The Effect of Motion on Presence During Virtual Sailing for Advanced Training

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Abstract

This paper explores the amount of motion simulation required to influence presence and immersion on a dinghy sailing simulator. We specifically focused on the effects of roll, pitch and heave, when sailing an course with up-, side-and down-wind sections in a virtual environment. A real dingy was mounted on a 6 Degrees of Freedom (DOF) Stewart platform; the participants could influence the course of a virtual boat by a rudder while experiencing physical displacement by simulated wind and waves. Five experienced sailors completed the same course several times while subjected to varying motion conditions. Results show a positive effect on presence and immersion when adding simulated motion in multiple degrees of freedom to the dinghy sailing simulator, especially by roll (>20 degrees necessary), while pitch is of less importance (<5 degrees necessary) and heave (less than 10 cm) can almost be neglected. These findings are of importance for developing boat simulators and other virtual sports applications that employ actuated platforms.

Keywords: **Sailing, Dinghy, Presence Questionnaire, Virtual reality, Training simulation, Motion platform**

1. The Effect of Motion on Presence During Virtual Sailing for Advanced Training

Virtual reality provides performance athletes tools to practise specific situations and can enhance learning speed of certain skills. For training sports such as sailing, it is known that the embodied interaction by physical movement is contributing to the sense of presence. Olympic sailing athletes have a requirement to train consistently and develop their knowledge and skills in a highly competitive environment. Skills are generally acquired by learning a set of facts about a task and developing appropriate procedures (Lathan et al., 2002). In a dinghy sailing context, the practise part of training often cannot be done in the actual situation, as the conditions in competitive sailing are never exactly the same. In these situations, a sailing simulator can provide an alternative training environment, that simulates the target task and environment.

We expect that by adding actuated rotation and translation to a sailing simulator, the presence will increase, thus having a positive effect on the effectiveness of the training program. However, the techniques to recreate movement by actuator-sensor networks are complex and consume a lot of resources. Walls et al. (1998) developed a sailing simulator that incorporates a mathematical model of dinghy sailing dynamics. This was later developed in a simulator system that[1] includes a moving dinghy, known as the VSail-Trainer. However, the level of realism offered by the proposed system lacks in the display and graphics. Furthermore, all known sail simulators only offer 1 DOF movement, while actual sailing involves pitch and heave as well. This has never been assessed in terms of presence and immersion. In devising a true high-performance training system, we need to examine which type of motion influences the sense of engagement.

This paper explores which parameters are required to train sailing manoeuvres in a virtual environment, based on a 6 DOF Stewart platform and experienced test persons. The intended audience are peer researchers in the field of virtual training systems and sports innovation. After discussing related work, the experiment hypotheses are discussed. Then the method is discussed, including details on the sail simulation implementation and the assessment of presence. The results section presents the preferred motion settings and experienced presence. In a discussion, we reflect on the limitations of the selected method. Conclusions and future recommendations end this paper.

[1] http://www.virtualsailing.com.au

1.1. Related work

In literature, we found several virtual reality sports systems with embodied interaction. Those who also investigated presence in sports covered rowing, handball, cycling and basketball are briefly discussed below.

In Wellner et al. (2010), a rowing simulation was made in an immersive Cave Automatic Virtual Environment (CAVE) , with a racing boat fixed to a platform while spring-motors were attached to the blades to give haptic feedback on the water resistance. The aim of the study was to determine whether virtual competitors would change the behaviour of rowers. This was done by subjecting participants to a race track, observe behaviour and track times. Furthermore, the Immersive Tendencies Questionnaire (ITQ) and presence questionnaire (PQ) were employed to assess presence.

The handball study focused on comparing the goalkeeper's movements in a virtual reality

system to a real-life situation (Bideau, et al. , 2003). A large-cylindrical screen was used to immerse the goalkeeper in a virtual simulation, a motion capture system captured his motion patterns and timing. In this study, the observed data of arm position and displacement were sufficient to investigate the similarity in motion, no subjective assessment was performed.

A number of studies involve cycling. IJsselsteijn et al. (2006) specifically focused on the training a participant by including virtual coaches. Participants were using a typical fitness cycling setup with a wall projection. To assess the performance the experiment included both observations (cycling speed, heart rate) and questionnaires ITC-Sense of Presence Inventory (ITC-SOPI) and Intrinsic Motivation Inventory (IMI). In Mestre et al. (2011), the influence on visual and auditory feedback on performance and enjoyment was studied by a similar setup. In this case, a motor was used to modify road resistance to mimic uphill or downhill scenarios.

A recent study on basketball (Covaci et al., 2012) explored practicing a free throw game indoors. Participants were put in a CAVE and a tethered position

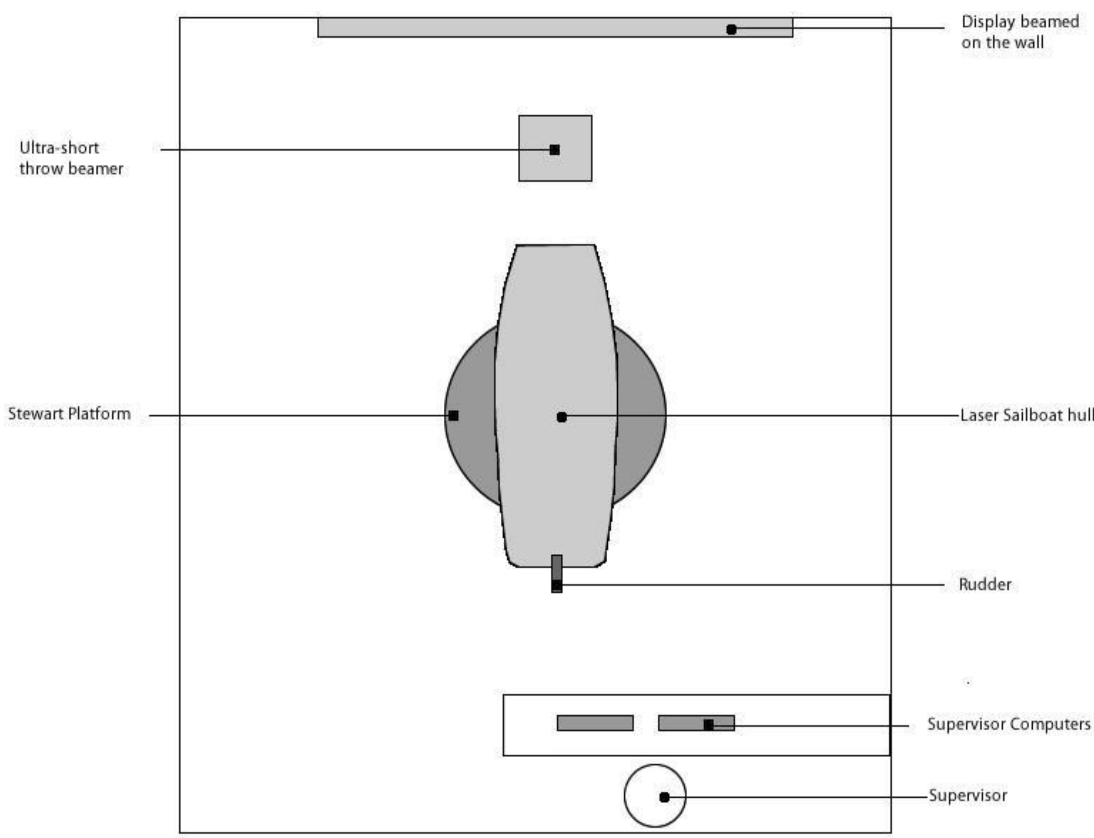

***Figure 1.* Physical layout of the experimental setup.**

tracking system was used to track arm movement. An undisclosed questionnaire was used and a comparison was made between successful free throws in a real field and in the simulated field.

1.2. Experimental hypotheses

1. If movement is added to a virtual dinghy sailing simulator, then roll is considered to be essential to enhance the feeling of presence.
2. If pitch is added, than it can be considered to be important to enhance the feeling of presence.
3. If heave is added, than it can be considered to be important to enhance the feeling of presence.

2. Method

This section introduces the experimental setup, the participants, variables and procedure of the experiment.

2.1. Experimental setup

The test setup is shown in Figure 1 and consisted of a Laser boat hull, shortened at the front and mounted on a 6 DOF Stewart platform by using a custom low-profile wooden frame. The frame was designed to bring the instant centre of rotation closer to the virtual water level. The boat was equipped with a standard rudder, which could be used by the participants to steer the boat in the virtual environment. A fixed mainsheet rope was installed in the boat allowing the participants to perform standard sailing manoeuvres. However, the rope had no effect in the virtual environment: the assumption was made that all participants sailed with a perfectly trimmed mainsheet rope. The hull was also equipped with a hiking strap to allow subjects to hike out, e.g. while tacking.

The experiment was conducted in a large room with no windows to avoid bright sunlight influencing the screen visibility. One ultra-short throw projector (Hitachi ED-A101) was used to display a sailing scenario on the wall (screen diameter approximately 2 meters). Surround speakers mounted on a truss system were used for sound effects.

For software, the experiment relied on D-Flow (Geijtenbeek, 2011). It aids in creating immersive virtual environments through inclusion of the test subject in a 'real-time feedback loop' with a visual programming metaphor. The standard setup used for rehabilitation has been modified through the inclusion of the virtual rudder as a control device as well as the influence of the 'incident wind' on most of the variables in the simulated physics engine. In the rendered 8 view a hovering purple arrow indicated the direction of the wind, while the current Speed-Overthe-Ground (SOG) and track-time were indicated in text to the side. The camera view was 3 degrees of freedom in X and Y position as well as Z-axis rotation, determined by the position of the virtual boat (hidden). The conceptual model of the simulation is depicted in Figure 2.

As this experiment focuses on roll, pitch and heave, the simulation determined these variables by a collection of simulation parameters specified in Table 1. The virtual environment parameters were varied by the experiment supervisor based on the feedback of the participant's. The factors in this experiment were calculated by the

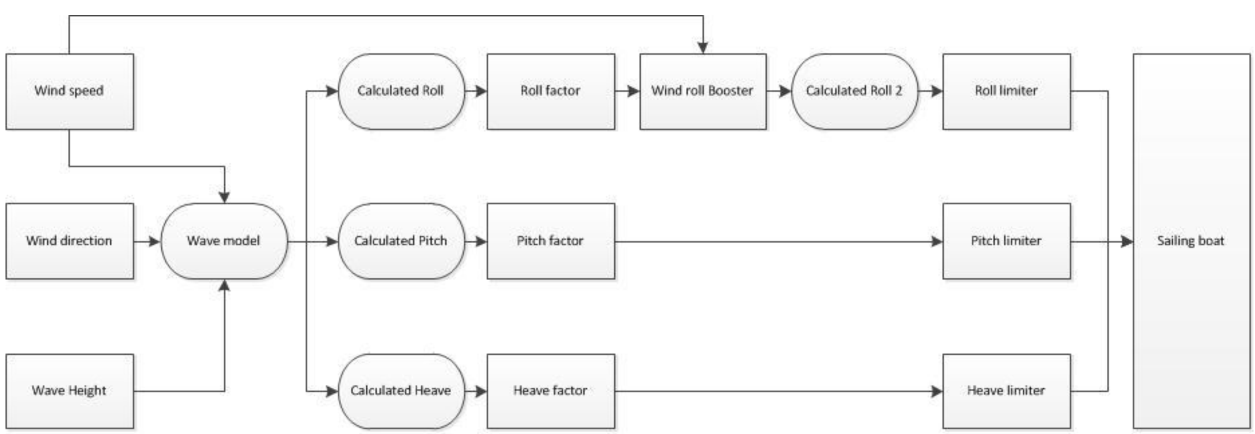

Figure 2. Conceptual model of the sail-simulation parameters in D-flow.

Table 1. Adjustable parameters during the session

Variable	Category	Description	
Maximum Roll	Movement	Limits the maximum angle of the roll	deg.
Maximum Pitch	Movement	Limits the maximum angle of pitch	deg.
Maximum Heave	Movement	Limits the maximum distance of heave	m
Roll Factor	Movement	Factor to influence the effect of the wave model on roll	
Pitch Factor	Movement	Factor to influence the effect of the wave model on pitch	
Heave Factor	Movement	Factor to influence the effect of the wave model on heave	
Wind Roll Booster	Movement	Factor to influence the effect of wind on roll, when the wind comes from the left or right side	
Rudder Factor	Control	Factor to influence the sensitivity of the rudder	
Wind Speed Wind	Environment	Sets the wind speed in the simulation	km/h
Direction Wave	Environment	Sets the wind direction in the simulation	deg.
Height	Environment	Sets the wave heights in the simulation	m

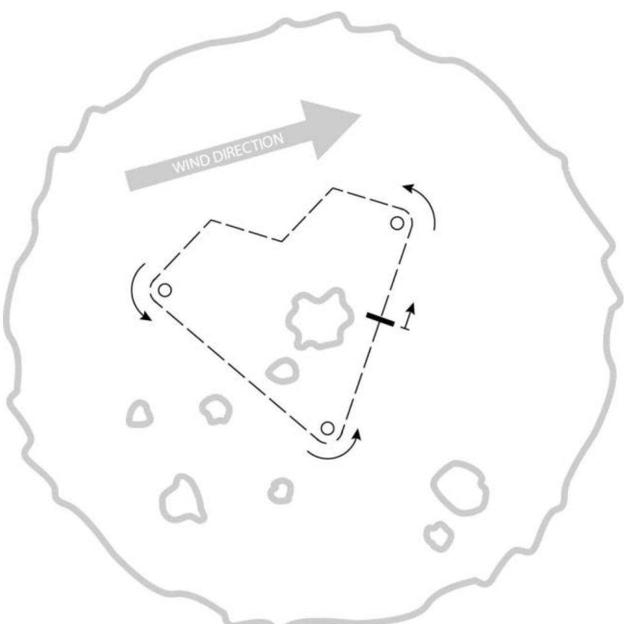

Figure 3. Map of the virtual sailing track

researcher to influence rudder sensitivity and the by D-flow generated wave model.

2.2. Test track

In the sail simulation, a closed-loop track was set up, consisting of three buoys with an up-, side-and down-wind sections (Figure 3). To aid guiding on the water, a landmass was set on the horizon surrounding the virtual lake. This was further enhanced by addition of smaller islands and large buoys with guiding arrows. The length of the track has been chosen to be long enough to allow for sufficient immersion but not too long as repeated trials would be performed.

2.3. Questionnaires

Slater and Wilbur (1997) defined presence as a state of consciousness, which is related to the sense of being in a place. Lombard and Ditton (1997) describes the concept of presence as "the perceptual illusion of non mediation '' which included social factors. Considering, presence is a subjective experience, post-experimental questionnaires are frequently used to assess presence (IJsselsteijn & van Baren, 2004). According to Witmer, Jerome and Singer (2005) questionnaire items are based on factors that have been identified to influence presence, for example immersion, involvement, sensor fidelity and interface quality.

In this experiment, participants completed a questionnaire on immersive tendencies (ITQ) before the experiment and on presence (PQ) after the sailing test. The ITQ was developed to measure the capability of participants to be immersed, whereas the PQ measures presence. Witmer and Singer (1998) have data from several experiments that indicate that PQ is a reliable and valid measure of presence. The PQ also has shown

Table 2. Overview of the sessions during the experiment.

Session	Roll (max degree)	Pitch (max degree)	Heave (max cm)
1	0 (no roll)	0 (no pitch)	0 (no heave)
2	0-20 (research value)	0 (no pitch)	0 (no heave)
3	Value session #2	0-20 (research value)	0 (no heave)
4	Value session #2	0 (no pitch)	0-20 (research value)
5	Value session #2	Value session #3	Value session #4

evidence of meaningful relations with learning. Both questionnaires were minimally adapted and analysed according to the suggested procedure by Witmer & Singer (1998).

2.4. Procedure

The participants received a short introduction upon entering the experiment area. Before the participants entered the sailing experimental setup, they were asked to fill in the ITQ. The total sailing procedure consisted of five sessions, whereas each session provided a different movement experience. In all sessions the participants were asked to sail the same course, which was designed in such a way that the participants experienced up-, down- and side wind (Figure 3). The sailing participants could not influence the roll with their body motion. This step will be evaluated in further research.

The sessions were performed in a structured order as shown in Table 2. The first session was designed to allow participants to get used to the physical setup, virtual environment, and rudder control. The participants were asked to comment their experiences to the experiment supervisor, who was allowed to change wind speed, wave height and rudder-factor until the participant had the feeling that the experience was optimal.

In the second session the roll motion experience was tested. The experiment supervisor was allowed to adjust the 'maximum roll', 'roll factor' and 'wind roll booster'. During sailing, the participants were asked to give subjective feedback to the experiment supervisor. According to this feedback, the supervisor increases or decreases the motion limitations until the subject perceives the simulated motion as realistic. As roll is considered to be vital for a sailing simulator, the value resulting from session 2 is added to the following three sessions. In sessions 3 and 4 the pitch and heave parameters were adjusted according to a similar procedure as in session 2. In the final fifth session the participants could experience all three types of motion combined and their subjective feedback was used to find the optimal setup by tweaking all movement parameters.

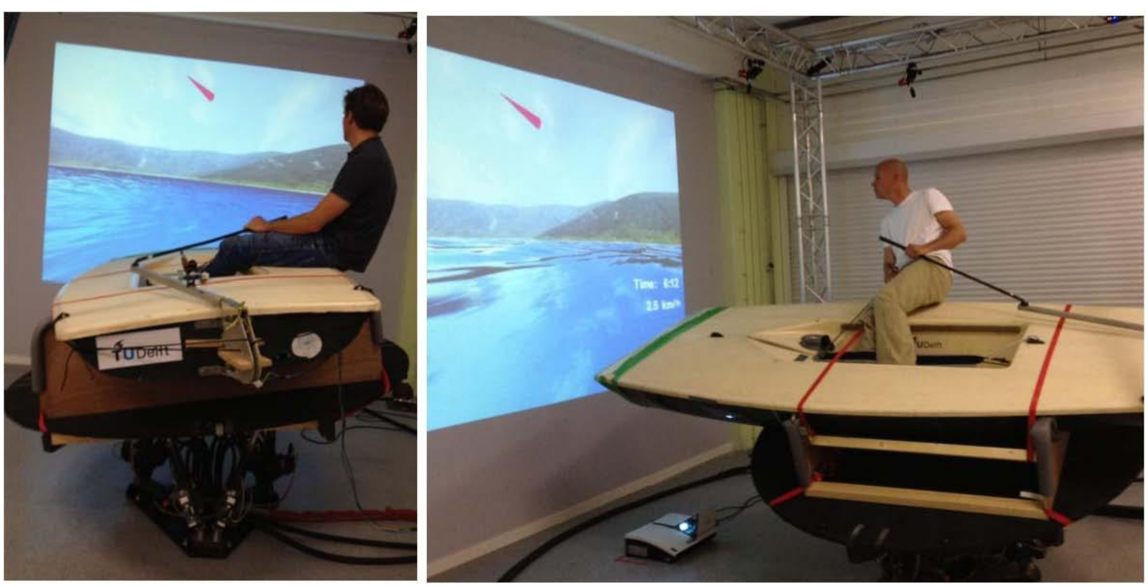

Figure 4. Impression of the sessions.

Table 3. Characteristics of the participants.

Number	Gender	Level	Experience	Current Class
1	Male	Competetive	International league	Laser
2	Male	Competetive	International league	Flying Dutchman
3	Male	Recreational	Youth Instructor	Laser
4	Male	Recreational	Youth Instructor	Laser
5	Male	Recreational	Youth Instructor	Yacht

After the sailing sessions participants were asked to fill in a PQ questionnaire. Then, they were interviewed in a separate location about their personal experiences and suggestions. A semi-structured interview method was used were participants were allowed to speak without being interrupted. All interviews were recorded with an audio-recorder.

2.5. Participants

Five male sailors participated in this study, cf, Table 3. All had experienced in sailing and teaching sailing, albeit at different levels: ranging from competitive to recreational. None of them had used this particular simulator setup before. However, three participants had experience on different sailing simulators, e.g. VSail-Trainer (Walls et al.,1998).

3. Results

The total experiment took about 1 hour to complete. Each participant completed the course in each session within 5 minutes. After the participants completed the course they were allowed to tune their preferred session-settings by sailing freely in the race area. Depending on the enthusiasm and feedback of the participants the total time of each session varied from 5 – 10 minutes. The questionnaires were completed in a few minutes and the interviews lasted 20 min on average. The final settings of each participant are displayed in Table 4, and the combined questionnaire results in Table 5.

3.1. Hypotheses and parameter preferences

The displacement data from the final session together with the subjective feedback from the interviews were mainly used to determine the necessary displacements and importance of Roll, Pitch and Heave. The general response of the participants to the experiment and the experienced displacement was positive. Comparing the displacement data and factors of all five participants, the calculated standard deviation is relatively low. This indicates that the participants 'preferred settings' correspond.

3.1.1. *Hypothesis 1. If movement is added to a virtual dinghy sailing simulator then roll is considered to be essential to enhance the feeling of presence.*

Table 4. Final settings as recorded from session.

Nr	Factor	Unit	Sailor 1	Sailor 2	Sailor 3	Sailor 4	Sailor 5	Mean	SD
1	Maximum Roll	deg	20	20	20	20	20	20,00	0.00
2	Maximum Pitch	deg	2	4	6	4	8	4.80	2.04
3	Maximum Heave	m	0.12	0.08	0.08	0.12	0.12	0.10	0.02
4	Roll Factor		1.00	1.00	1.57	1.00	0.90	1.09	0.24
5	Pitch Factor		0.4	0.56	0.64	0.53	1.23	0.67	0.29
6	Heave Factor		0.28	0.06	0.12	0.22	0.25	0.19	0.08
7	Wind Roll Booster		4.0	4.6	2.0	2.8	3.0	3.28	0.92
8	Rudder Factor		150	150	150	200	200	170,00	24.49
9	Wind Speed	km/h	6	6	8	10	12	8.40	2.33
10	Wind Direction	deg	85	85	85	85	85	85.00	0.00
11	Wave height	m	0.5	0.5	0.6	0.3	0.3	0.44	0.12

Table 5. Questionnaire results, Answer scales were from 1 to 7; Immersive Tendencies Questionnaire (ITQ); Presence Questionnaire (PQ).

Variable	1	2	3	4	5	Mean
ITQ_{Focus}	5.1	5.0	4.7	5.9	4.9	5.1
$ITQ_{Involvmt}$	5.5	4.5	3.0	3.5	4.0	4.1
ITQ_{Games}	2.0	1.0	1.5	3.5	2.0	2.0
ITQ_{Total}	4.5	4.2	3.8	4.7	3.9	4.2
$PQ_{inv/ctrl}$	2.7	4.2	4.5	5.7	4.9	4.4
$PQ_{Natural}$	2.3	3.3	2.7	6.0	5.7	4.0
$PQ_{Sensory}$	3.2	3.0	3.0	5.4	4.8	3.9
$PQ_{Distract}$	4.0	3.5	2.8	3.3	3.0	3.3
$PQ_{Realism}$	3.0	2.7	2.7	4.0	3.7	3.2
$PQ_{Control}$	2.5	4.7	4.1	5.9	5.5	4.6
PQ_{Total}	2.5	3.8	3.5	5.2	4.6	3.9

When only analysing the displacement data (Table 4, 1-6), it can be seen that the roll displacements (M = 20 deg, SD = 0) can be considered as most important. The measured displacement data corresponds to the subjective feedback gathered during the interviews. The roll factor (M = 1.09 SD = 0.24) is higher than 1, increasing the influence of the environment to the roll angles. Due to the limitations of the Stewart platform no maximum roll angels could be determined.

3.1.2. *Hypothesis 2. If pitch is added than it can be considered to be important, to enhance the feeling of presence.*

Although, roll in combination with pitch is considered to be more engaging, the necessary pitch angle determined from the fifth session (M = 4.80 deg, SD = 2.04) is under 5 degrees. Furthermore, the pitch factor (M = 0.67, SD = 0.29) was less than one, reducing the effect of the environment on the pitch motions. Therefore, pitch be considered of less importance.

3.1.3. *Hypothesis 3. If heave is added than it can be considered to be important, to enhance the feeling of presence.*

The combination heave, with roll is considered to feel ‘unnatural’ to all participants. However, when adding heave to roll and pitch, low heave displacements (M = 0.1 m, SD = 0.02) are acceptable. The subjective feedback from the interviews indicated that heave displacements are quickly perceived as extreme, making the wave sensation unrealistic. Subjective feedback from the participants indicated that sensing the influence of the heave as performed in session 5 was difficult. Although, at first the maximum values seem not really low, participants preferred to have a low heave factor (M = 0.19, SD = 0.08) reducing the influence of the waves on the heave value to almost a minimum. Therefore, in our opinion the heave displacement can almost be neglected.

3.2. Presence and immersion

Although the session settings of all the participants were similar, there could be made a clear distinction in subjective feedback and sense of presence between the competitive and recreational sailors. The recreational sailors clearly achieved a higher sense of presence with this experimental setup. An explanation for the more critical approach of the competitive sailors may not only be the amount of experience in a Laser these participants have. It can also be explained by higher scores on the ITQ involvement factor. Therefore, a comparison was made of the data for both groups separately.

3.2.1. Competitive sailors. Participant #1 is specialised in the Laser class and competed in Olympic events. From the interviews could be concluded that he was very positive about the roll motion but the pitch and heave were in many cases to extreme for him. Although the three types of motion challenged him to perform certain sailing manoeuvres, he had difficulties managing to fuse the visual information from the screen with the perceived motions. The visualisations of the waves where not realistic which had a large influence on his sense of presence (PQtotal = 2.5, ITQtotal = 4.5). Therefore, during the sessions he was asked by the experiment supervisor to shift his focus on the displacement factors only. In the interview he mentioned that the displacements quickly stimulates and challenged him to sail, although the movements were not natural enough to achieve a high sense of presence.

Participant #2 was more positive than #1, as manifested in a higher sense of presence (PQtotal = 3.8 ITQtotal = 4.2) and his statement that the experimental setup can act as a core of a future sailing simulator. From the interview could be concluded that he had less difficulties to shift his focus on displacement. Roll displacements were perceived as natural, at some occasions he could predict the displacements before they were happening.

3.2.2. Recreational sailors. Participant #3 had experienced in other simulators, which can explain the lower sense of presence and more the more critical feedback in the interview and questionnaires. This explains why this participant scores resemble the competitive sailors.

Participant #5 was able to name most shortcomings of the experimental setup matching the critical approach of the competitive sailors. However, as an experienced trainer he could recognize the potential of this experimental setup, which can explain the higher rating of presence. He suggested that this setup could already be used to train novice sailors on roll performance. Although, less critical in his feedback this position also applies to participant #4.

4. Discussion

We only had a limited amount of time to implement the sail simulator and to carry out the experiments. This raised issues that require further discussion.

4.1. Sampling

Given the exploratory setting of our investigation, the results contain sufficient data to determine the effect of pitch, roll and heave for later implementations. However, the number of participants is too low to perform proper statistical generalization. Furthermore, we can identify differences between the competitive and recreational levels. Based on the PQ answers and interviews, the required level of realism is much higher for competitive sailors. From the observations, this group preferred lower wind speeds and higher waves. In follow-up experiments, we will engage participants from a more homogenous level.

4.2. Sail simulator limitations

This study employed a hydraulic Stewart platform with a maximum tilt angle of 20 degrees – we already knew from on water field tests that the roll angle of a real dinghy can be much larger. In extreme manoeuvres such a roll tacks, the angle is 45 degrees. This disabled us to determine the maximum value of roll. Furthermore, during straight lifts the platform moved the boat asymmetrically. This is caused by weight of the sailor being of centre and the performance limitations of the platform.

The computer simulation included a crude implementation of waves and hydraulic behaviour – it did not display realistic wave fields or wind gusts as normally experienced on the water. The involved computer graphics did visualize the environment and the objects of study, but lacked physical reality in rendering. This was noticed by all participants, and should be improved to get a better directional sense.

The computer graphics were cast on a wall by a single ultra-short throw projector. A wider view would improve the engagement, to experience wave changes and motion parallax in the peripheral vision.

5. Conclusion and recommendations

In this article we presented the pilot study of an experimental setup to test physical motion of a dinghy during competitive sailing. This included a real boat mounted on top of a Stewart platform, able to move in 6 degrees of freedom. Five participants with sailing experience were involved in setting the parameters of roll, pitch, and heave.

Although the statistical data is not conclusive enough, the findings show that the roll angle is extremely important; due to platform limitations the preferred maximum value could not be determined. Pitch adds some realism to the sense of sailing, a maximum angle of 5 degrees is sufficient. Heave (vertical movement) is only important in combination with roll and pitch. Furthermore, participants preferred a low heave factor reducing the preferred heave displacement (10cm) to a minimum.

There is a difference in preferences between sailor levels: competitive level athletes require higher levels of realism than the current setup could offer in terms of computer graphics. Visuals are specifically important to convey a sense of speed. Novice sailors may accept the level of graphics of the current setup.

To obtain solid findings we are planning a follow-up experiment in order to create a high-performance sail simulator.

In future systems, motion capture should be used to allow sailors to compensate the boat movements with their body weight. Furthermore, a wider display with more graphic detail should be used (wave behaviour, hydrodynamic modelling). For testing, we will focus on a single level of sailors to get more robust findings.

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