from inboard cabins) motion sickness is prevalent.

This project has taken a first step towards answering the main question: How could intelligent lighting help to negate perceptual conflict effects? The objective of this project is to explore the possibility of using dynamic light to reduce seasickness and to develop a requirement document for future designs. To reach this goal, we must be able to answer two questions:

Can dynamic lighting help to reduce motion sickness?

&

What are important aspects when transferring this technology into a successful design?

For the first question we must obtain sufficient knowledge about the cause of motion sickness, human perception, induced motion and the effect of lighting on perception and experience. The second question mainly concerns human behavior, experience and context.

1.1.2 Approach

Table 1 represents all research questions derived from the two main questions and approaches used to answer these questions. Several approaches to solve these questions were proposed, including literature research, expert interviews, user focus groups, interviews in context and prototype testing. Each method answered multiple questions and, where possible, served as input for other methods. For instance, what we learn from literature research and interviews has informed the design of prototype testing.

Table 1. Research Questions and Methodology

	Methods to answer the questions				
Research Questions	**Literature Research**	**Expert Interview**	**Focus Group**	**Interviews in Context**	**Prototype Testing**
Can dynamic lighting help to reduce motion sickness?					
What causes motion sickness?	●	●			
For which occasions does motion sickness pose a problem?	●		●	●	
What are common solutions and are these effective?	●	●	●	●	
What type of visual stimulus is most effective in reducing the perceptual conflict?	●	●			●

How can we build a realistic simulation?	●	●			
What kind of visual stimulus would be optimal?	●	●		●	●
How to transfer the technology to a product?					
Who are typical passengers on ferries?	●			●	
Who do not travel by ship due to seasickness?	●			●	
What do people want to do in a cabin?			●	●	
How does seasickness influence behavior on ships?			●	●	
How does a ferry company currently deal with motion sickness effects?				●	
Are (percepts of) all degrees of freedom of a ship equally relevant for motion sickness effects?	●	●			
What kind of technology can be used to make artificial lighting work? (includes measurement of motion)	●	●			
How can we install the product in the cabin?				●	
What does a ferry company desire from such a product?				●	
What control should a user have regarding such a product?			●	●	●

1.2 Report structure

This process report is divided into 6 sections. Every section will focus on one method employed during the project. Per section the objectives, method, analysis and results will be covered. Section 2 discusses a review of current scientific insights, both from literature and an expert interview. Section 3 deals with a focus group. Then, section 4 elaborates on a qualitative prototype evaluation. In section 5 insights on the business perspective, applicability and relevance are covered based on our visits to two ferry companies. Following these separate results, conclusions are drawn and recommendations are given for future endeavors. We end with a discussion on the potential of interactive light for application on vessels and related areas.

In a separate report requirements are described towards interactive light appliances aiming to reduce motion sickness effects. These requirements are based on the research and conclusions found in this report. In accordance with the instructions, given these requirements have not been reworked for this second version of the reporting.

2. Literature & Expert Review

2.1 Introduction

The aim of the project is to investigate the possibility of using interactive light as a means to prevent people from seasickness. The first step is to establish the current state of the art. Knowledge was sought from the following domains:

1. Motion sickness
2. Visual motion perception
3. Ship motion in relation to seasickness
4. Effect of lighting on human factors
5. Effect of visual reference on human perception

Next to reviewing literature, we interviewed dr. Jelte Bos, an expert in the field of motion sickness, to learn from his perspective on the state of the art. He is currently the lead scientist at TNO Human Factors Research Institute, regarding their man and ship motion research and has been active in the field of human perception and performance in relation to vessel motion in recent years. From the interview, valuable knowledge as well as additional literature has been gained (cf. appendix 1 for details on the interview). Knowledge gained from the expert interview and literature will be integrated in the relevant sections of this chapter.

Overall, we intend to fulfill three objectives through literature research and expert interview: (1) explore the phenomenon of motion sickness and its contributing factors; (2) validate evidence for and against the use of lighting as a solution; and (3) determine how human factors, perception and experience can influence the potential of such application. Specifically this chapter tries to answer the following questions:

1. What is motion sickness and what causes it?
2. What are the characteristics of seasickness?
3. What are common solutions for motion sickness?
4. What are personal factors that influence the susceptibility to motion sickness?
5. How does motion perception work?
6. What kind of ship motion is most provocative to seasickness?
7. What are the different effects of central and peripheral vision stimuli?
8. What is the effect of lighting on human factors?
9. What is the effect of visual reference?
10. Are there any proven applications of using interactive light as a reference to prevent people from seasickness?

2.2 Motion sickness

2.2.1 The nature and scope of motion sickness

Almost everyone has some experience with motion sickness, perhaps when traveling by bus, by ship, when taking the elevator or when playing computer games (Benson, 2002). But what is the nature of motion sickness? The short answer to this question is that motion sickness is not a disease but rather a functional disorder. In 1975 Reason and Brand proposed a clear answer to this question, describing motion sickness as a neural mismatch. Hill refers to it as being "a normal response to an abnormal situation" (1936, cited by Reason & Brand, 1975, p. 28). Namely, motion sickness is a functional disorder of the intact, healthy individual (Reason & Brand, 1975). In fact, if a person cannot get motion sick, she may have a dysfunctional vestibular system. By these definitions, medical or age related causes of nausea and balance problems are not within the scope of motion sickness (Reason & Brand, 1975).

2.2.2 Theories explaining motion sickness

2.2.2.1 Sensory conflict theory

Reason and Brand (1975) suggested the sensory conflict theory (also known as sensory rearrangement theory or neural conflict theory) to be the most satisfactory explanation for motion sickness. According to this theory, in every condition of motion sickness, there is a sensory rearrangement – the information received by one set of receptors is systematically incompatible with that received by functionally related receptors (e.g. information received by visual receptors and vestibular receptors). Because of this sensory rearrangement, there is a conflict between the total pattern of sensory input and the pattern expected on the basis of past experience and that's what causes motion sickness. The rearrangement can happen between visual and vestibular signals and within the vestibular system, that is between canal and otolith signals (i.e., the two organs in the inner ears responding to translation and rotation respectively). According to this view motion sickness can be subsumed under two headings: (1) visual (A) – inertial (B) rearrangement; (2) canal (A) – otolith (B) rearrangement. Within the two headings, three different types can also be distinguished: Type I stands for the situation that both A and B system sense motion but in an incompatible way; Type II stands for the situation that system A senses motion but B doesn't; Type III stands for the situation that only system B senses motion. The classification of motion sickness and typical instances for each type are presented in Table 2 (The two instances in bold are concerning seasickness, which will be fully discussed in Section 2.3).

Table 2. Classification of motion sickness

	Visual (A) - Inertial (B)	Canal (A) - Otolith (B)
Type I (A and B)	**1. Watching waves over the side of a ship** 2. Looking out of the side or rear window of a moving vehicle 3. Making head movements while wearing some optical device that distorts vision	1. Head movements made about some axis other than that of bodily rotation-cross-coupled angular accelerations 2. Low frequency oscillations: between 0.1-0.3 Hz

	Visual (A) - Inertial (B)	Canal (A) - Otolith (B)
Type II (A, not B)	1. "Cinema sickness" 2. Operating a fixed-base vehicle simulator with a moving visual display - "simulator sickness" 3. "Haunted-Swing" type of fairground device	1. Weightless flight - "space sickness" 2. Calorific stimulation of the outer ear. 3. Positional alcoholic nystagmus associated with alcohol and heavy water
Type III (B, not A)	1. Reading a map in moving vehicle **2. Riding in a vehicle without external visual reference** 3. Being swung in an enclosed cabin	1. Rotation about an Earth-horizontal axis 2. Any rotation about an off-vertical axis 3. Counter-rotation

(This table is adopted from the book Motion Sickness (1975) by Reason and Brand, p. 106)

The sensory rearrangement theory provided a comprehensive view of motion sickness and it is still the most popular theory for motion sickness today (according to Bos, personal interview). However, it lacks specific criteria for when and how conflicts will happen. For this reason there are various later theories that try to specify the classical theory. Two important theories are discussed in the following sections.

2.2.2.2 Subjective vertical-conflict theory

Subjective Vertical-conflict (SV-conflict) theory was introduced by a group of researchers of TNO (Bles, Bles & Groen, 1998; Bos et al., 2008). According to this theory, only when people’s subjective perception of what is vertical (i.e., the internal representation of gravity) is at stake, they will experience motion sickness. For example, when the participant stays upright, roll and pitch are the most provocative movements, but yaw is not. If the participant changes their poison to lay flat on their back, yaw and pitch head movements are provocative but roll is not (for the explanations of terms about ship motion, see Section 2.4).

The SV-conflict theory can be further explained in a mathematic model of motion sickness model (see Fig. 1), which was proposed by Oman (1982) and refined by Bos and his colleagues (Bles et al., 1998; Bos et al., 2008). Basically, this model describes how humans control their body motion and which part in this process is associated with motion sickness. In the model, $\mathbf{u}_d$ stands for a desired body state. It enters a preparatory phrase (P) and directs a controller (C) that generates motor commands (m) that subsequently drive our body to achieve the desire. When there is an external perturbation ($\mathbf{u}_e$), the actual body state (**u)** will be sensed by visual (vis), vestibular (vest) and somatic (som) sensors. With the subsequent processing by central neural system, this results in afferent signals representing the state of the body ($\mathbf{u}_s$).Besides this single path, there is an internal model based on previous experience, comprising a copy of the primary path (B’, som’, vis’, vest’ LP’). If the body state ($\mathbf{u}_s$’) expected by the internal model is different with the one sensed ($\mathbf{u}_s$), there will be a multi-dimensional conflict $\mathbf{c} = \mathbf{u}_s - \mathbf{u}_s'$.

When looking at the SV-conflict theory in more detail, it is centrally about the conflict between the internal representation of the body’s state (based on previous experiences) and the actually senses body state. According to SV-conflict theory, the gravity (vertical) component of the so-called multi-dimensional body state conflict **c** correlates with motion sickness. It is argued by Bles and colleagues (2008) that the SV-conflict theory fits experiment data better than the original sensory conflict theory.

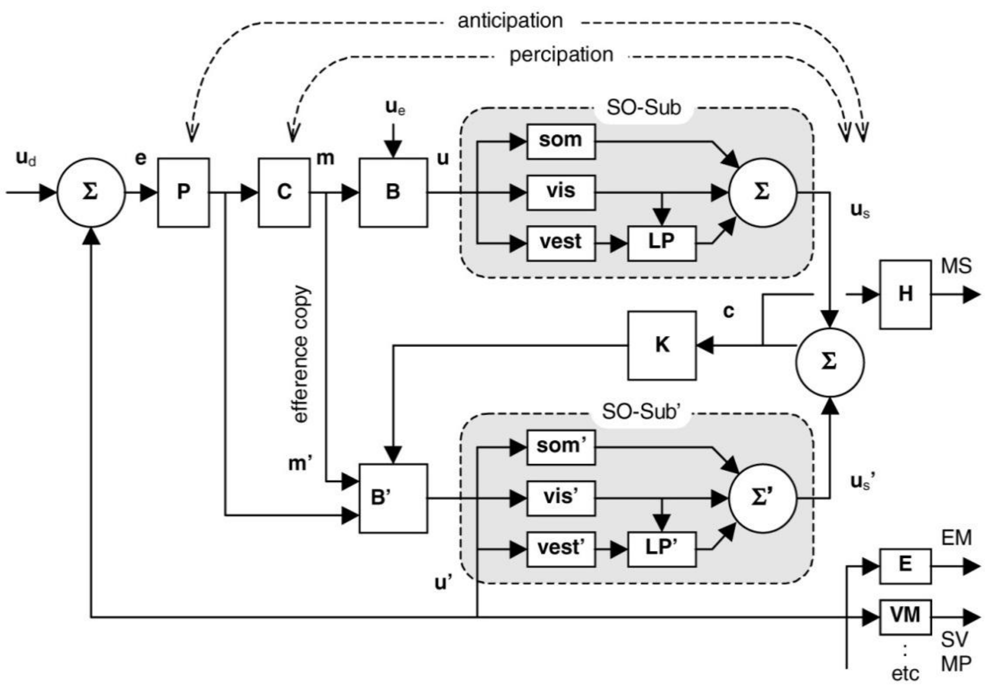


Figure 1. The internal model of motion sickness, adopted from Bos et al. (2008), p. 49

2.2.2.3 Rest frame hypothesis

Prothero and Parker (in Hettinger et al. (2003)) argue that human perception of environmental movement and self-motion can be described by a rest frame hypothesis. This theory states that one “particular reference frame, the ‘rest frame,’ is selected as the comparator for spatial judgments. When a strong enough reference frame can be provided that is in accordance with inertial orientation and motion cues, the onset and magnitude of motion sickness can be reduced. Providing stronger perceptual evidence for (non-)motion cues reduces internal conflict as the incongruent information can be given less weight, thus having a clear winner in terms of what is stationary.

The rest frame hypothesis is based on the premise that human perception selects certain things as being stationary to minimize the efforts of finding a reference for integrating sensory information (Prothero & Parker, 2003). This means that when an environment is considered stationary visual motion stimuli of this environment are interpreted as caused by self-motion, e.g. when cycling the visual stimuli ahead seem to move towards the cyclist which leads her to the conclusion that she is actually moving forward herself. Because the ground (i.e. the surface behind all other surfaces and objects) provides reliable stationary cues the brain attaches a large weight to such a visual background. The visible sea and horizon through a window on a ship provide such a strong anchor of what is stationary. Removal or replacement of such background stimulus can have profound effects on ability to assess the correct frame of reference and it can lead to motion sickness if someone is unable to pick the right frame of reference (Prothero & Parker, 2003).

Prothero and Parker relate this rest frame hypothesis to virtual environments and presence research (i.e. the study of what constitutes the experience of being in a certain state or environment) by reasoning that actively experiencing the presence of an artificial visual stimulus - such as a virtual environment - makes it more likely such stimulus is able to overrule incongruent perceptual motion cues (e.g. people are less aware of the real world situation). Imperfections in the simulation such as lag and a general mismatch of perceptual stimuli and / or expectations could induce motion sickness. Such mismatch effects imply that motion sickness results “not from conflicting motion cues but rather from conflicting rest frames implied by those cues” (p.53). Again, the introduction of a stable reference frame or removal of conflicting frames should improve matters as shown by Prothero and Parker (2003).

2.2.3 Seasickness and other typical instances

The above sections deal with motion sickness in general. Here the focus is on characteristics of seasickness, which is the focus of the project. The reason to mention other instances of motion sickness is their relevance to other methods, e.g. group interviews and prototype evaluation.

2.2.3.1 Seasickness

A distinctive element of seasickness, compared to other types of motion sickness, is that journeys at sea often take a long time while a person suffering cannot stop or evade the cause. This fact makes seasickness the most problematic type of motion sickness and the one that attracts the most interests in the field. However, the severity of seasickness can vary widely between individuals, from slightly uncomfortable to a state of desperation and helplessness (Benson, in Pandoff & Burr, 2002). Generally, nausea, vomiting, pallor and cold sweat are the four most typical symptoms of motion sickness according to a review by Benson (2002). Besides the previously mentioned symptoms, a person suffering can also experience sighing, yawning, hyperventilating, flatulence, headache and social indifference. Indirect dangerous effects of seasickness are an increased risk of drowning when in the water and a loss of body weight due to vomiting and reduced appetite.

In terms of causes, there are two types of seasickness, corresponding to Visual (A) - Inertial (B)/Type I and Visual (A) - Inertial (B)/Type III in Table 2. The former situation is when people stand on a pitching vessel and look down. Because motion of the boat does not correlate to the random motion of waves, people can get sick. It has been suggested that the only way in which the visual and inertial inputs can be made to match up aboard a ship is when the passenger is able to fixate on the horizon or some visible landfall (Reason & Brand, 1975). This provides a stationary reference point against which the perceived motions of the whole body can be accurately and synchronously compared. This is in line with the rest frame hypothesis (Prothero & Parker, 2003).

The focus of the project is the latter situation - when a person stays in the cabin or another enclosed space without windows. In such cases the visual field is stationary but the vestibular system senses motion. This conflict induces seasickness. Birren (1949) has suggested that the presence of some form of artificial horizon may be effective in reducing symptoms when any external visual reference is absent. However, from the view of SV-conflict theory, only when the determination of the subjective vertical, the internal representation of gravity, is challenged, seasickness could follow. The common experience that sight of the horizon reduces sea sickness is most likely due to the fact that seeing the horizon helps to keep the sensed and subjective verticals aligned (Bles et al., 1998).

There is a recent study on the effect of vision on the second type of seasickness (Bos, Mackinnon & Patterson, 2005). Three different conditions were tested: an earth-fixed outside view, and inside view that moved with participants, and with no view (blindfolded condition). The results revealed that the level of sickness was highest in the inside view condition, intermediate in the outside condition, and least in the blindfolded condition. However, the severity of sickness in the blindfolded condition was equal to inside view condition during the first 5-10 min of the test. This research clearly proved that a lack of visual cues of motion is the cause of seasickness for people suffering inside a cabin.

2.2.3.2 Other typical instances of motion sickness

Motion sickness is prevalent in more situations than just out on the sea: carsickness, aerial sickness, space motion sickness, cyber-sickness, rollercoaster-induced sickness and skyscraper sickness form a non-exhaustive list of situations where motion sickness can play a role. Among these the causes of carsickness and aerial sickness are similar to seasickness. A common characteristic is that passengers in these three situations all stay in an enclosed space – they cannot see the motion but can still feel it. Since the causes are the same it is meaningful to talk about these experiences during the focus group.

2.2.4 Human susceptibility to motion sickness

Theoretically speaking, everyone with a healthy vestibular system is susceptible to motion sickness, but the severity of this problem can differ much from person to person. Appreciating this individual difference is also important for recruiting the right participants for focus groups and explorative experiment. Most literature focuses on differences due to age and sex but the susceptibility is also related to personality (extraversion vs. introversion), perceptual style (field-dependent vs. field-independent) (Reason & Brand, 1975) and orientation capabilities (Huizinga et al., 2007).

2.2.4.1 Age effect

Studies have revealed a clear age effect. Reason and Brand (1975) discuss this at length. Infants below two years of age are immune to motion sickness because they have not yet learned the natural arrangement of sensory information. Susceptibility appears to be at its highest level around the age of ten to twenty years. After this age there is a noticeable decline of susceptibility as resistance to motion sickness increases due to protective adaptation and also because of reduced activity of the sensory transduction mechanism. A recent research by Bos and his colleagues in TNO also confirmed this trend of age. (Bos et al., 2007) However, according to Bos, if the situation to be considered is unnatural, such as computer games or simulators, elderly people can suffer more (Bos, personal interview).

2.2.4.2 Gender effect

Women are more susceptible to motion sickness than men across all age groups. The most likely explanation points to the functioning of the female endocrine system (Reason & Brand, 1975). A recent study by Bos and colleagues replicates the effects mentioned, indicating a predicted illness rating by females of at most 60% higher than the ratings of males (Bos et al., 2007). Rise and fall of predicted illness ratings as a function of age illustrates females are most sensitive at a younger age (± 11 vs. ± 22 for males) and face a more rapid decline (though never getting below male ratings). However, it may be the case that physically both genders are equally susceptible to motion sickness, but females are more open to express their feelings than males (Bos, Mackinnon & Patterson, 2005).

2.2.5 Known solutions for motion sickness

In this section existing solutions to motion sickness are discussed. These solutions can be divided into two basic categories: medical solutions and non-medical solutions. The medical solutions are all similar in scope. Similar to painkillers these medicines work by suppressing relevant neurotransmitters and hereby reducing the symptoms of seasickness.

Similar to medication, food is often mentioned as both a cause and relief. There is quite some folk wisdom concerning food. Some foods are said to work quite well against motion sickness, although many of them lack scientific support (e.g. studies on ginger are inconclusive, Ernst & Pittler (2000) find no difference in effect from a placebo). The non-medical solutions can be divided into two categories: experience and adaptation, or environmental solutions.

2.2.5.1 Experience and adaptation

Coping abilities differ between individuals and are lower for people that worry or anticipate motion sickness. Therapy can help to alleviate the effects and potentially reduce sickness to such extent that normal behavior such as performing work is no longer impossible. In addition, better knowledge of how the human body behaves in certain circumstances can help coping abilities. Training can reduce the effects for people to negligible proportions, indicating that there is potential for non-medical solutions. Biofeedback can also be used to improve coping abilities by aiming at making people aware of their breathing (similar to relaxation techniques), skin temperature and muscle tension. Another beneficial method is to avoid tasks involving prolonged visual search (e.g., reading a map or book) and direct the visual attention to a stable orientation reference such a distant point on the road ahead or the horizon at sea (Benson, 2002).

Most of the time however nature provides its own solution: adaptation. A constant exposure to the stimuli causing motion sickness can help to reduce the sickness. For instance, pilots are usually exposed to a desensitization therapy which "typically involves a ground-based phase with twice-daily exposure to provocative, cross-coupled (Coriolis) stimulation of progressively increasing intensity" (Benson, 2002). Bos also confirmed that people are generally able to adapt (personal interview). The adaptation will take at least six hours, but it could take as long as several days. Most people do not experience serious problems after three days of exposure. There is only a very small percentage of people who continue to suffer from sickness after several days of stimulation.

2.2.5.2 Environmental solutions

One of the most effective external solutions is to optimize the design of a vessel's hull. Design choices can influence the response of a vessel to different sea states and the amplitude of motion. This is especially important in the critical 0.1 - 0.3 Hz frequency band in which humans are mostly susceptible to seasickness" (Benson, 2002). Stabilizers, if installed, can also counter provocative movements of the vessel. The latter solution may be installed for passenger comfort as well as for keeping the cargo stable (Stena Line, personal communication).

Other solutions that have received scientific or commercial interests are stroboscopic viewing through active shutter glasses (Webb et al., 2009, Rescke, Somers & Ford, 2006) and elasticized wrist bands (Benson, 2002). For the former, although the authors remark that objective measurements are as yet inconclusive, subjective measurements do show positive effects. Understanding the reason why stroboscopic viewing might work relates to human motion perception, the next topic of this chapter. For the latter, the wristband, the positive effects are scientifically dubious and are better regarded as a placebo effect.

2.3 Motion perception

Since motion sickness is related to visual perception, vestibular perception and proprioception, a basic knowledge in these fields is required. Because the solution discussed in this project is about visual stimuli, the focus in this section is on perceptual phenomena of the visual system: central and peripheral vision, and visual motion perception. Other perceptual systems are not covered here (cf. Mather (2009) for a detailed discussion).

2.3.1 Central and peripheral effect on motion perception

Movement in the visual field can be perceived as caused by a stationary position of the self in a moving environment called egocentric motion perception, and as self-motion in a stable environment called exocentric motion perception. Whether egocentric or exocentric motion is perceived depends on the location of the motion in the visual field (Brandt, Dichgans, & Koenig, 1973). If the perceived motion is located in the central part of the visual field, it will be perceived as egocentric motion. This effect holds for motion seen in up to 30° of the centre of the visual field (Brandt, Dichgans, & Koenig, 1973). On the other hand, motion in a peripheral part of the visual field or in a combination of the central and peripheral visual field (more than 30° of the centre) leads to the perception of exocentric movement. In addition, rotating motion of the stimulus leads the perception of circular vection (perceived self-rotation) according to Brandt, Dichgans and Koenig (1973).

2.3.2 Visual motion perception

This project concerns visual presentation of motion (i.e. representing motion relative to a stable reference). In order to detect motion the human visual system uses neural motion detectors. These motion detectors are "direction selective," that is, they perform best for one direction. However, each single neural motion detector can only response to a small portion of the image because of the restricted receptive area. A second stage of processing is involved to integrate all the local responses, so humans are able to perceive meaningful motions. (cf. Mather (2009) for a detailed discussion).

One important phenomenon associated with motion perception is the "motion after effect" (Mather, 2009). After viewing a moving image for some time subsequently viewed images appear to briefly move in the opposite direction. This motion adaptation effect lasts about 15 seconds, but lengthy adaptation may result in effects that can last many hours.

2.4 Ship motion

2.4.1 Classification of ship movement

Understanding of ship motion is important both for understanding the causes of seasickness and for making a suitable motion simulator for an explorative experiment (as detailed in chapter 4). Like any physical object a ship's movement can be described with six degrees of freedom, which can be divided in two types: translation and rotation movements. There are three sub-types of translation according to their direction: heave (moving in and out of the water), sway (moving to the left and right in the water) and surge (moving forwards and backwards in the water). There are also three sub-types of rotation according to the rotating axes: yaw (moving around the vertical axis), pitch (moving around the abeam axis) and roll (moving around the longitudinal axis of the boot). All types are illustrated in Figure 2.

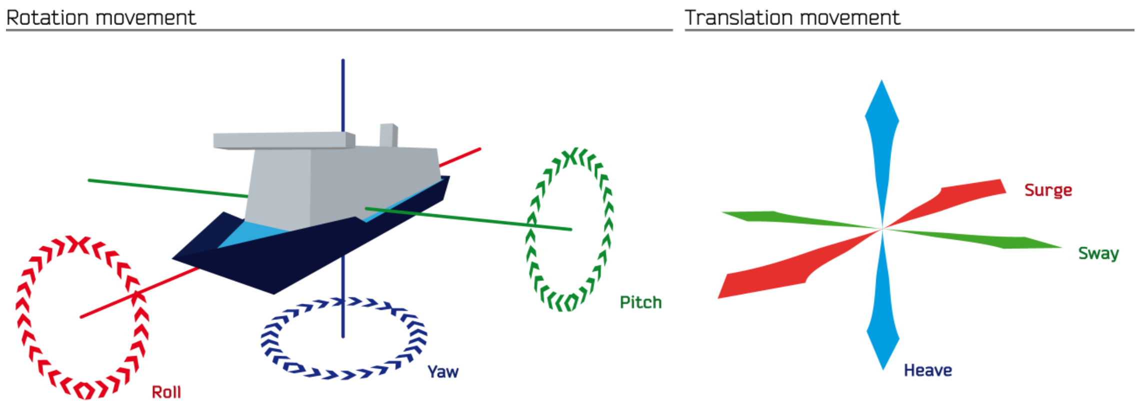


Figure 2. Six degrees of freedom of the ship motion

2.4.2 Consideration of degrees of freedom and frequency

What is important to mention is that motion sickness induced on a floating vessel indeed requires consideration of all degrees of freedom (compared to e.g. a car which usually does not move or rotate considerably besides the forward movement). Among those, vertical motion (heave) is the most provocative to seasickness and when it's integrated with lateral motion and angular motion (rotation), the problem becomes more complex and severe (Bos, personal interview). Besides this, the actual movements of a ship and the intensity of the movements depend on the direction of the ship relative to the wind direction and the state of the sea (e.g. waves) (Stena Line captain, personal communication).

In addition, the provocativeness of motion is also related to the frequency of motion. Based on recent studies (Bos, Bles & Groen, 2008; Benson, 2002) it appears that the peak of provocativeness is around 0.1 - 0.2 Hz while both very low and very high frequencies do not make people sick.

2.5 Effects of light

When using interactive light to help people suffering from seasickness, it is also important to consider the effects of light on the users. If being applied improperly light itself can negative effects users' well-being. On the contrary, it is also possible to make the interactive light comfortable and enjoyable to use, adding value to the solution. In order to achieve this, emphasis is paid to the human factors of light.

Light can be seen as multiple interrelated variables that have varying effects on humans. Light can have a direct effect on appraisal, visual comfort, and visual capabilities, and by these variables it indirectly affects task performance, motivation, mood, health and wellbeing (Veitch et al., 2008). Light can also have indirect effects through associations caused by variables like intensity, color, temperature (Metha & Zhu, 2009), localization, direction and association of light. Furthermore, knowledge about the light source, and perceived control affects preference (Boyce et al., 2006). Finally, each variable interacts with the context of use, and therefore the context needs be taken into account. This section will discuss relevant literature regarding light for use in a cabin.

2.5.1 Visibility

The visibility of a light such as the artificial horizon depends on its luminance and size, amongst others. Luminance is about the relation between the light and lighting levels of its environment (in this case the cabin on a ship). In photopic conditions the relation between the minimum luminance of the horizon (Lh) and the luminance of the background (Lb) is determined by Weber's law ((Lh-Lb)/Lb = k, where k is a constant) (Boyce, 2003).

For the size, there are several things should be considered. First, the required size for relatively small objects is negatively related to the background luminance. In addition, the required object size depends on the location on which it is viewed, that is central or peripheral (Boyce, 2003). Besides, perceived size of a projected element depends on the distance from the (projected) light. This means that the larger the distance the larger the size. However, this does not affect the required luminance intensity in relatively small areas like cabins.

2.5.2 Color associations

Different colors result in different associations. However the specific effects of certain colors are not straight forward, because such effects also depend on the context and individual differences. Because passengers on a ship use the cabin mainly to sleep in (Stena Line, personal communication) only the relaxation context is elaborated on in this section.

Light can influence a person's ability to relax. For instance, when trying to sleep a bright light can be very uncomfortable. The exact color of the light is also important to preference. Kaya and Epps (2004) found that in general principle colors are experienced as most positive. In their study the color green resulted in the most positive emotion and in "associations with nature and relaxation" (Kaya & Epps, 2004, p. 396). A result that is specifically interesting for this project is that the hue yellow-green was rated less positive and was associated with vomit and elicited feelings of sickness and disgust.

Besides the previous mentioned variables, there are also differences in preference related to age. Elderly people can experience blue light as more activating but less pleasant at the same time (Laufer et al., 2009). The actual age of the target population can therefore also influence the best color option.

2.5.3 Biological effects

Biological effects of light are, in contrast to association effects, dependent on the specific hue and intensity of the light. Specific cells in the retina called melanopsin retinal ganglion cells cause these biological effects. These cells are especially sensitive to bright bluish light (Holzman, 2010).

Generally, biological effects of light can be divided in acute and longer-term effects. The acute effects of bright light (such as sunlight) are a more alert state, a change in body temperature, a change of heart rate, and a decrease of melatonin and cortisol secretion (Holzman, 2010). In some conditions the alert state is preferred by people but in other conditions this is not (e.g. late at night people might not want to be active). On the other hand, exposure to bright light for a longer period of time results in a shift of the circadian rhythm (Holzman, 2010). Especially in situations where other time cues are unavailable (e.g., in a windowless cabin) this can result in a change of rhythm. The change can result in negative subjective experiences comparable to a jetlag.

Both acute and longer term effects are time-dependent. They occur more during nighttime because of the high level of melatonin. Although subjective responses to light are the same during the day, psychological responses caused by physiological factors, like heart rate, differ (Rüger et al., 2005).

2.6 Effects of visual reference

It is well-known that a horizon or an artificial horizon can reduce seasickness (Reason & Brand, 1975). In fact, a horizon is a special kind of visual reference which can help people to evaluate their direction and to keep their balance. This visual reference effect strongly relates to SV-conflict theory (Bles et al., 1998) and the rest frame hypothesis of Prothero and Parker (2003) already discussed earlier. This section will discuss the validity of artificial reference and reviews some factors that may influence the effectiveness of the application.

2.6.1 Validity of using lighting to reduce seasickness

A crucial goal of this project is proving whether the general idea of using artificial lighting could work. This section discusses convincing empirical support for the solution of interest. Bos and colleagues of TNO have performed studies on an application similar to the idea proposed in this project – investigating the effect of an artificial three-dimensional earth-fixed visual reference on seasickness (Houben & Bos, 2010). The reference was presented by a display of three-dimensional world of stars which moves in the opposite direction of the ship's motion. The stars were arranged in three distinguishable horizontal layers varying in distance to the observer to give a notion of one's orientation. The three dimensional representation was chosen because with a simple 2D line projection people cannot distinguish all relevant degrees of freedom of the ship, especially pitch and heave (Bos, personal interview). In the experiment, participants were sitting in a ship motion simulator and performing a task in three different conditions: without display, with display on the laptop or with display projected on the panoramic screen. The authors found a significant effect of the visual reference on reducing motion sickness, suggesting that it could be a promising solution for reduction of seasickness. Their results also revealed that there was no difference between the condition with laptop display and the condition with distant larger projection. This implies that the position of the projection is not crucial.

2.6.2 Factors that influence the visual reference

In order to make the artificial reference effective, there are some factors to considerate. Firstly, according to Fuentes and colleagues (2005), moving images with a significant amount of detail increase the intensity of motion sickness when compared with moving images with low detail. This study thus suggests that high spatial frequencies would deteriorate any beneficial effects of artificial dynamic lighting.

Secondly, it is also important that a vessel's motion is measured accurately and that this information is translated into movement of the artificial lighting in real time. Any considerable lag in keeping the lighting up-to-date could induce simulator sickness which would have adverse effects on a person's wellbeing (Duh, Parker & Furness, 2001). According to the US Federal Aviation Administration the time delay should be less than 150 ms (Frank et al., 1988) when a visual display follows system motion.

Thirdly, there is phenomenon called "rod-and-frame effect" that may influence people's perception of artificial reference. The judgment of tilt of a tilt line (the rod) is affected by the tilt of the main axis in the environment. Specifically, it is perceived as closer to one of the main axes than it is in reality (Di Lorenzo & Rock, 1982). In a slightly tilted cabin with no outside view, this implies that an artificial horizon will be perceived as closer to the horizontal axis of the cabin than it is in reality, giving room for some imperfections to occur without failure of the intended orientation effect.

2.7 Preliminary conclusions

Through literature research and an expert interview a comprehensive knowledge of motion sickness was gained. Motion sickness is a functional disorder caused by the conflict between sensed body state provided by visual, vestibular and somatosensory systems and the past experience, especially the conflict concerning the subjective gravity according to SV-conflict theory (Bles et al., 1998; Bos et al., 2008). Another recent theory explains the cause of motion sickness to be the inability to find a stationary frame (Prothero and Parker, 2003). There are age and sex effects on the susceptibility for motion sickness. The most susceptible age is between ten to twenty years old and women are more prone to the problem than men (Reason &Brand, 1975; Bos et al., 2007). Current solutions for motion sickness include both medical and non-medical methods. Non-medical solutions emphasize either on personal experience or environmental factors.

Seasickness is one of the most problematic instances of motion sickness. In this project the focus is on the seasickness experienced in the cabin when the information received by visual system is incompatible with the one received by vestibular system (Reason &Brand, 1975). All degrees of ship motion are related to seasickness, with heave to be the most provocative one (Jelte Bos, personal interview). The most provocative frequency of the ship motion is between 0.1-0.2 Hz (Bos et al., 2007). The well-known idea that artificial horizon can help people suffering seasickness (also the idea of this project) was proved to be true by Houben and Bos

(2010). Their experiment revealed that 3D earth-fixed visual reference can reduce seasickness. Thus the experiment and the focus groups discussed next in this report are more of a subjective assessment than an attempt to prove the concept

In addition, relevant human factors that may influence the effectiveness of the visual reference were examined in literature research. Factors we need to consider for the application includes central and peripheral vision, motion after effects, visibility, color association and biological effects of light, image detail, translation delay and the rod-and-frame effect. The most important implication is that the visual representation of the system should be a three-dimensional representation which moves synchronously (delay less than 150 ms) to the ship motion and covers more than 30° of the central visual field. More requirements derived from these factors can be found in the requirements document.

3. Focus Groups

3.1 Introduction

For a complete understanding of the effects of motion sickness on human behavior, it is important to explore which topics are influential to the experience of motion sickness. Because of time constraints of the project and the need for rich qualitative data, the focus group interviewing method was most suitable to gather this information.

It is of utmost importance to the project to know how people currently deal with the problem of motion sickness, what their attitude is towards traveling by ship, and what the role of seasickness is on their attitude toward this form of traveling. In addition, the focus group can be used to explore preliminary attitudes to the use of the artificial horizon in cabins onboard ships.

It was planned to do two focus groups but practical concerns limited the study to one focus group. This single focus group already resulted in a multitude of insights beyond what could be explored in the analysis. The analysis elaborates on the most relevant insights regarding the project focus.

3.2 Objective

The focus group was aimed to yield rich information about attitudes and perceptions that includes desires, motivations, values, and firsthand experiences of a sample of people who are experienced with motion sickness. The main questions in the focus group that were used to gather this information are:

Attitudes towards motion sickness

1. Which circumstances and conditions result in experiences of sickness?
2. What are experiences and attitudes toward motion sickness during traveling?
3. To what extent is motion sickness seen as a serious problem?

Problems and solutions related to motion sickness

4. In which situations is motion sickness a problem? How is it dealt with?
5. How do experienced people deal with seasickness?

Behavior effects of motion sickness

6. Is anyone not using a ship due to motion sickness? What other events do people avoid because of motion sickness?
7. How does seasickness influence behavior?
8. What do people want to do during their traveling time?

Attitudes towards the artificial horizon

9. What are people's thoughts and expected values regarding an artificial horizon?
10. What options should the users have to interact with the artificial horizon?

3.3 Methods

3.3.1 Participant selection

The artificial horizon will be most effective for people who are highly susceptible to motion sickness. In addition, people with high susceptibility will be more experienced with dealing with the negative effects. Therefore the level of perceived susceptibility to motion sickness was the main criterion in the choice of participants.

The second criterion was related to boat trip experiences. For the focus group all types of motion sickness experiences are important, but experience on a ship could be of additional value. The exact age of participants was of less importance, because we consider age does not influence the actual experience of sickness but rather affects susceptibility. Furthermore, because we selected only participants with high susceptibility to motion sickness we do not expect large differences between age groups.

The initial goal was to find users from four target groups: elderly travelers, adults traveling without children, adults traveling with children, and truck drivers who travel by ferry. These target groups resulted from a team brainstorm related to travel activities, partly based on information gathered from ferry company websites (e.g. www.stenaline.nl).

An invitation to fill in a screener questionnaire for the focus group was send to two hundred adults (eighteen plus) in the JF Schouten School participant database, and in addition to students of the faculty of Industrial Design. In the screener there were, amongst others, questions related to the susceptibility to motion sickness, the frequency of traveling, and sailing experiences. For the 'screener invitation text' and the complete screener see appendix 2

Fifteen persons responded to our invitation and filled in the screener questionnaire. The first selection was based on the susceptibility to motion sickness. People who rated their susceptibility with a five or higher on a scale from one to seven (one: not susceptible, seven: very susceptible) passed the first selection round. Eleven participants passed this first criterion. One participant was excluded from further selection, because he could not speak Dutch. Because not enough participants reported to have experience with ships, this criterion was dropped. In addition, too little participants responded to make a separation between the above mentioned target groups. Therefore all ten participants that met the first criterion were emailed and invited to a focus group. Unfortunately, not all participants were able to attend the first group interview. Proposing a second date did not resolve the problem. Because of this a single focus group has been performed.

3.3.2 Participants

Four women and one man participated in our focus group. All participants were Dutch, and the age varied from eighteen to fifty six. All participants had scored a of six on the motion sickness susceptibility scale in the screener. In addition, each participant had some experience with traveling by boat, although they did not mention this in the screener.

3.3.3 Compensation

Each participant received € 17,- (€ 15,- for students) in cash for participation, in accordance with the rules for use of the JFS participant database. This was registered via the common forms available.

3.3.4 Interview process

The focus group started with an introduction during which the purpose of the focus group was explained, the process was elaborated and the rules were discussed. In addition, the role of the assistant was mentioned, and it was explained that the whole interview was recorded. After this informed consent forms were signed by all participants. For the complete introduction see the focus group guide in appendix 3.

The discussion started with questions about general motion sickness and traveling experiences, followed by more in depth questions about their experiences. The other topics were respectively 'dealing with motion sickness', 'activities during travel time', and 'the artificial horizon'. For the exact questions that belonged to each topic see the focus group guide in the appendix 3.

After all topics were discussed a wrap up ended the discussion. Afterwards the participants were thanked for participation and payment took place.

3.4 Analysis & results

3.4.1 Transcription

Based on the observation notes of the assistant and the recordings made during the focus group, a transcription was made of the focus group data. The transcription was selective and based on the relevance and frequency of the data; notes with the same content were removed. In total this transcription resulted in approximately 130 useful notes. For analysis purposes these notes were translated into English. For these notes see appendix 4.

Each note consisted of the transcription of the speech data, the participant name, the time code, and a content code. The used content codes were experience general, boat experience, solution, idea, opinion, symptoms, causes of motion sickness, and problems. For the abbreviations used for these codes see appendix 4.

3.4.2 Affinity diagram

The affinity diagram method was used to start the data analysis process. In this process all group members participated to discuss a suitable hierarchy of the data. For this purpose all notes were copied onto yellow paper and distributed across team members. This process resulted in the affinity diagram depicted in figure 3 (also see appendix 3 - affinity diagram).

The exact hierarchy in which the affinity diagram resulted can be seen in table3.Some categories in the hierarchy have overlap with data we already found in literature. Therefore the relevance of each category in the hierarchy and the influences on our research will be discussed next.

3.4.3 Results

3.4.3.1 Effects

In the first category effects there are three subcategories: social constraints, symptoms, and personal handicap. The 'Social constraints' category is about the feeling of inability to communicate to others in a normal way. This inability is experienced by the participants in two ways. The first is in the current situation when dealing with motion sickness. As one participant mentioned:

> *"I really don't like that I cannot be social to others when I'm in a car. For people I know well it is not a big problem, but for instance for people for my work I find it a problem. When we have to go somewhere for work by car, I sit like an idiot in the front of the car only staring forward. I really find that stupid. I'm afraid that they see me as a socially disturbed girl," & "I can talk to them but I will only look forward."* - Participant P (female, 19 years old)

The second inability is foreseen in the use of the artificial horizon system. Participants were afraid that interacting with the system would be an antisocial experience as well. As the above mentioned participant puts it:

> *"I would feel stupid if I have to watch the wall all the time, it's the same as when I'm in a car." & "It makes it less social."* - Participant P (female, 19 years old)

The second subcategory is symptoms. The symptoms were the same as found in literature, but the variation in symptoms and their severity was larger than expected. Not every participant experiences the same symptoms and in addition the symptoms differed for each activity. This even was a surprising fact to the participants.

> *"I always feel a bit dizzy then."* – Participant M (female, 56 years old)

> *"I don't have problems with my head, but I feel nausea. And I experience a lack of motivation to do something."* – Participant Sa (male, 18 years old)

"I always experience a 'heavy head'." – Participant P (female, 19 years old)

"I have the feeling like I am falling backwards." – Participant Sb (female, 48 years old)

Figure 3. Affinity Diagram

Motion sickness & the artificial horizon	I. effects	social constraints	social limitations
			bound by the system
		symptoms	general symptoms
		personal limitations	acceptance
			personal perceived limitations
			practical limitations
			fun limitations
			meanwhile activities
	II. situational causes	visual orientation	requirements for orientation
			light effects
			looking
		adaptation	age effects
			habituation
		location	being outside
			claustrophobia
	III. main problem space	cause	characteristics of the environment
			characteristics of cars
			characteristics of trains
			movement
		current solutions	avoidance of sickness
			food
			medication
			lying down
			alternative solutions
	IV. the system	expectations for the horizon	expected support
			objections to horizon
			readiness to try
		suggestions for the horizon	keeping interest
			ideas for horizon
			other fields of application
			other things the projection could do

Table 3. Affinity Diagram

The third subcategory of the effect category is personal limitations. In this subcategory the topic of acceptance is included which' main idea is that our participants currently all accept their limitations caused by motion sickness and accept that there is often no solution for it. Other topics are about first-hand experiences of limitations caused by motion sickness. The results show that participants have problems with all possible types of moving objects, varying from an air mattress to a ship. But not all participants have problems with the same things; some participants could not read while being in a train, while others could. The next quotes illustrate the impact but also the variety of the experienced limitations.

> *"Sometimes I want to join when my children are playing a computer game on the Wii. But I really feel like the puppets, I sometimes even jump with them, and it doesn't make me feel nice. I really don't like it that that is not possible for me."* – Participant Sb (female, 48 years old)

> *"I would really like to go on a nice boat trip once. I heard from a colleague of mine that she went to Antarctica, and I was very jealous. I know it is never going to happen for."* – Participant H (female, 47 years old)

> &

> *"I even don't like it to sit in a stationary car."* – Participant P (female, 19 years old)

The last topic included in the effect category is meanwhile activities. Participants stated that they would like to do something while traveling, because they were bored or because they wanted to do something useful.

> *"I really would like to do something in the bus when I go to school, because I find it very boring. But it is not possible."* - Participant Sa (male, 18 years old)

3.4.3.2 Situational causes

The second category 'situational causes' has three subcategories. The first subcategory visual orientation can be summarized as similar to the starting point of this project: looking at a horizon can help to reduce motion sickness. Although there were also some skeptical remarks about this:

> *"For me there is nothing that helps when I'm on a boat."* - Participant H (female, 47 years old)

This subcategory contains a topic 'requirements for orientation'. For this topic we found that not only a view is important, but the direction of a view can also be important. Viewing direction aspects of an artificial horizon are not researched in this project, but should be investigated in a follow up study to be able to guarantee the effectiveness of the system. As one participant of the focus group mentioned:

"They told me I had to lay down when I was on a boat, to reduce the symptoms. I did not want to do that; I wanted to know which direction we were heading." - Participant P (female, 19 years old)

The data in the subcategory adaptation was almost completely in line with our literature research. An interesting finding, however, was that habituation is more subtle than described in literature. By this is meant that it is not so much, for instance, the driving in a car itself that someone needs to get used to, but more the specific type of the car, smell of car, and the characteristics of the driver's behavior:

"It has to do with habituation. You don't know what will happen when someone else than your own parents are driving." - Participant P (female, 19 years old)

The third subcategory location is about the effect of space on the perceived sickness. A general advice when experiencing seasickness on a ship is to stay outside. Staying outside can help because of multiple factors. It could be that it has to do with the horizon, the fresh air or smell, but one participant mentioned also the topic of claustrophobia that she experienced when being inside a small cabin on a ship.

"I think it has also something to do with claustrophobia. It is something that won't make it better. For me those things belong together." - Participant P (female, 19 years old)

3.4.3.3 Main problem space

The third category is the 'main problem space'. This category includes the two subcategories: causes and current solutions. The main causes are similar to the causes mentioned in the literature research. All participants agreed that swinging movements were most problematic, and that a boat trip was the worst means of transportation for a person suffering from motion sickness. Some people reported that the traveling direction in a train was important while for others this was not the case. General agreement was found for the topic of smell. According the participants smell can be a very important environmental variable.

"Sometimes you open a door of a car, and you smell it, and you instantly know that your chances are lower." - Participant M (female, 56 years old)

The second subcategory is about current solutions. The most used solution according the participants is the avoidance of sickness inducing events. Taking a walk or going by bike was mentioned by the participants as a preferred alternative to traveling by bus. In addition, all participants said that while steering a car themselves they did not experience motion sickness related problems. This resulted in the following obvious solution:

"I always ask people if I can give them a ride." - Participant H (female, 47 years old)

Not eating or drinking some specific types of food or drinks is another common solution, just as using medication. Although the medication varies per participant in effectiveness, most of them agree that they rather not use pills for the sickness reduction. This opinion has to do with the negative attitude towards medication in general but also with side effects. One participant mentioned that she does not like to take medication because it makes her feel sleepy.

Lying down is also an often mentioned solution, although it was mentioned that it only postponed the negative feeling. One implication of this result is that it should be taken into account that users will often use the system while lying down. Therefore aspects of readability and visibility need to be taken into account.

"For me it helped to lie down in the back of the car when we went to France for holidays when I was younger. When I afterwards woke up I felt very nauseous, but it helped for me to fall asleep." - Participant P (female, 19 years old)

Different alternative solutions to motion sickness were mentioned during the interview that varied from magnetic wristband to tissues with eau-de-cologne. Unfortunately none of these were sufficiently effective. An interesting alternative solution that was mentioned by multiple participants was the effect of psychological resistance. But unfortunately also this technique is not effective for all symptoms and in all contexts.

"When I have to sit backwards in a train it helps when I tell myself: 'we are traveling this way again and again'." - Participant P (female, 19 years old)

3.4.3.4 The system

At the beginning of the topic about the artificial horizon system, we explained the system to the participants in a very simplistic way. We explained that our project was about the implementation of an artificial horizon in cabins on ships. For the exact description see appendix 3. The next topics were addressed after this explanation.

The system includes two subcategories. The first subcategory, expectations of the horizon, describes three topics. The first topic is expected support. The results show that participants see the system not as a goal of itself, but as a tool that can help to relieve them from negative feelings they experience while being on a ship. As can be seen in the below mentioned examples, participants think the system can help them distract from negative physical and psychological matters.

"It can help by distracting you from the feeling of nausea." - Participant H (female, 47 years old)

“It can help you to forget how small the cabin really is.” - Participant M (female, 56 years old)

The second topic is about objections towards the horizon. There were no real objections to the artificial horizon system, but there were doubts about the effectiveness. This can mean that additional information about the proven effectiveness of such a system and about the source of the exact position of the shown horizon is required to convince people to use it.

“I think I would think it is a fake image. And that I should not fool myself.” & “That could block the effectiveness for me.” - Participant P(female, 19 years old)

The third topic was about readiness to try. Although there were some doubts about the system everyone was willing to try it. Participants were skeptic towards any new non medial solution for motion sickness, because they said they had already tried everything, but nothing really helped. As one participant puts it very clearly:

“If I have to go by boat and someone has thought of a solution, I will always try it.” & “I get sick anyway, so it is not wrong to try it.” - Participant H (female, 47 years old)

The second subcategory of the category the system is ‘suggestions’. This subcategory includes four topics: keeping interest, ideas for horizon, other fields of application, and other things an artificial horizon system could do. As mentioned in the part about the expectations towards the system, participants see the tool not as an end goal by itself. In addition they say that they do not like the idea of staring at a wall all the time (see subcategory social constraints. The importance of these aspects can be seen in the suggestions they provide for the system. The general suggestion is that the system should create a pleasant experience in which users will not notice that they are looking at a wall. The comments on this topic resulted in a few interesting ideas:

“The image should be made interesting, so you have something to talk about. (…) like when you see islands floating by.” - Participant Sa (male, 18 years old)

“Then you could also show an interesting movie.” – Participant M (female, 56 years old)

“Maybe it would be nice if someone tells a story.” & “Information through your ears does not cause sickness (…, perhaps) a story about something on the image.” - Participant Sb (female, 46 years old)

3.5 Conclusion

The focus group resulted in useful information about the experiences of the participants, and gave us a better idea about the variables influencing motion sickness. In general, the main finding was that there is more variation in both causes and symptoms than expected. In addition the experienced limitation caused by the susceptibility varied broadly. These facts were also unknown to the participants of the focus group.

The attitudes towards motion sickness were quite similar amongst the participants. All perceived it as a personal limitation but accepted it. The solutions were also based on the acceptance attitude; participants mentioned that the main solution to motion sickness is avoiding motion sickness inducing events, even if this would mean walking home instead of going by bus. When avoiding an event is not possible looking at a view is the most effective, but not a complete solution.

The possible use of the artificial horizon was also seen as a second choice solution, in case they had no other choice than to go by boat. The attitude towards an artificial horizon system in general was positive, although there were some doubts about the effectiveness. All participants thought of the idea of an artificial horizon as a system that required full attention. This could be caused by the fact that they are very susceptible to motion sickness which makes it necessary for them to concentrate on the horizon. In addition, the system could provide the susceptible user with new possibilities by creating a leisure activity in the focus of the horizon. During the focus group participants mentioned some interesting ideas about possible activities that could be provided by the system. This direct focus on the system has several implications on the system requirements. The main implication is that the representation should be interesting enough to make sure users will not be bored by the system. On the other hand it is important to keep the less susceptible users in mind. Less susceptible users could want the system to stay on the background of their attention. This could result in contradictory requirements.

4. Explorative Experiment

4.1 Introduction

Past research has proven that an artificial horizon actually provides relief to people suffering from motion sickness (Houben & Bos 2010). The “3D earth-fixed visual reference”, as Houben & Bos (2010) called the artificial horizon, presented visual motion in the opposite direction of the ship motion. However, it is still unknown what the effects of depicting the horizon using different images would be. Therefore, the aim of this explorative experiment is to determine the characteristics of a suitable representation for the artificial horizon to the users. These characteristics were analyzed to obtain requirements for the artificial horizon as a product.

The measures and the techniques used to analyze the results were qualitative, based on level of annoyance, the ability to attract attention, and the general preference of the participants. A mid-fi prototype was used to simulate the artificial horizon and the six degrees of freedom of a vessel. Even though the experiment was not performed with a large sample of participants and extensive quantitative measures, the differences across participants and conditions were minimized. Thus this study should be interpreted as an explorative experiment using qualitative measures.

The experiment was divided into two parts, which will be described in the next two sections in more detail. For test one, images with different levels of abstractness and subtlety (i.e. extrovert and introvert) were presented to the users. In the second test, relevance, complexity and color were varied. Less abstract and less subtle images are expected to be preferred, because they provide explicit references. Relevant, simple, and colored depictions are also expected to be more popular, because these are representative, do not increase sickness and are more agreeable to see, respectively.

4.2 First experiment

4.2.1 Introduction

In order to determine the characters of a suitable representation of the artificial horizon, in this first experiment, two variables were considered: abstractness and subtlety.

The abstractness variable was chosen to explore if an abstract artificial horizon (e.g. used by Houben & Bos., 2010) would differ in effectiveness compared to a more realistic scene. A similar idea triggered the necessity to test introvert and extrovert projections. In this study, we wanted to know whether people need a tool that attracts a lot of attention (extrovert) or whether they want something subtle that can merge with the environment (introvert). Previous research has proven that the visual input influences the severity of motion sickness (Bos et al., 2005), as described in literature section 2.1.1.4. As differences in the movement and illumination of the surroundings have an impact in motion sickness, two control conditions similar to the blind folded (i.e. dark condition) and the view moving with the subjects (i.e.

moving-light condition) were included in this experiment. Both control conditions will serve as reference on whether the artificial horizon really diminishes the feeling of sickness in the participants.

4.2.2 Study Design

The experiment was a 3x2 within subjects design. Two independent variables were taken into account: Abstractness and Subtlety. The independent variables were manipulated, so that the abstractness had three values: abstract, less-abstract and realistic; and the subtlety two: Introvert and Extrovert. Additionally, two control conditions were considered: a dark condition and a moving-light condition. All participants were exposed to eight conditions in a randomized order.

4.2.3 Participants

TU/e students around 20-30 years old were invited to participate in the experiment, because in this range of age the susceptibility to motion sickness is highest (Bos et al. 2007). Each participant received € 5,-(non TU/e students €7,-) in cash for participation, in accordance with the rules for use of the JFS participant database. This was registered via the common forms available. 11 students volunteered, 4 of them were female and 7 were male. The average age was 24 years old.

4.2.4 Setting and Apparatus

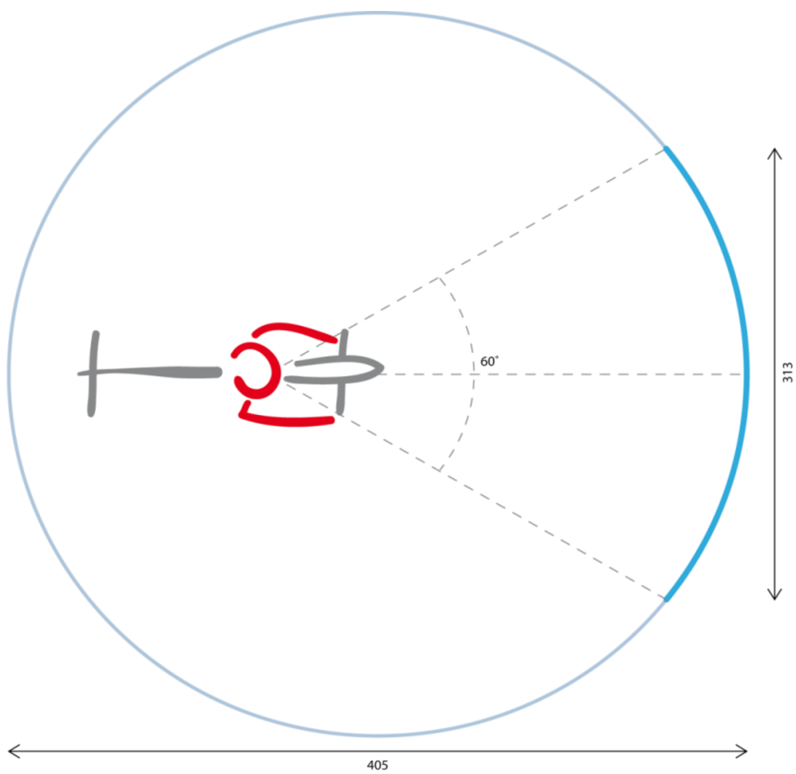
From the interview with Jelte Bos we learned that all the degrees of movement of ships are of significant importance to motion sickness. A simple prototype was constructed to simulate these movements (figure 4). For this prototype a 'wipkip' (a playground object for children called a spring rider) was used. Since a wipkip can move in the six degrees of freedom, it is an easy-to-build and cheap option. The movement of the Wipkip was manipulated manually through a handle installed in the back part of the Wipkip-simulator. The movements were produced by the experimenters. The experimenter who produced the movements varied among participants but was the same person across all conditions for one participant.

Figure 4. Movement simulator (Wipkip)

Participants had to sit down on the device for approximately 1 minute per condition, while motion was induced by one of the experimenters.

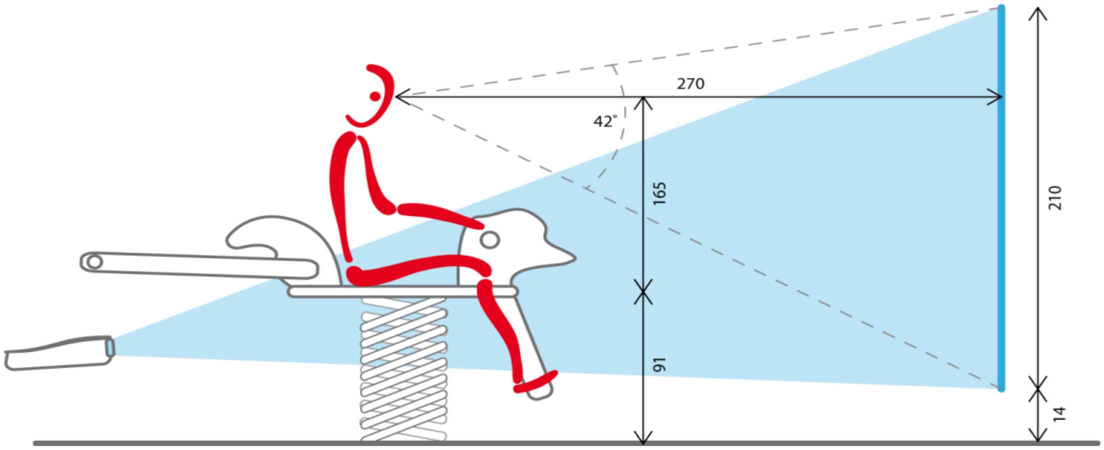
Around the participants was a circular projection screen which had a double purpose: (1) eliminate external references like the corners of the room and (2) provide a screen to project the artificial horizon on. This circular screen had a diameter of approximately 4 meters. The wipkip was placed near to the perimeter (figure 6) to make sure a horizon can be perceived as distant scenery. At the chosen distance from the participant to the screen, the depth perception cues accommodation and convergence are not of influence anymore (Cutting and Vishton, 1995). For the exact measures see figures 5 and 6.

Figure 5. Sketch of the setup, top view



The image of the artificial horizon was projected on a projection screen in front of the user by using two beamers and covering 60º of the visual field. The displayed images were split in half, so that each one of them could be projected by separated beamers using different computers. During the test the projection covered 60° of the visual field, as shown in figure 5.

Figure 6.Sketch of the setup, side view



The beamers were placed one at each side of the Wipkip so that the projected images of both beamers fitted together in the center of the screen. The image of the left beamer projected on the right part of the screen and the image of the left beamer, on the right side. Both images were made to fit as well as possible. However, even small differences between the beamers caused brightness, contrast and color temperature differences. Even though these differences among left and right side were sometimes mentioned by the participants, these observations were not taken into account for the analysis because these were not relevant to the project. For the resulting setup please see pictures 7 and 8.

Figure 7.Setup pictures. Left: back-sided view of the setup, showing the grid used to adjust left and right images. Right: front-sided view, showing the two beamers used to project the image on screen.

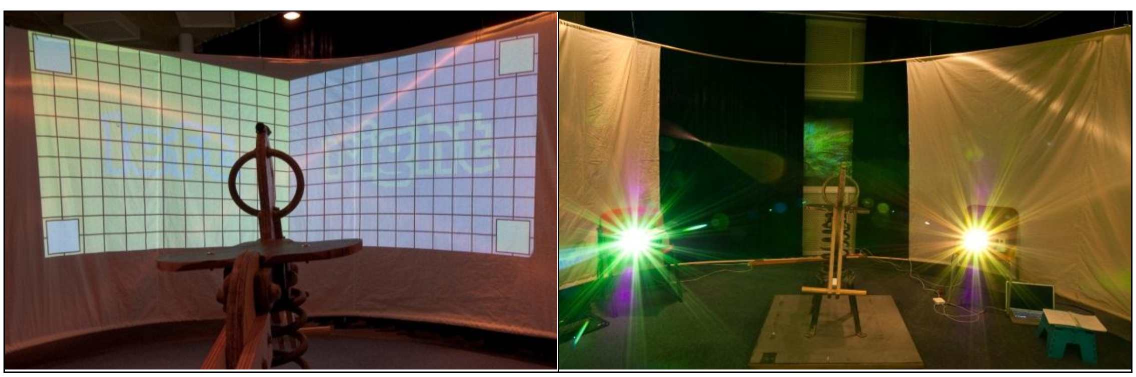
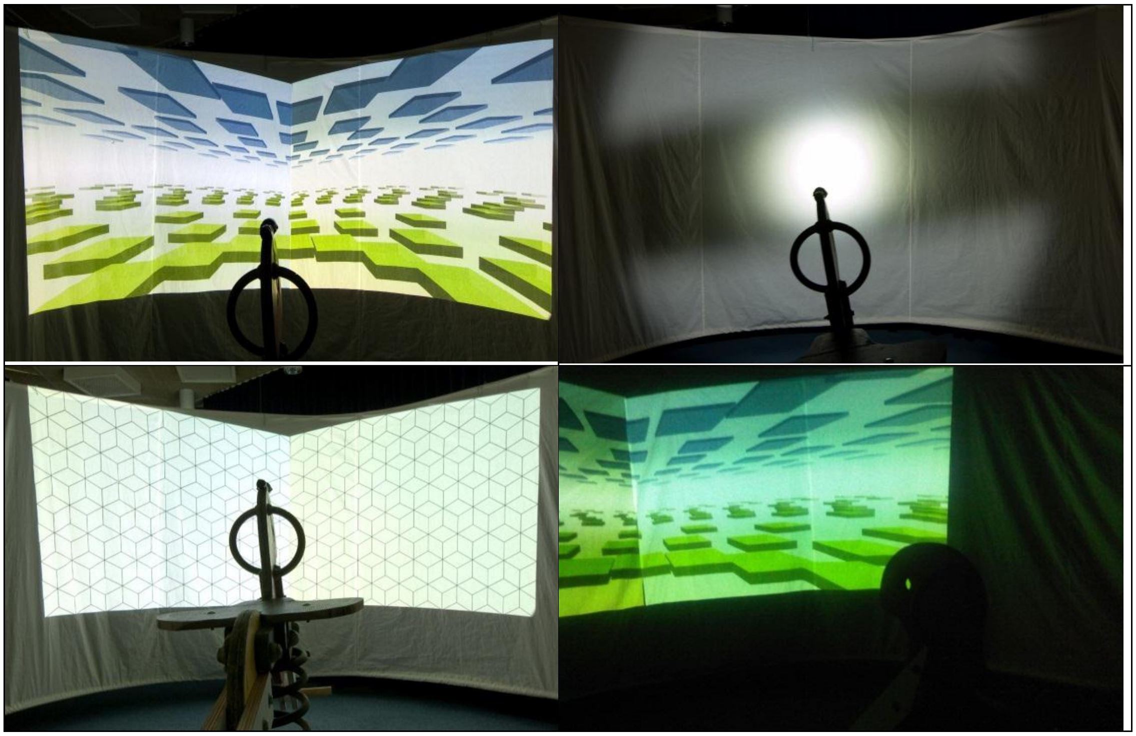


Figure 8. Setup pictures. Examples of the images of the artificial horizon projected on screen. In the top-right image is depicted the moving-light control condition.



In order to make both images fit nicely and to be able to change the projections of the both beamers at the same time, a program was developed. Two instances of the program were run on different computers, in a client-server setup, so that every change of picture made in the server computer also resulted in a change in the client one in real-time[1].

4.2.5 Stimuli

4.2.5.1 Artificial horizon

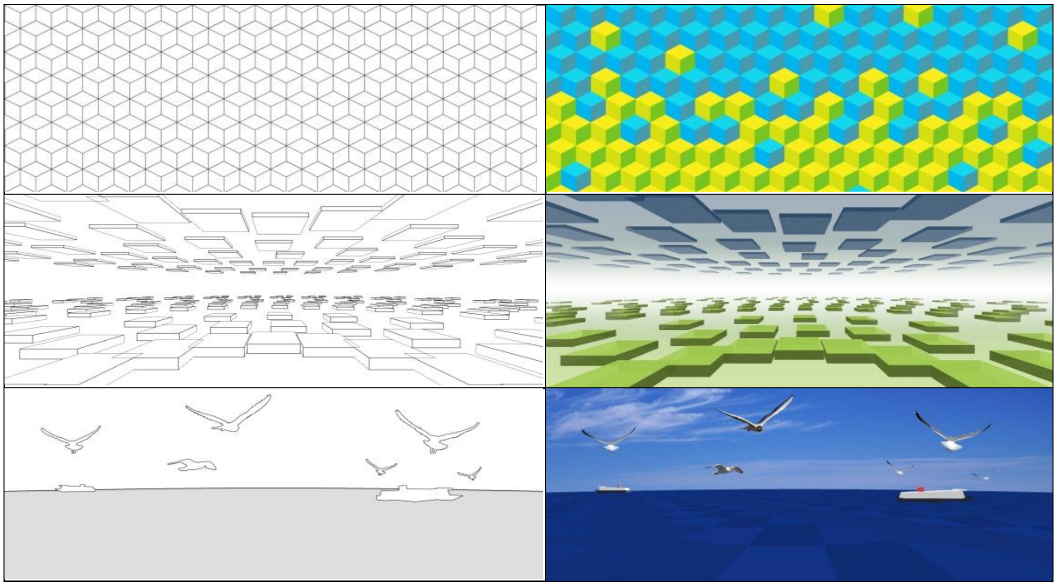
The participants were exposed to 6 experiment conditions and 2 control conditions. A description of each one is outlined below.

Three different images were selected to represent the different levels of abstractness and they were labeled as abstract image, less-abstract image and realistic image. Both an extroverted and an introverted version of them were used to provide different levels for the subtlety variable. For introvert a wireframe image was used and for extrovert a filled image.

The images used for this first test can be seen in figure 9. For larger images see appendix 7.

[1] The change was almost instant, but at times, some delays were visible due to high traffic in the network.

Figure 9. First test images. The first column represents the introvert images and the second the extrovert ones. From top to bottom: abstract, less abstract and realistic.



The abstract projections were chosen to depict a pattern of cubes which could be interpreted as three-dimensional but do not convey distant depth information. The extrovert version uses bright colors with blue on top and yellowish green below to provide a very abstract idea of the colors of a horizon.

The middle abstract projections use cubes in an evident three-dimensional fashion which is thought to create a stronger sense of depth while remaining abstract (i.e. no life-like representation). The extrovert version includes some texture on the cubes as well as coloring that reflects a natural horizon (blue on top and green for lower parts).

The realistic images depict a scene that could indeed be seen onboard a ship, thus with water, a clear horizon line and some typical elements such as seagulls and distant ships. The introvert variant employs black strokes surrounding the white-filled elements, hereby partially losing the depth sensation due to the water being one even color. It is important to mention that the water and the ships present a low level of detail because they were, at first, designed to be a 3D rendered image able to move in synchrony with the movement of the ship/prototype. The sky and the birds were, as all projections were, composed in Adobe Photoshop.

The moving-light condition consisted of a light projected on the screen, which was moving in the same direction as the simulator and it is equivalent to a view moving with the subject. In the so-called dark condition there was no projection, and all lights were off. This condition served as control condition to compare the effects between the presence and absence of the artificial horizon.

4.2.5.2 Movement of the simulator

It was agreed to make the movements of the wipkip circular, as wide as possible, with an approximate duration of 5 seconds. Alternating directions were produced in the same condition, in order to reduce the feeling of control of the participant. If the participant was moving towards one side, the wipkip was moved in the contrary direction, for both avoiding the sensation of control and safety issues. The safety issues mainly concerned the maximal amplitude of participant movement that would be desirable; if the movement induced was in the same direction of the movements of the user, the strength of both movements added, producing the feeling that the participant could fall of the simulator.

4.2.6 Measures

Participants were asked several questions about their opinion about the presented image, and about possible symptoms of motion sickness that the participant had experienced. The questions asked were related to the condition that the users just experienced.

The motion sickness level experienced by the participants during each condition was rated according to the following open ended questions: (1) do you have any uncomfortable feelings?, (2) if so, when did you start feel uncomfortable? And (3) are there any symptoms and how serious are these?

Concerning the projected image, the questions asked were open ended as well: (1) did you use the image in some ways? (I.e. as reference), (2) did you find it makes you feel better or worse? And if so in which way?, (3) where did you fix your eye on the image and why?, (4) did you look at other things besides the image? (e.g., curtain, ceiling, et cetera), and, (5) what do you like and dislike about the image?

Participants were also asked to order all pictures shown in the order of their preference by using cards with the images printed on them. Afterwards, they were also asked to tell why they have chosen that specific order. The exact test instructions are included in Appendix 8. The participants also reported their susceptibility to motion sickness after the test, in a scale from 1 to 5, where 1 is the least severe and 5 the worst. A video recording of each participant was made during their experiences on the wipkip. The interviews have been voice recorded as a backup in case of failure of the video recorder.

4.2.7 Procedure

Firstly, all participants were informed about the goals of the explorative study, the procedure and their option of quitting at any time. Also, the participants were asked for written consent with our aims and recording of the test using audio and video.

Afterwards, the participant sat on the wipkip and the eight conditions were presented in a random order. The data obtained from this study is exploratory and qualitative. However, in order to make the data as reliable as possible each participant was provided with the same conditions and treatment. The test-time for each condition was approximately 1 minute with

1,5 minutes of rest in which the questions were asked. Even though the simulator was sickness inducing, it was not our purpose to make the participants sick. Therefore, the exposure to each condition was kept short, and the participants were explicitly informed to tell us when they feel uncomfortable so that they could take a longer break, stop or postpone the experiment.

After each condition, some questions about the health state and the attitudes of the participant towards the picture where asked. Once all conditions were tested, the participant was asked to rank the images presented according to his/her preferences, from the best to the worst and to explain why she had chosen so. Finally, the participant rated her susceptibility to motion sickness and filled out her personal information on the payment form. Then she was thanked, debriefed and paid.

4.2.8 Analysis

The data obtained in the experiment was qualitative. We used the methodology 'Parts in Context, "Patterns among the Patterns"' described by Seidel (1998) to analyze the results iteratively. In the first iteration, the main goal was to identify the common preferences of participants and the variables they used to come to those preferences across the different conditions, without leaving out interesting exceptions. The "parts in context" methodology was applied in the transcripts of the video and sound recordings. The commentaries made by the participants were transcribed into a matrix per participant. By using a matrix, the answers of the participants and the transitions between conditions would be visible and easy to compare. As the first step, all the transcript tables were examined in order to search for patterns among the opinions of the participants and what they thought was important. That is, the questions were more a trigger to give inspiration to the people, so that they could explain what they found interesting, relieving, nice, annoying or helpful about each picture

In the second iteration, we looked for patterns over pair 'abstractness-introvert' and 'abstractness-extrovert' conditions (see images), which were deliberately included in the design of the study to contrast realism and depth perception among images of the same level of abstractness and different levels of subtlety. The pair 'abstract extrovert – less-abstract extrovert' was carefully compared as well, in order to obtain information about the depth, color, brightness and focus differences among two images of the same subtlety and different abstractness levels. The rankings were analyzed using non- parametric tests, specifically, the Friedman's ANOVA in SPSS.

4.2.9 Results

After looking for common topics among the answers participants, 11 variables were found that were influential in the preference development of the participants: realistic/abstract, color, balance, darkness, light, brightness, ability to distract, orientation/reference, perceived depth, detail, patterns and focus. A detailed description of each topic is given in table 4.

Table 4. Summary of the topics found among the participant's comments

Topic	Definition
Realistic	For our purposes, realistic accounts for an image that is close to reality or a picture of reality.
Abstract	Abstract is an image that differs from the representation of reality, and that has an implied subjective representation.
Color	Any comments about color in the image.
Balance	Comments about keeping balance in the wipkip, and/or its relationship with the image.
Darkness	Any comments about darkness or black in the image.
Light	Any comments about light.
Brightness	Any comments about brightness in the image.
Ability to distract	Whether the image can draw attention or not.
Orientation/reference	Whether or not the image provided means to orientate or reference points.
Perceived depth	Whether or not the image provided the perception of depth.
Detail	Comments on the level of detail in the image (crowded or complex) image
Patterns	Comments on the patterns of the image.
Focus	Comments on where in the image the participants focused.

It was found that not every comment the participants made had an implicit attitude. For example, in the realistic image, several participants declared having focused on the birds, however, this statement did not mean that they liked or disliked specifically the birds. On the other hand, there were comments with implicit attitudes. For example the remark "I don't like these squares because they are meaningless. I kept thinking it's very boring. It's only lines and cubes and black and white"(Participant 8, female, 22 years, abstract introvert condition) has a well-defined negative attitude towards the image. Also, from the answers of the participants it can be noticed that their attitude towards the image was dependent on how they felt: "At the beginning I disliked the picture because I thought it was going to make me feel sick, but after a while I focused in a spot of cubes of similar color, to see the image as flat as possible. I like the cubes have different colors because they help me to refresh when looking at different spots" (Participant 2, female, 23 years). Therefore, the attitudes of the participants per topic were also taken into account, considering three levels: positive, negative and neutral.

In a second iteration, relevant pairs of conditions were compared. See Appendixes 10 and 12 for further details. To see the complete set of comparisons, please see appendix 11. The main findings per relevant condition are described below.

4.2.9.1 Abstract vs. Realistic

For the realistic extrovert vs. abstract extrovert comparison the main differences found were related to the focus of the participants in the image. In the realistic image participants mentioned focusing more in the pop-up items[2], than in the abstract image, where they focused either in the furthest or nearest point. The participants liked that both images had a clearly defined horizon because it gives a reference. The participants also felt that they were moving towards certain elements of the realistic extrovert (i.e. the birds); even if the seagulls were not moving.

Participants had no specific preference towards abstract or real images in general. In addition, some participants mentioned a feeling of motion in both abstract and realistic images, caused by the depth aspects in the abstract image and the arrangement of the items in the realistic one.

4.2.9.2 Introvert vs. Extrovert

For the realistic introvert vs. realistic extrovert comparison, the main difference was that in the extrovert image, elements pop-up more easily. Also, in the introvert image, people perceive less movement "in the image", when compared with the extrovert one. There is no specific preference for color / no colors.

In the less-abstract introvert vs. less-abstract extrovert comparison, it was found that the focus was in the near/far spots towards the middle in both conditions. In the extrovert one, the bottom green part attracted more attention. People liked more the colored one because it provides more detail and depth information. Differences in brightness are mentioned more for the extrovert version. Also both introvert and extrovert images gave the sensation of moving forward.

For the abstract introvert vs. abstract extrovert comparison, people preferred the colored extrovert image, because it was easier to focus on something specific inside the image. Namely, in the introvert version participants said that there was no pop-up to use as a reference point, and therefore it was more difficult to find a spot to focus on. In addition, people found the patterns boring, annoying and confusing. For the abstract images participants did not mention an experience of movement.

4.2.9.3 Control conditions

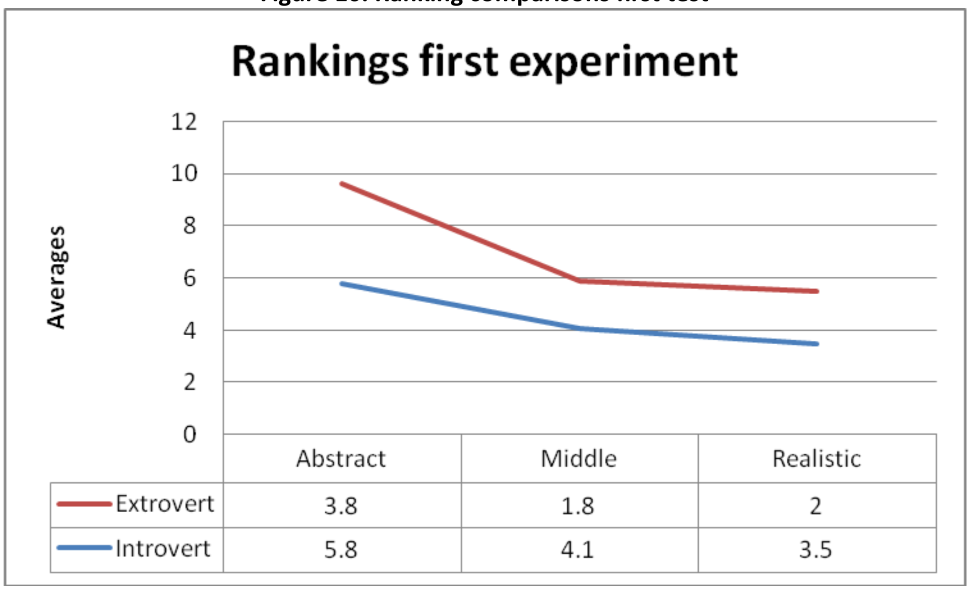
In the control black and control light conditions, people often felt worse if they were already sick, or they felt bored if they were not uncomfortable with the movement. Usually people looked at the light and its movements to predict what the movement is like. An interesting but unexpected result was found when during one test the phone of the experimenter rang. The participant who was currently experiencing the dark control condition mentioned that the sound of the phone helped her to focus herself on something. Further research can be done to see if auditory stimuli can be used as a solution for the investigated problem.

[2] Those elements which are really irregular or outstanding in an image. For example birds, ships, big buildings and big trees.

4.2.9.4 Ranking

After all test conditions a subsequent ranking task was performed to measure the preferences for each condition. The condition that was preferred most got score of one, and the condition that was preferred less got a score of six. Based on standard deviations, there is not much variance for Abstract-Introvert, Middle-Introvert, and Middle-Extrovert. For the other images variance is above 1, with especially the Realistic-Introvert projection being 'controversial'. The averages of the ranking of each condition among participants are show in figure 10. From the graph it is evident that the extrovert images were preferred over the introvert ones, and that the realistic representations score higher.

Figure 10. Ranking comparisons first test



The average of past susceptibility of motion sickness among participants was 2.

The original 2×3 factoring design was collapsed into two simple comparisons: the main effect of introvert/extrovert and the main effect of abstractness (abstract/middle/realistic). Then Friedman's ANOVA was performed to compare the mean ranks of introvert/extrovert and abstractness. *Post-hoc* tests were also performed for the three levels of abstractness. The significant level was set at $\alpha = 0.05$.

Introvert – Extrovert: the extrovert conditions rank higher than introvert conditions with mean ranks of 1.91 and 1.09 respectively. The effect is significant ($\chi^2 = 7.364$ (1), $p = .007$).

Abstract – Less-Abstract – Realistic: The main effect of abstractness is significant (with mean ranks of 2.82, 1.73 and 1.45; $\chi^2 = 12.600$ (2), $p = .002$). The critical value for *Post-hoc* tests is 1.02 ($\alpha = 0.05$, k = 3, N = 11). Thus abstract conditions rank significantly lower than middle conditions ($|\bar{R}_{Abstract} - \bar{R}_{Less\text{-}Abstract}| = 1.09 > 1.02$) and realistic conditions ($|\bar{R}_{Abstract} - \bar{R}_{Realistic}| = 1.37 > 1.02$). However, the difference between middle conditions and realistic conditions is not significant ($|\bar{R}_{Abstract} - \bar{R}_{Realistic}| = 0.28 < 1.02$).

4.2.10 Discussion of first test

The main objective of this experiment was to determine characteristics of a suitable image to represent the artificial horizon, according to the variables abstractness and subtlety. Friedman's ANOVA showed that the introvert projections score well below the extrovert ones and that the abstract pictures scored below the realistic ones. Opinions differed for the two realistic images; some participants liked the calmer / muted visual quality of the introvert one, but thought the extrovert one was more interesting. The introvert versions of the abstract 3D boxes scored low, while the colored variants scored high. The qualitative analysis also confirmed that, in general, the introvert imagery was perceived as less positive, except for the Realistic Introvert projection which had both positive and negative remarks.

The abstract projections (both introvert and extrovert) received strong negative comments regarding its pattern which led to confusion and provided a poor reference frame, confirming the results from the rankings. In general, patterns were disliked and made the participants feel worse. Participants preferred projections that provided clear reference points, and objects that pop out. Pop-ups helped the users to find a reference spot, and a moderate number of pop-ups were able to attract more attention of the user than did regular patterns in the image.

Even though participants disliked patterns, no specific preference towards abstract or realistic images was found in the qualitative analysis. However, the consistency within the image was mentioned as important. If the image is real, it should not have abstract elements, and all depth cues should be carefully watched. Mismatches tend to be annoying for participants.

By attracting the user's attention, images and sounds can be helpful to reduce motion sickness themselves. Some participants commented feeling better when having a representation of interest (i.e. with sufficient detail or room for interpretation) to look at while being moved. This happened despite of the affirmation by González Fuentes et al. (2005) about high spatial image frequencies that are said to increase motion sickness levels. Therefore, the inclusion of more complex imagery into a second iteration of the test was proposed.

Given that realistic, lifelike images were helpful in reducing motion sickness levels, the question rose whether the relevance of the image plays a role or not. Therefore, in order to gain further insight, new imagery was included in a second test.

4.3 Second experiment

4.3.1 Introduction

From the results of the first experiment, it was concluded that the relevance and complexity of the image also play an important role in influencing the levels of motion sickness. The real representation of the sea used in the previous experiment was regarded as positive, because it simulated the real situation and feeling of looking through the window of a cabin, however, people who had previous experiences of seasickness also associated the relevant image with the feeling of being sick. Therefore, the more specific question of "Would a realistic but irrelevant to the context image (e.g. rainforest) influence the users with similar attitudes as a relevant image (e.g. a sea scene)?" was proposed.

Real extrovert images were also preferred, even though these are usually more complex than introvert ones. This was a contradictory fact to the affirmation of González Fuentes et al. (2005), which states that high detail increases motion sickness. Therefore, the question of "Would a more complex image help in reducing the subjective experience motion sickness when compared with a simple one?" was further investigated in this second experiment.

As result, this study had as variables the complexity and the relevance of the image. Color was also included to gain insight of the effects of a black and white picture compared to a color one. The images that scored highest in the first experiment were included as well, in order to keep a reference to the first test.

4.3.2 Study Design

The design of the second experiment was an 8x1 within users study. Three variables were considered: complexity, color and relevance. Individual images were compared, contrasting the relevant variables, i.e. simple vs. complex, color vs. black-and-white, relevant vs. irrelevant.

4.3.3 Participants

TU/e students around 20-30 years were invited to participate. Each participant received € 5,- in cash for participation (7,- non TU/e students), in accordance with the rules for use of the JFS participant database. This was registered via the common forms available. 11 students volunteered one female and ten males. Their average age was 22 years.

4.3.4 Setting and Apparatus

The setting for the second experiment was basically the same as in the first one. Only the images representing the artificial horizon were changed. Figure 11 shows some examples of the setup.

Figure 11. Setup pictures. Top: Examples of the images of the artificial horizon projected on screen. Bottom: Side-view of the setup.

4.3.5 Stimuli

4.3.5.1 Artificial horizon

The projections chosen to answer the research questions are shown in image 12. For larger images see appendix 7. The same two control conditions considered for the first test were also included: the dark condition and the moving-light condition.

The painting was Van Gogh's "Wheat Fields Under Threatening Sky". It was used to find out how people would react to a very bold and impressionistic (i.e. somewhat abstracted) depiction of a natural scene. The relevant characteristics of this image are that it is natural, abstract and that it has high detail.

The rainforest image was used to investigate whether a natural, vivid scene of an irrelevant, that is mismatching environment, would be valued differently from more relevant views. This image was also used to gain insight on whether detail is helpful or not, because of its complexity. The relevant features are that this image is natural, realistic; it has high detail and low pop-ups.

A black and white photo of Hong Kong's Central Island skyline has been included to find out whether an urban scene as seen from the water would raise interesting comments. The reason to use a muted black and white version instead of a bolder, colored version is based on the availability of other colorful projections in this set and thus to provide an alternative. The main characteristics of this image are that it is an urban representation (non-natural), it is realistic, it has high detail and high number of pop-ups, and of course, it is black and white.

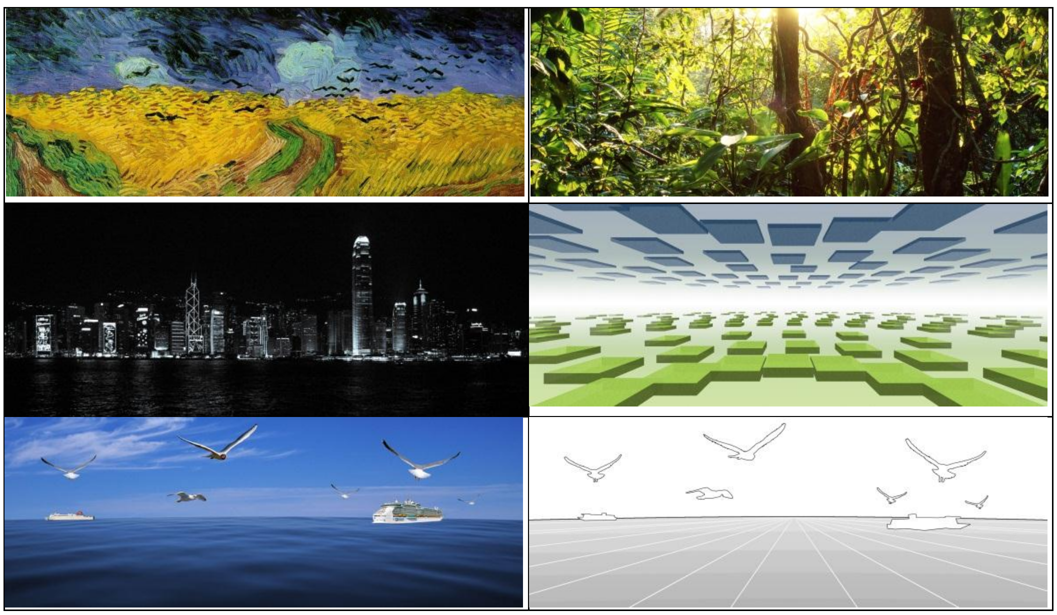
Because the middle abstract extrovert version was highly regarded by participants during the first test, it was included in this second experiment as well. Relevant characteristics of this image are: non-natural, semi abstract representation; i.e. low detail, high number of pop-ups.

The realistic extrovert image was also included because of its popularity in the first experiment. However, it was slightly adapted to accommodate the negative comments from the initial run.

The water and ships were updated, based on real imagery of ships and water, to increase the sense of realism and especially reduce the awkward combination of 3D rendered images and photos of seagulls. The relevant features of this picture are that it is natural and realistic; it has a high detail and a high number of pop-ups.

The realistic Introvert was included as well because it was among the most preferred. This image was also slightly changed. The water was updated to increase the sense of depth by including converging lines and a slight gradient. The idea was to reduce the most salient negatives while maintaining the overall impression. The relevant characteristics of this image are that it is natural and realistic representation with low details and high number of pop-ups.

Figure 12. Second test images. From top to bottom and from left to right: Painting, rainforest, skyline, middle abstract extrovert, realistic extrovert and realistic introvert.



4.3.5.2 Movement of the simulator

The protocol for the induced movement (on the wipkip) was kept the same as for the first experiment.

4.3.6 Measures

The interviews realized included the same questions as in the first experiment. The ranking explanations were videotaped this time to keep record of the images that the participant pointed at, and the elements depicted in them.

4.3.7 Analysis

The methodology used to analyze the results of the second experiment was the same as in the first one (i.e. Parts in Context, “Patterns among the Patterns” described by Seidel, 1998).

4.3.8 Results

It was found that the same 11 variables found in the first experiment were applicable to the results of the second experiment (Table 4). Also, from the answers of the participants it was be noticed that their attitude towards the image were dependent on how they felt, as well as in the first experiment: “At the beginning I liked the picture, but after a while it made me feel worse, then I disliked it”, “I think the painting is pleasant because it provides some distraction while being moved”.

However, the relevant comparisons did change:

- The realistic extrovert condition was compared with the realistic introvert one, to gain insight in the effects of detail in the image.
- The realistic extrovert vs. painting comparison and the rainforest vs. painting comparison looked for the effects of realism in the image.
- The comparison of the forest condition against the realistic extrovert condition sought for the effects of relevance, context and focus.
- The forest vs. city comparison looked for the effects of detail and color in the image.

4.3.8.1 Introvert vs. Extrovert

In the realistic extrovert vs. realistic introvert second test, the focus was again on pop-up elements and there was no specific preference between introvert and extrovert. The introvert version gave a sensation of direction (because of the perspective lines) while the extrovert gave a sensation of being lost. Also, people liked the introvert because it is simple, clean and quiet. Both images were able to distract people from the sensation of being sick.

4.3.8.2 Realism and complexity

For the realistic extrovert vs. painting comparison, the focus was mainly on the pop-ups. There was no specific preference between abstract and real and the sensation of movement was present in the paint while in the realistic was not.

4.3.8.3 Relevance and complexity

In the forest vs. realistic extrovert comparison, the results showed that focus for pop-ups was more outstanding in the realistic extrovert image than in the forest image. Some participants mentioned that because there were so many elements they could not find a spot to focus on. Also people mentioned that although the forest was not a relevant image in a sea context, it could help. However, when the people really felt sick or were prone to motion sickness, the relevant image actually made them feel worse, because it reminded them of the sensation of being sick. Another interesting thing was that because the image of the forest was very crowded it could distract attention at first, but if people were feeling bad they could easily find a reference spot.

Both the forest and painting pictures were able to attract the attention of the participants. There is, however, a limit on how much complexity a person can handle, especially if they are feeling sick. Participants said that they cannot focus on something because both images were unstructured or too complex.

4.3.8.4 Color

In the forest and Skyline conditions, there were some participants that mentioned crowdedness as something negative. For the forest, people liked the sun shine, the brightness and the green. Also, there was a negative attitude towards seeing solely black and white.

4.3.8.5 Ranking

The results of the ranking task for the second task were not conclusive. The scores of all conditions were close to average, and in addition the standard deviations were relatively large. For this reason the qualitative interview data were given more weight in the analysis of this second test.

Even though several participants felt dizzy during the experiment, only one asked additional rest between conditions to feel better. One interesting finding was that there were also many participants who did not experience motion sickness; the average of past susceptibility of motion sickness among participants was 2.

4.3.9 Discussion of second test

The ranking task of the second experiment did not result in a clear preference. This is probably caused by the complexity of the images presented to the users, and the less controlled conditions. However, this second test did result in interesting insights from the interview data.

The results in the realism and relevance sections confirmed that pop-up elements are responsible of attracting the user's attention and the perceptual cues of depth should be consistent in the image for it to work as a reference. However, there is a limit to the number of pop-ups that can be tolerated before the user starts feeling worse again, confirming the statement by González Fuentes et al. (2005) that detail increases motion sickness. The exact boundaries between feeling relief or not, according with the number of pop-ups should be investigated in further research.

Participants preferred color over black and white representations, because black and white made them feel lonely. Preference of a sea view over other non-relevant representation was not found. In addition, some participants prone to motion sickness mentioned that the representation of the sea made them feel worse because it reminded them of previous experiences.

An unexpected result was that participants experienced motion of a static image. Specifically, one participant expressed the feeling of a seagull moving towards her. All possible illusions of motions should be considered in order to maintain the consistence between these illusions and the desired motion of the ship represented in the artificial horizon. This possible conflict should be investigated in further research in order to be able to guarantee the effectiveness of the system.

4.4 Discussion of results

Even though these experiments were merely explorative, they provided the basis for the requirements that the artificial horizon should have. Also, they lead to formulate further quantitative research questions related to the exact limits where these requirements are applicable and regarded as positive.

As expected, simple images were helpful but only when these included the so-called “pop-ups”, distinctive elements that stand out in an image. A certain amount of pop-ups should be available in the representation, but there is also an upper limit: many pop-ups confuse the user and tend to withdraw from the image the focus that they provided individually. Further research should be conducted in order to quantitatively determine how much detail is too much.

There were also accidental findings. Unexpectedly, the results have shown that irrelevant images are also effective and even preferred over relevant representations of the sea by people who has suffered before from motion sickness. Some participants also mentioned that they liked only one side of the projection because it was brighter or because it was less bright. In order to avoid this brightness across the image should be even. This phenomenon also happened when the horizon was a horizontal line and it did not match nicely between two projections due small differences between the two projectors.

A drawback of this experiment is that the movements of the simulator were not equal for all participants. Due to the different weights of the participants, it was difficult to keep the movements constant across participants. It also was difficult to counter move the participants if they were tense or moving excessively.

5. Interviews in context

5.1 Introduction

This report investigates one particular role that dynamic and intelligent application of lighting can take towards improving human experiences, namely the reduction of nauseous feelings people may experience onboard large vessels. During the project interviews were scheduled with employees of two ferry companies: Stena Line and DFDS Seaways. Both interviews were performed in context; the captain, steersman and General Manager Ship Operations & Port Services of Stena Line have been interviewed onboard the ship Stena Hollandica (operating the Hoek van Holland - Harwich line) and four crew members (hotel services, cook, and bartender) of DFDS Seaways have been interviewed on the ship King of Scandinavia (IJmuiden - Newcastle). Both ships were in port while the interviews were conducted.

The main goal of these interviews was to get a good understanding of the applicability of the system onboard ships and the practical considerations that need be made. Therefore the main topics during the interviews concerned implications of seasickness for the company and passengers, the context of the ship, and the general attitude of the companies towards the implementation of an artificial horizon system. In this chapter the results of the interviews are presented. The results are ordered by the main topics of interest and the information gathered from both companies is combined due to similarities in responses.

5.2 Implications for the company

According to both companies seasickness is an issue on their ships. At Stena Line seasickness was described as not a very large problem with five percent of the passengers getting sick during trips with strong winds and rough seas. The people interviewed at DFDS describe seasickness as a larger problem of which up to forty percent of the passengers get sick to some extent during an average trip. It was mentioned that during trips in stormy weather this percentage could go up dramatically (up to eighty percent according to Stena Line). These situations however occur only occasionally, about one day per three months.

The effects of seasickness are a problem for both passengers and crew members. The problem seems less severe from the perspective of the crew. This is because crew members are adapted more to the ship movements than are passengers and because crew members with high susceptibility do not endure the life on a ship, hereby being selected for the job. In addition it was found that seasickness amongst crew members is to some extent a taboo. Many crew members may camouflage their sickness because of potential embarrassment. But all crew members susceptible to seasickness report it as a very uncomfortable experience, often inhibiting their ability to perform or find rest.

The companies already employ several measures that counter motion sickness. Both ships have stabilizers installed to reduce the ship’s movements and thereby prevent passengers from getting sick. Another preventive and general used solution is providing medication. This medication can be acquired onboard. In addition, a system in the ship constantly refreshes the air inside the ship to prevent uncomfortable feelings by the passengers.

Cabins are seen by both companies as part of the solution for people suffering from seasickness. Based on their experiences it shows that people are far less likely to report seasickness related issues during the night (although it might be the case that people are simply less likely to report, not less likely to suffer from such matters during the night). Given that both companies are regularly sailing at night it appears that seasickness is less problematic during the many nightly hours of operation.

5.3 Personal implications

Passengers onboard the ferries interviewed cannot easily be categorized in terms of demographics or travel goals. The variety in age and demographics are large although the largest group is in the 40+ range. For both companies truck drivers present a large target market (nearly one third of the passengers). These drivers are frequent travelers (some travel more than ferry employees) who use the time onboard to rest. The interviewees indicated that truck drivers appear to be less likely to get seasick, perhaps due their considerable experience onboard. Inexperienced travelers are more likely to get sick as well as the ones who worry about getting sick. Most people spend their time in the public spaces as the standard cabins are simple and small, rendering it unpleasant for activities beyond sleeping.

As stated earlier medication is the go-to preventive measure against seasickness. If symptoms crop up passengers often lay down on available sofas in the public spaces. When passengers do get sick after all, the first advice from the crew is to get in the centre or lower part of the ship where the movements are less severe in amplitude. Going outside on the deck is another option, but is mainly seen as 'getting some fresh air.' This can relieve the symptoms but not for every passenger. A crew member of DFDS mentioned that some passengers even want to throw themselves overboard when experiencing sickness. This illustrates nicely how uncomfortable experiencing seasickness can be. When sickness remains passengers are advised to lie down. Lying down is described as the most effective solution when passengers feel very sick. In practical terms this means the staff advises people to go to their cabins and try to sleep. The general impression is that when someone lies down the symptoms become less almost immediately.

For crew members seasickness can be a problem just as it is for passengers. This is especially true for the service and cleaning personnel who basically live onboard for months. Crew members also use medication to counteract seasickness but because of their job they often cannot take a break. This can result in uncomfortable situations. Common tips such as eating light food and lying down are followed by the staff if possible. Based on their experiences it shows seasickness can inhibit the ability to counter its effects. For example, due to the onset of unpleasant feelings the desire to eat is less which in turn increases proneness to seasickness, "but how can you eat when feeling like that?" Another crew member tells from experience she has a hard time falling asleep if she already feels uncomfortable. It is likely passengers have similar experiences but this could not verified within the current inquiry.

Looking at the horizon outside is not suggested by the crew of both companies. An interesting comment given by several staff members is that they felt looking at the horizon through the windows had an adverse effect, because they then saw the movement of the ship relative to the water. The chef of the Stena Hollandica mentioned that one should not look out of the window, because “it makes you even sicker.” A similar response was given by a bartender who mentioned that she never goes near the windows when she feels slightly uncomfortable as this has adverse effects for her. These experiences, though common for the interviewees, are at odds with the experimental data of Bos and colleagues (2007), as well as with recent findings by Mayo, Wade, and Stoffregen (2010) whose results suggest looking at the horizon does reduce body sway (which is a first symptom of sickness).

5.4 Context of use

The general layout of a ferry as used by Stena Line and DFDS could be described as follows. The lower decks are taken up by freight and cars. This is no area to spend time. Higher decks hold the cabins where people can retreat for rest. For all other activities passengers go the public areas which are found on decks close to the cabins. While awake, passengers spend most of the time in public spaces, and only a very limited time is spent inside the hut. There are numerous facilities on board like bars, restaurants, shops, cinemas, work spaces, conference rooms, and internet cafés. Within the public spaces most seating arrangements are located near the long sides where windows are available (see figure 13 for an impression).

Figure 13 - Photos of the public spaces (top) and typical cabins (bottom), with imagery from Stena Line (left) and DFDS Seaways (right).

The aim of the onboard cabins is to provide a retreat for the night. At the start of this project these cabins were identified as most suitable for the artificial horizon system due to their windowless setup. There is quite some diversity in room layout and size although on both ships the largest amount of cabins are rather compact and the inboard cabins are without windows (see figures 13 and 14 for an impression). These cabins have two to five beds. In the smaller cabins there are no possibilities to retreat for other purposes beyond using the bed and bathroom. In larger cabins there are more facilities (e.g., a sitting corner, mini bar) and in addition these cabins have windows.

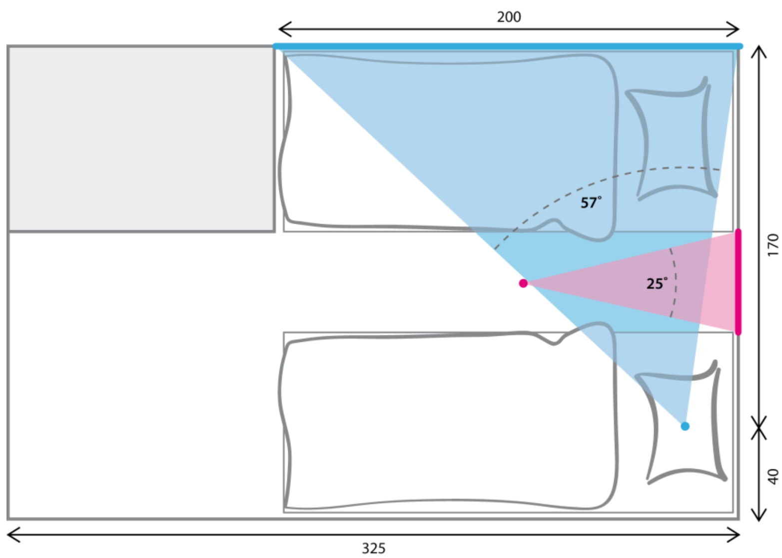


Figure 14 - Illustration of an average two to four person cabin size (measures in centimeters) showing the small space. Also shown is the potential horizontal view angle as seen from one person lying down (in blue) and the perspective one meter from the sidewall, a typical view when sitting on the bed (in pink).

5.5 Perspective on proposed system

During the interviews the core concept of the Stabilight project has been introduced and discussed. The response to this idea of implementing an artificial horizon was similar for most interviewees. They are all interested to hear about the idea but all are skeptic; as one interviewee put it when asked about her first impression: “Let’s see!” Both companies are interested in solutions to seasickness but there is some doubt about the effectiveness of the system. The main concern about the effectiveness of the system is directed at its main idea: looking at a horizon. It was often said by crew members that looking at waves makes them sick.

When the system does actually work every person would like to have the system on board. It is most often mentioned that the system should be located in central public places because these are the locations where passengers spend their time during the day, and where they actually get sick. Staff members themselves only retire to their cabins for sleeping; they have their leisure spaces elsewhere. They feel anything addressing their issues is best not limited to such cabins. In addition, it was suggested that the proposed idea could be implemented in cabins specially dedicated to susceptible passengers. This means only a limited set of cabins would incorporate the proposed technology, hereby striking a balance between probable costs and customer benefits.

In the large public spaces there are multiple options to implement the system, such as blank walls in the restaurant and relaxation / work areas. The available wall size is important because the system requires at least thirty percent of the visual field. Whether such a field of view is available depends on each specific location on a ship but in general it can be said such space is available. In cabins an implementation would be a bigger problem. Because of the small size the space is used efficiently and no large walls are visible (see also figure Y). This small size constraint of cabins also presents a potential benefit since this size can also cause stress (claustrophobia). Therefore the possible effect of a projection to make a space look larger is very interesting to Stena Line.

5.6 Discussion

Ferry companies acknowledge the effect of seasickness on the wellbeing of passengers and staff alike. From their perspective motion sickness is a well-known but, depending on the weather and type of ship, relatively minor to considerable problem. Percentages of passengers suffering are hard to give but the educated guesses range from nearly no one to over 50 % in very bad circumstances. They do acknowledge that for those fallen ill it is a taxing experience. For those who suffer, the most prevalent approach is to offer a cabin to lie down. This seems effective. In addition, a common symptom of seasickness is the perceived sleepiness, so these passengers are thought to fall asleep quickly (although some interviewees disagree). Because passengers mostly sleep during the nightly ferry and do not suffer nearly as much as they would during the day, the view of the people interviewed is that cabins are part of the solution. They suggest looking at the public spaces instead or perhaps limited application in cabins that they could advise to sensitive people.

A surprising finding stemming from the comments of the interviewees is that looking outside through the windows is considered bad advice. In principle scientific evidence suggests it should help but apparently subjective experience indicates otherwise. One possible explanation for this apparent contrast is that the windows on a ship as seen by the crew member show the world outside at a small visual angle, not enough to establish it as the true stable reference. Such contradictory self-reporting shows additional research is necessary to study the effects of dynamic lighting in context while taking into account the subjective experience.

Summarizing this section we learned that from the companies' perspective the impact of seasickness is smaller than expected, also for staff members. Still it can be said that even lower percentages of just five percent amount to a large number of people when considering the yearly number of passengers onboard such ferries (close to one million per year when combining Stena Line and DFDS Seaways on the UK-Netherlands routes, according to the respective company websites). Furthermore the initial focus on cabins requires reconsideration. We think the important findings require cross-validation with experiences of passengers which have not been acquired during this project.

6. Discussion & Conclusions

6.1 Reviewing the most striking results

The objective of this project was to explore the use of dynamic light to reduce the effect of motion sickness, specifically aimed at seasickness onboard large vessels. The central goal was to assess dynamic lighting as an opportunity to ameliorate passenger experiences and to develop requirements for future designs. For those who suffer from motion sickness it can be a dreadful experience. It presents not just unpleasant feelings and symptoms but it can also limit a person’s ability to partake in and enjoy certain activities such as traveling.

This project has taken a first step towards answering the question of how intelligent lighting could help to negate perceptual conflict effects which lie at the core of motion sickness. As laid out in the introduction work was focused on answering two main questions: Can dynamic lighting help to reduce motion sickness? & What are important aspects when transferring such technology into a successful design? Throughout the project the focus has been on a dynamic lighting solution which projects an image on a surface inside a cabin. Although the idea can be translated to various other ways of using lighting it was decided using a projection is the most valuable way to investigate the issue.

6.2 Important findings and recommendations

The approach taken is a combination of literature review and qualitative methods. Based on the scientific evidence found it can be concluded that there is support for the general idea of using dynamic lighting to negate motion sickness in closes environments. Because this conclusion already answers whether lighting can help this project has taken a more explorative direction towards understanding human attitudes towards motion sickness.

A focus group interview with people who were prone to motion sickness learned that individual differences are large and consequences can be large. People can experience motion sickness as a limitation in some parts of their life. Next to being impractical motion sickness can be perceived as a socially limiting factor due to the inability to engage in social activities. Such commentaries suggest the experiential qualities of motion sickness need be taken into account.

Performing a prototype evaluation yielded an array of subjective measures that give insight into people’s preferences regarding such projections while experiencing being moved beyond personal control. The results of the test indicate a clear preference for realistic or semi-realistic images that show an identifiable horizon. Participants prefer projections that provide clear reference points (e.g. objects that stand out). In addition, preference of a sea vista over other non-relevant presentations is not found. In addition, some sickness-prone participants mentioned that the representation of a sea made them feel worse because it reminded them of previous experiences.

Similar comments from experienced staff on ferries suggest the effect of seeing a moving sea through the windows can be different from what scientific literature suggests, that is the view may be detrimental to one's well-being. This indicates there is a difference between qualitative findings over large numbers of people and individual experiences when it comes to seasickness. Again it shows the value one should give to such subjective measures. Field testing is necessary to establish a clearer view on the effects in context. With regard to such field experiments we suggest to consider presence and its effect on what people judge as their perceptual reference. We expect that the extent to which people do feel part of the projected lighting scene can influence the overall effectiveness. Further practical advice for testing can be distilled from the requirements report.

The initial focus of this project on a dynamic lighting solution within a windowless cabin may have merit but less so than originally expected. Having discussed this project with interviewees onboard two ferries it appears seasickness may or may not be a large problem depending on the weather and type of ship. When people do get sick the cabins are seen as part of the solution by ferry employees and not, as assumed, part of the problem. It was therefore suggested to reconsider the focus from cabins to public spaces onboard where people actually spend most of their time. Alternatively a limited number of cabins could incorporate the Stabilight concept as a special service to sensitive passengers.

An aspect not explored in this project is the 'interestingness' factor of helpful visual stimuli. As participants remarked during the focus group and prototype evaluation the provided stimulus should be interesting enough to hold attention. We can imagine using an interactive experience to engage people and perhaps stimulate predictability by getting people to anticipate movements. As an example consider a driving game where the road ahead is shaped according to predicted movements of the vessel. Playing the game could increase engagement and the feeling of being part of the game world. We offer this as a suggestion for a future project.

6.3 Conclusions

Previous studies have shown that the general idea of using dynamic light to negate motion sickness can work. This project has laid down the most relevant scientific state of the art and has made a start towards understanding human experiences based on the qualitative research conducted. Generalizability of the results is an issue due to relatively small numbers of participants per method used. Further research should be conducted to prove the results can be generalized.

A clear gap in the current knowledge is how ferry passengers experience the trip and how they value the impact of motion sickness. Within this project the inquiry is limited to first hand experiences of ferry staff and their second hand impression of passenger experiences. We recommend that this important knowledge is taken into account during future projects.

One important question which cannot readily be answered from the findings of this project is whether the Stabilight project should be continued. Scientific evidence is available to prove the core of the idea but we feel a test in context would be better suited to evaluate whether dynamic lighting has merit in ameliorating sickness effects from the users' perspective.

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