Using Hand Gestures To Control Electric Vehicles

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MASTER THESIS

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Abstract

The automotive industry is now electrifying at a faster rate than ever before. Everything from electric bikes to Segways and electric longboards requires new kinds of interactions to control the engine. For example, Segway has used the user's tilt to decide whether they want to go forward or backward. Electric longboards often use a handheld controller that has a gas button. Now, this electrification is coming to surfboards. The Swedish manufacturer Radinn offers various electric surfboards with a handheld wireless controller to accelerate when pressing a throttle button. However, it is interesting to find out new kinds of interactions for this kind of electric boards. Therefore, we investigated the possibility of using different hand movements as an interaction to control the surfboard. The result was a new gesture controller that controls the board by raising and lowering the hand. By raising the hand, the surfboard accelerates. Lowering the hand lowers the speed. Comparison of the System Usability Scale and NASA Task Load Index scores between the new and old controls showed that the traditional solution is better on virtually all fronts. The difference is believed to be partly due to the physical feedback and limitation that users receive from a traditional controller, but which is lacking when using hand gestures. The master thesis is an initiation for exploring alternative interfaces and provides knowledge of users' surfing behavior and gesture preferences that can be built on to develop the concept further.

Sammanfattning

Fordonsindustrin elektrifieras just nu i en snabbare takt än någonsin. Allt från elektriska cyklar till Segways och elektriska longboards. Alla dessa kräver nya sorters interaktioner för att styra motorn. Segway har till exempel utnyttjat användarens lutning som ett medel för att bestämma om personen vill åka fram eller bak. Elektriska longboards använder sig ofta av en handhållen kontroll med en gasknapp på. Nu har denna elektrifiering kommit till surfbrädor. Den svenska producenten Radinn erbjuder flertalet elektriska surfbrädor som i nuläget styrs med en trådlös kontroll som hålls i handen och gasar genom att trycka ned en gasknapp med tummen. Det är dock intressant att ta reda på nya sorters interaktioner för elektriska brädor. Det har därför undersökts en möjlighet för att använda olika handrörelser som interaktion för att styra surfbrädan. Resultatet blev en ny gestkontroll som styr brädan genom att höja och sänka handen. Höjs handen, gasar kontrollen, sänks handen, sänks hastigheten. Jämförelse av System Usability Scale och NASA Task Load Index poäng mellan den nya och gamla kontrollen visade att den traditionella lösningen är bättre på i princip alla fronter. En stor del av detta tros vara på grund av den fysiska återkopplingen som användare får av en traditionell kontroll men som saknas i den handrörelsebaserade kontrollen. Examensarbetet är en initiering för att utforska alternativa gränssnitt och ger kunskap om användarnas surfbeteende och gestpreferenser som kan användas för att vidareutveckla konceptet.

Keywords: User Interface (UI), User Experience (UX)

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Contents

Chapter 1

Introduction

This chapter will give a short description of the thesis's goal, problem specifications and a background for the product we are developing. An overview of the design process, related work and the writers contributions to the thesis will also be mentioned.

1.1 Background

Electrified transport vehicles are currently being developed at a faster pace than ever before. Not long ago, products such as the Segway, OneWheel, and Electrical Longboards were only a thing of the imagination. These new products have developed new exciting ways of human-computer interactions. For example, the OneWheel and Segway capitalize on the users standing position to determine the speed. If the user leans forwards, the product moves forward, and if the user leans backward, it backs. Electrical Longboards often use a handheld controller that controls the speed via a throttle button. These new interaction designs have enabled new transport vehicles for the masses. Before, driving a longboard as a transport vehicle required hours of practice; now, it can be used by amateurs in a fraction of the time. Now the electrification has come to surfboards. They are currently being controlled with a handheld controller. This thesis will investigate the possibilities of a new type of interaction with the surfboard, using hand gestures to control the speed. For capturing the user's hand gestures, a smartwatch with an accelerometer and gyroscopes will be used.

1.1.1 Radinn

Radinn is a company whom develop and produce electrical jetboards. The jetboard speed is controlled with the help of a handheld controller. A picture of the board and controller can be seen in figure 4.2 and 4.3. Using one single hand, the driver presses the throttle down with the thumb to increase speed and releases the pressure to slow down. In addition to managing the speed, the controller also has four LEDs on the device's side. At first, when the jetboard and controller are turned off, all the LEDs are turned off. Once the controller is turned on, the LEDs act as a battery indication. If the battery is full, all four LEDs are on; if the battery is empty, no LED lights. To use the controller with the jetboard, the user needs to connect them. When the controller tries to connect to the jetboard, all of the four LEDs start to blink synchronously. Once the connection is complete, the controller switches to showing the battery of the jetboard instead of the controller's battery. This process can be tricky for customers to understand.

However, this is not the only flaw with the controller. It is also described as clunky and old-fashioned. The relatively big device is attached around the driver's wrist using a safety wire, making it possible to drop the controller and not lose it accidentally. But since the controller is rather large, it becomes in the way when surfers try to swim with their hands on the board.

Furthermore, ergonomics of the existing controller could be argued to be inadequate based on the findings in "Effects of Finger Posture on Carpal Tunnel Pressure During Wrist Motion" by Peter J. Kier et al. [1]. Most likely, the finger posture that is continuously used while boosting with the controller harms the carpal tunnel's health. The study's findings showed that with metacarpophalangeal joint angles at 90 degrees, the pressure is high in the carpal tunnel. The metacarpophalangeal joints are where fingers attach to the hand, and this pressure is an important associating factor for Carpal Tunnel Syndrome. While using the controller, these joints are angled and the thumb is pressed down with a 90-degree angle towards the end of the button. There is also a physical resistance in the button's actuation, which requires more pressure from the thumb.

All in all, the controller requires improved usability with an emphasis on visibility. Therefore, there is an interest in exploring the possibilities of using hand gestures with a wearable to control the surfboard. This new controller aims to improve the user interface (UI) and the user experience (UX) compared to the old, handheld controller.

1.2 Problem Specifications

As Radinn's controller has several flaws with their product, it is of interest to develop and try new interaction designs to improve the usability for their customers. Therefore, the problem specification for this thesis will be to compare how a new controller stands out compared to Radinn's handheld controller. As for this thesis, the new controller will be a gesture based controller. It will also compare how the product's UI compares with the new controller UI compared to Radinn's flashing LEDs.

1.2.1 Our Selected Hardware

In order to use hand gestures for controlling the jetboard, the hand gesture must be measured and recorded. For this purpose, we use a smartwatch from Sony, conveniently called Sony Smartwatch 3. The choice for a smartwatch controller was due to it having sensors such as an accelerometer and gyroscope that can be used to measure how the user moves and angles his hand and is waterproof to a certain extent, which is essential for the product. The smartwatch also solves another problem, the UI. By using the built-in screen, showing statuses such as jetboard battery and connectivity can be easy. It can also display the drivers' speed using the built-in GPS, which delivers additional content to the user compared to the old controller. The wearable has Bluetooth compatibility, which is needed to communicate with the board. When the smartwatch is wet, its touchscreen might not register any touch input, but it can help set up and configure the system before surfing.

1.2.2 Scientific Questions

- Does gesture controlling improve the usability of jetboards?
- How can wearables and gesture interaction be designed to support interaction in a watersport environment that involves challenges such as body pose control and human-aquatic interactivity?
- Is it possible to improve the existing UI for jetboard battery and connectivity status with a smartwatch application?
- Does a gesture based controller enhance or reduce the mental task load for users?
- Does a gesture based controller enhance or reduce the Usability of the System?

1.3 Our Contributions

This project aims to deliver on knowledge for Radinn in three main areas. First, for examining the feasibility of improving the existing surfing experience by the hand gesture solution. Secondly, identifying if the usage of a smartwatch can reduce the UI/UX's current complexity, helping new customers understand system communications such as battery life and connectivity to the board. On top of that, a study of how wearable technology can improve user experience during a ride.

We are equally involved with our conducted studies. As for implementation, Julian has been developing more of the connection and Bluetooth integration, while Kasper has been more involved with the product's controller and screen UI.

Chapter 2

Related Work

Hand gestures are part of the human communication channels and appear along with speech as body language to convey information. They belong as a novel mode for human-computer interaction in gestural interfaces. In the center of our focus are midair hand gestures for the development of an alternative design to the prior controller of the Radinn jetboards. See figure 2.1 for an example view of gestures in still motion.

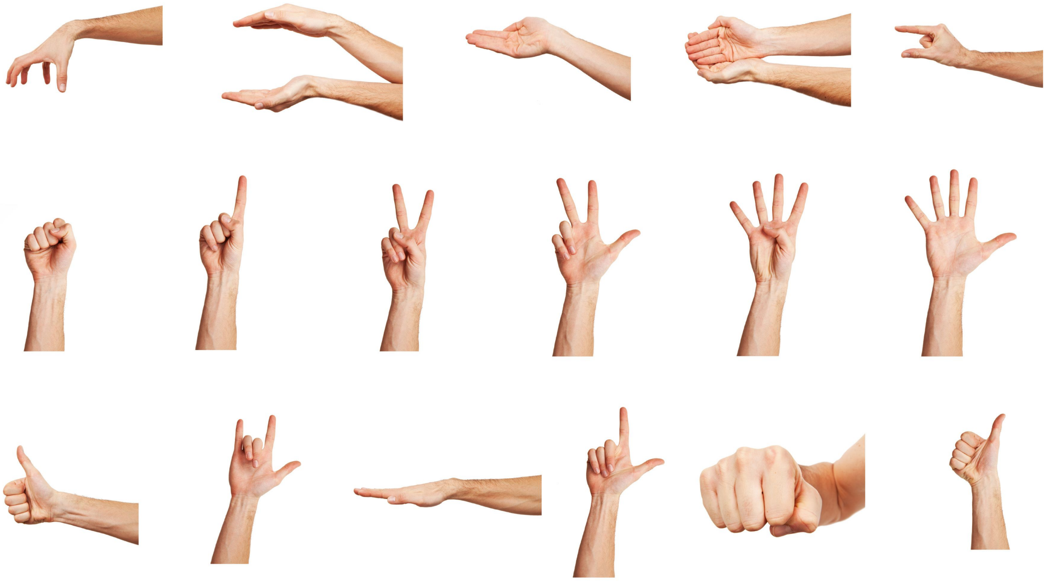


Figure 2.1: A set of hand gestures [2].

2.1 Research

Similar works are in experimental phases of developing gestural interfaces. Sofia Pescarin et al. [3] approach gesture based interaction systematically by citing taxonomies intended for classifying gestures such as the one by Karam and Schraefels [4] for human-computer interaction. Aigner et al. [5] conducted a study of Human preferences, a joint study of companies and academia, which extends the same taxonomy further into five different types: Pointing, Semaphoric, Pantomic, Iconic, and Manipulation Gestures.

The first work uses a gestural interface to enhance museum visits. The latter uses interactions more broadly to determine mappings of user-defined gesture types for generic tasks in content creation, manipulation, management, and navigation. Both teams use Computer Vision to recognize gestures, and it enables gestures to be recognized without requiring any physical contact with an input device, whereas we require a wearable.

Sofia Pescarin et al. have evidence that human-machine communication done with gestures is dependent on cultural ties, which both studies noted as a potential limitation. This is shown in "NICH" as the selected users for their experiments came from Sweden, Italy, and Egypt. When asked to mimic actions with a gesture "show an object, selection" and gesture "turn the object, rotate", there were dissimilarities in each country-specific group's execution. When apps are in more languages to widen the potential user base, and language being a cultural dependency, we can presume the culture of a target user demographic to also play a role in choosing a mapping of gestures for controlling a jetboard due to the found evidence. Since Radinn are selling their boards globally, it is important to take this factor into account.

The study “Understanding Mid-Air Hand Gestures: A Study of Human Preferences in Usage of Gesture Types for HCI” comes up with guidelines for designers and researchers for ten different gesture effects. Yet, as most of their examined gesture effects do not match the interactions we are looking for when controlling a jet board, one of their gesture effect “Refuse” is feasible for a match as their definition for this effect includes “stop”. Our first user study has most users being positive about using an open hand and waving sidewards for the gesture “Wave no with open hand” to decelerate the jetboard, which is precise with their user's behavior for gesture effect “Refuse”. With this, we strengthen their findings that there are preferences in using gesture types for this effect as both of our results were highly consistent. Back to the point before that, there is a cultural dependency; the authors Roland Aigner et al. add, “While particular gesture selections may vary across cultures, we hypothesize that only minor differences in gesture type would be observed”. If this is true, then translating a set of gestures across one culture into another might be solved quicker by examining the gesture type of a gesture beforehand and then retrieving a new one from the set of its type to inspect if it is suitable.

Donald A. Norman and Jakob Nielsen [6] write about the problems gestural interfaces tend to have in “Gestural Interfaces: A Step Backward In Usability”. While they say that gestures add fun, they have trouble following fundamental interaction design principles. We could not find a 100% reliable implementation for recognising a wrist flick and many other gestures for a wearable in the literature. This is bad. According to the authors, lack of consistency is a threat to the viability of such systems, and that “these interaction styles are still in their infancy, so it is only natural to expect that a great deal of exploration and study still needs to be done.”

Chapter 3

Approach And Theory

This chapter will describe the process of the thesis and a theory part for scientific methods used in the work.

3.1 Overview of the Design Process

The Design Process used in the report is in figure 3.1. At first, preliminary research on gestures and technical implementations was done. A Field Study was then conducted to analyze how users operate the board, from beginner to expert level. Potential gestures for controlling the board were then body- and brainstormed. Next, these gestures were analyzed in a user study to gain insight into which were the most liked for implementation. Based on the feedback from the user study, four different controller prototypes were implemented. The prototype implementations were tested on the water together with a jetboard to find out which to optimize. Lastly, a final user study was performed on the optimized controller to determine the newly made controller's user experience. The final study was performed on land and used the NASA Task Load Index and System Usability Scale (SUS).

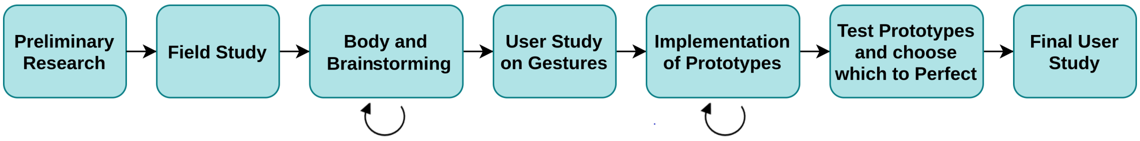


Figure 3.1: Methodology used in the report

3.2 Theory

The theory will explain important concepts used in the work.

3.2.1 Field Study

A field study is a qualitative method for gathering data and gaining insight into natural behaviour by observing people in a specific scenario. A group of people is set into the specific scenario, and the researchers are observing and analysing the way they interact in that specific scenario [7].

3.2.2 Bodystorming

Bodystorming is the act of prototyping different new technologies by acting them out. The goal is not just to formulate new ideas, as with brainstorming, but to act them out and feel how they are being embodied. [8]

3.2.3 System Usability Score

System Usability Score (SUS) is a test to understand how well a product's usability is. SUS has a scoring system with 500 underlying products as a foundation. It is concluded from all of these studies that the average product gets a score of 68. Meaning that if a product gets a lower than 68 SUS score, it is below average in usability, while if it is higher than 68, it is above average. A score of 80 results in being within the top 10 percent of all product's usability. The SUS questionnaire consists of ten claims that users are set to answer. For example, "I think that I would like to use this system frequently", "I found the system unnecessarily complex", "I found the system easy to use". The scores from all of the claims are then used to calculate the final score of the product. The full guide of the test can be found in the references [9].

3.2.4 NASA Task Load Index

NASA Task Load Index (NASA TLX) is a test to measure how much task load the users experience when using the product. Since task load is a negative concept, designers want to have as low of a score as possible in the NASA TLX test, resulting in a low task load for users. The Task Load Index measures six different categories: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration. The final score scales up to 120, and a score of 10-29 is considered to have a "medium task load" for users, while a score of 30-49 is considered to have a "somewhat high task load". If the score is less than 10, it is considered to have a low task load [10, 11].

Chapter 4

System Design

This chapter will shortly describe how the system operates and the components needed to make the product work. The blue marking in figure 4.1 signifies that this chapter is a part of our "Preliminary Research" in the design process, as mentioned in chapter 2.

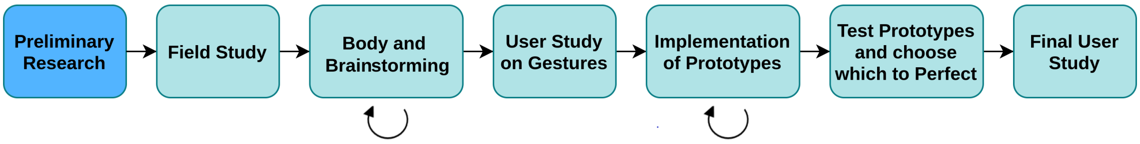


Figure 4.1: The Preliminary research

4.1 Radinn's product

Today, Radinn's solution consists of four different main components. One being the controller seen in figure 4.2 and the second being the board, which can be seen in figure 4.3, third being the dead man's switch and the last being the jetpack in figure 4.4. The board's physical form is 190 cm in length, 70 cm in width, and 12 cm in height and weighs about 45kg when the battery is connected.

Figure 4.2: The Existing Controller that Radinn currently use [12].

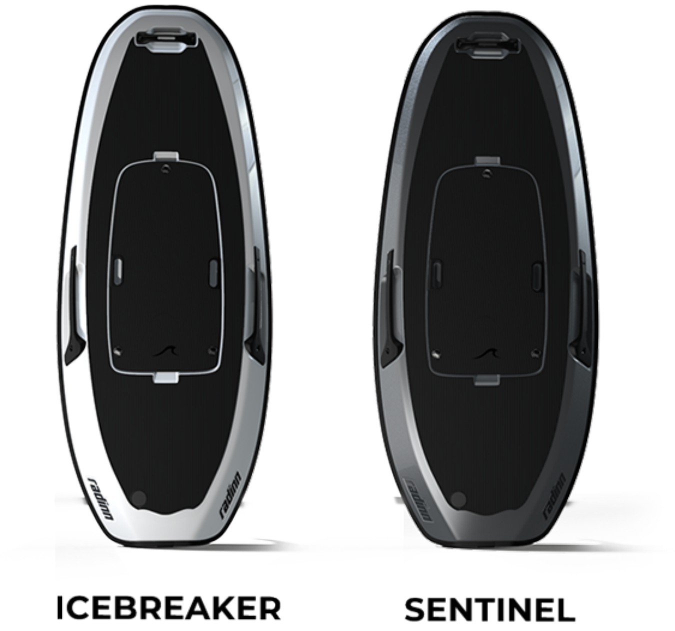


Figure 4.3: Two of Radinn's jetboards [12].

Figure 4.4: Radinn's board, together with the driving jetpack and the battery [12].

4.2 System Architecture

Figure 4.5 shows a brief description of how the two controllers operate together with the board. The board is coupled with a worn hand controller strapped around the middle of the hand. There is a round magnet acting as a dead man's switch, which fits a circular insertion point at the back of the board and is attached to the user's leg at the start of a ride. If the user falls off the board, the wire pulls the magnet out of the board, and the engine turns off immediately. The board communicates with the Radinn's controller using Gazell but uses Bluetooth Low Energy to communicate with the smartwatch.

Our unique smartwatch solution used in this thesis to record users' hand gestures will communicate more information than Radinn's solution. With Radinn's solution, the board continually advertises to the controller that it is available. Once they are paired, it sends battery status, and it listens to the speed given by Radinn's controller. As for the smartwatch solution, the board advertises availability until it has connected with the smartwatch. It continuously sends data such as battery status, dead man's switch attachment status, and the board's current speed while simultaneously listening to speed inputs from the smartwatch. LEDs of the Radinn's controller represent the battery status or connection status, while the smartwatch application shows more screen information.

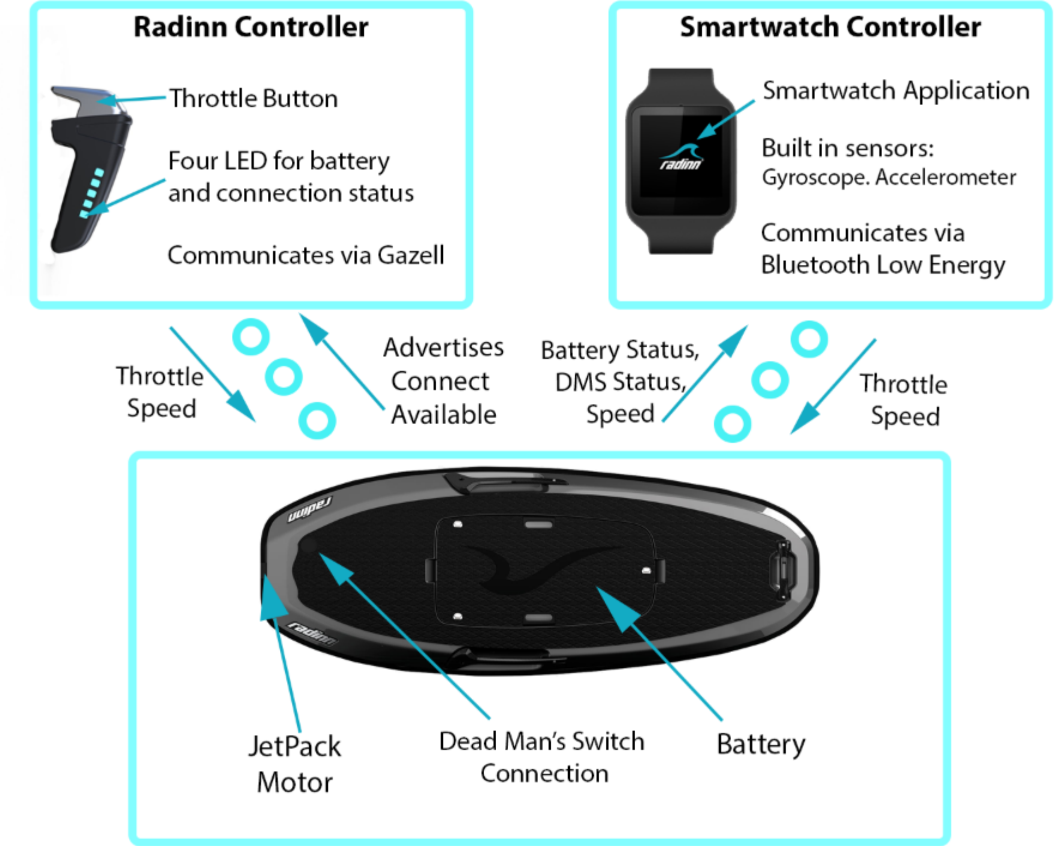


Figure 4.5: System Architecture with Radinn's controller and Smartwatch solution [12].

Chapter 5

Field Study

A Field Study was set up to gain a basic understanding of the product and its users. The goal was to explore natural body movements and actions while driving and understand the constraints for developing a gesture based controller.

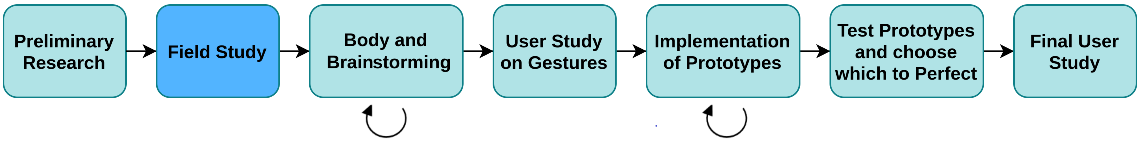


Figure 5.1: Field Study part of the design process.

5.1 Experimental Setup

Eleven different users participated during an After Work that the company had set up and were analyzed, from beginner to average and to the advanced level. Observations of users were structured after sex, age, and the level of surfing skill each user possessed. The number of falls was documented, but not all were captured, and notes were written down about how each user operated the board. On top of that, we captured videos of each person. Video content analysis generated input, which merged with the previous notes gathered from the real-time observations.

5.2 Takeaways

Key takeaways from the Field Study are listed here. There are more detailed notes on each of the users in the study in the appendix. (see Table A.1)

- Users start driving by laying on the board and eventually rise as the speed increases. It is challenging and almost impossible to stand on the board with no speed.
- Users typically use the support of at least one hand on the board when trying to stand up on the board.
- Some experts want to place one hand in the water when making a sharp turn.
- Most of the time, users have their hands in the lower peripheries of their body when surfing upright.
- Skilled users tend to drive towards waves to make jumps in the water. They try to do tricks with the board, which results in spontaneous hand gestures to regain balance.
- Driving fast requires either a lounging body position or a wide stance between the legs and the body angled towards the side.
- It usually takes 5-10 minutes for new users to stand up for the first time.
- Initial speed is necessary to gain balance, similar to bycycling.
- Some users hold the controller in the left hand, and some use the right hand.

5.3 Experiment Discussion

5.3.1 Experienced Users

Skilled users can operate the board very well with stable body composition and without unnecessary hand motions. As seen in figure 5.2, their neutral hand position is around the lower parts of their body. It is noted that some advanced-level users want to try to perform tricks while driving the board. This way of surfing can be seen in figure 5.3. Actively seeking out waves from which they can jump. This style of driving creates many hand motions to stay balanced on the board. These hand motions would potentially result in false positives for the smartwatch hand gestures and could risk worsening the user experience. The definition of an experienced user in this study is a user who has operated the board or tried a similar activity, for example, kitesurfing, at least two times before. With less experience, the user is considered to be a beginner.

Figure 5.2: An expert operates the board with high speed.

Figure 5.3: Expert jumps with the board.

5.3.2 Beginners

There is a clear difference between how a beginner operates the board compared to an experienced user. See the comparison between figure 5.4 to figure 5.2. The most noticeable difference is how beginners tend to spend several minutes lying on the board while veterans can get into a standing position within seconds. The laying position puts constraints on hand gestures for controlling the board. With the current controller from Radinn, users can hold their hands onto the board and press their thumb down on the throttle to increase speed. This action would not be possible using certain hand gestures requiring a freehand motion like circular hand motions or typical wrist gestures. The prone pose can be seen in figure 5.5 and 5.6. Users also tend to get balance by leaning the hands onto the board when they try to stand up, as seen in figure 5.8. These natural movements are important to adopt the gestures after.

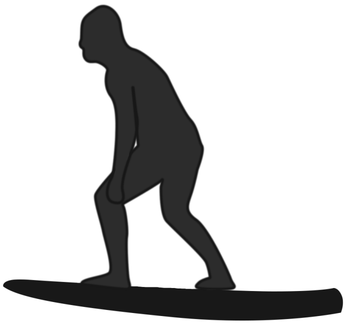


Figure 5.4: A beginner driving the jetboard.

Figure 5.5: How users operate the board at the beginning before standing up.

Figure 5.6: A sideways view of the prone stance.

Figure 5.7: A user sitting on the board.

Figure 5.8: A user is trying to stand on the board.

5.4 Takeaways

As a result, it is determined that the smartwatch controller will compromise the usability and not allow users to operate the board in ways that are possible with the throttle controller. Depending on how it will be designed, the smartwatch solution will determine the possible ways a user can interact with the board. For example, hand gestures may be harder to perform in a prone position compared to standing upright. This complexity will make the new controller harder for beginners, as they tend to spend more time in a prone position than experienced users. However, it may also lead to a worsened experience for advanced-level drivers that want to perform tricks on the board.

The session also found a set of crucial interactions when operating with the board. The interactions needed are Acceleration, Deceleration, Panic Stop (Abrupt Stop), and Connect to Board. An optional interaction that may enhance usability is Cruise Control (Pause Controller). These interactions can be seen in figure 5.9. It is vital to ensure that all of these operations work while prone and standing on the board.

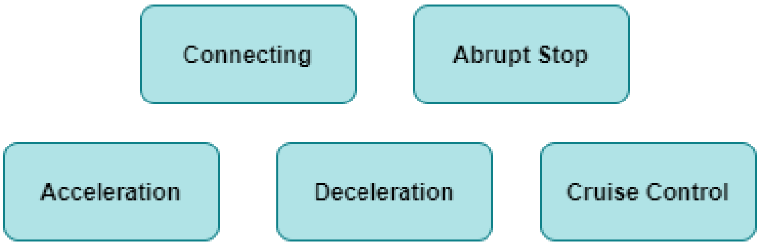


Figure 5.9: The interactions found in the study.

Chapter 6

Bodystorming sessions

Several Bodystorming sessions were done to experiment with new gestures for the controller. The authors performed them to understand better which gestures and motions would be possible to use as input for the controller. The bodystorming consisted of three different sessions, driving the jetboard on water. Each session lasted about 1-2 hours. The need for several sessions was because of the learning curve for driving the board. It typically takes 1-2 sessions before a user can control the board efficiently. In the first session, we barely learned to stand up, while at the last session, we were fully functional to operate the board. Moreover, to be experienced enough to test the early development products, we had to master the regular controller to have a chance to operate test versions of the new controller. Before starting the bodystorming sessions, the thesis writers had no experience with surfing a jetboard before. However, one of the thesis writers had experience with kitesurfing. By the end of the bodystorming, the writers considered themselves "average" to "skilled" level users. For clarification, the bodystorming sessions in this chapter are chronologically between the Field Study and the first user study. The prototype testing made in "Test Prototypes and choose which to perfect" is not written in this chapter.

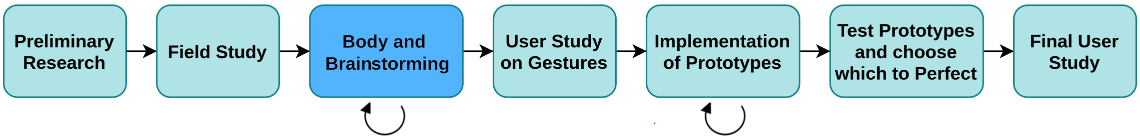


Figure 6.1: Bodystorming section of the design process.

6.1 Session 1

While surfing upright, gestures could be performed more easily but how forgiving they were towards affecting the surfer's balance depended on the initial greatness of balance, which itself depends on different situations such as turning or heading straight. A beginner's surfing experience felt like a fight with the surfboard to find a point on which the surfer can balance the body while standing. The tricky part was to find a suitable upright body position on top of the board without tipping over.

Countless different body poses manifested during a ride. First, there were many different starting body poses for launching, which the user explored and tried to gain a footing on the board. The body poses consisted mostly of laying down with the tester's body in a prone position with his hands stretched to grip the handles at the tip of the surfboard. However, some of the body positions had the tester assume a kneeling position and grip the surfboard sides.

The control felt unresponsive at times. There were some windows, seemingly only when starting, where the interface did not react to the throttle's push down. After a moment, it would respond and then held a good connection and was very reliable. The controller had a minor impact on swimming with the arm it was connected to and was mildly annoying

Attaching the dead man's switch was a very annoying experience since the cable had to be positioned away such that you would not stand on it. It was also annoying in a mental way since you might not have registered that it had come off, and the interface then would not work. Attaching the dead man's switch required great effort not to lose balance if you were already on the board since you had to twist your body towards the attachment point. There were cases when the board flipped over because of the maneuver. Even just checking if the dead man's switch was attached was a troublesome task. Sometimes you would notice your balancing was compromised during riding because the cable would get stuck under your feet and the board.

6.2 Session 2

In this bodystorming session, we thoroughly explored the possible gesture space of performing gestures in varying surfing poses as the rider could now comfortably stand upright when surfing.

The three most likely surfing poses are prone, kneeling with either one or two knees in surface contact, and lastly, standing. When lying down on the board, both arms are locked from moving freely, often simultaneously. Even if this pose could be done with just having one arm gripping the board or resting on the board, it is more comfortable to rest or grip with both arms. When doing so, either a whole arm is in contact with the board and the contact area is along a line, or it is the elbow that is in contact with the board at a point. It leads to two restricted gesture spaces. With the formerly described contact with the board, the user is restricted to only the wrist and fingers' movement. The latter described contact point with the elbow should have a slightly larger gesture space than the former with wrist, finger, and forearm movement free.

The quick thinking of performing any gestures at the moment when surfing in the prone position generated a tapping the board gesture for speed and waving an open hand from side to side as the usual human to human communication of a "no" for deceleration. These gestures were tested out with the user using one hand for performing the gesture simultaneously as using the Radinn controller with the other hand. These gestures felt quite natural for manipulating the speed if imagining that the speed was being manipulated in a discrete way and held constant until the next gesture, so not analogous to the current interface logic for applying power to the jet. When the arm was in contact with the board at a point with the elbow, the freed-up movement of the forearm led to the same gestures, however, with a greater range of downward and upward motion for the tapping gesture and it felt more enjoyable when doing the sideways movement of the open hand "no" gesture.

Kneeling and standing on the board did not strictly restrict the user from performing a given gesture in any way. However, due to balancing on the board, the gesture space felt more natural if the whole arm's movements were constrained to be performed around under the center of the body. In grave balancing situations where the surfer had to duck and lower their arm, there could be that the closing-in distance to the water would compromise the gesture space.

Gestures such as flicking fingers, thumb presses, and other finger gestures felt natural. Gestures that used more parts of the arm also felt good, such as waving with the forearm held down—using other body parts for gesturing felt bad. Tapping the foot on the board felt good. However, it compromised the balancing at times and made the user unable to steer right or left. Likewise, when surfing in the prone position, the user felt unable to steer right or left when performing gestures with the legs. Raising them from the water had a significant reduction in jetboard steerability. Moving the head felt uncomfortable and harmed balancing.

6.3 Session 3

A new interaction was discovered. Riding in water with some seaweed can cause blockage for the jet motor water intake. The user must flip the board over and pull out the seaweed from the intake. During this procedure, it would be good if the gesture controlling would be switched off or not register any false positives resulting in an undesired speed manipulation. Tapping the board gesture has similarities with the pulling out seaweed action and could trigger a false positive if this state is not handled correctly.

6.3.1 Takeaways

The bodystorming sessions have resulted in about 30 potential gestures to control the jetboard with the interactions found in the Field Study and in the previous chapter in figure 5.9. Some examples of these potential gestures for the different actions could be to use the hand gesture "clench fist" to make the action "speed up", while "release fist" can be used for the action "slow down". As for the action "panic stop", a gesture of "waving no with an open hand" could be used. Finger snapping could be used for actions "cruise control" and "connecting to board. The bodystorming also resulted in the idea of using speech recognition for input to the board. An example of this could be to say "connect to board" for the action of connecting the smartwatch to a jetboard. All of the 30 potential gestures and interactions can be viewed in the appendix. In the next chapter about our first user study, we present some of these gestures to potential users.

Chapter 7

First User Study

In chapter 5, the previous study discovered crucial takeaways for implementing a gestural interface for surfing. Through early user observations, future design errors that would most likely occur without the study's knowledge were prevented. Consequently, for correctly implementing the gestural interface for users, more studies involving users were desired.

The user study's goal was to understand natural body movements and find potential gestures for operating an electric jetboard to filter out which of the bodystormed gestures users enjoyed the most. Users were first asked to give their ideas for gestures. Then they were asked to fill in a survey to rate a set of gestures and user stories.

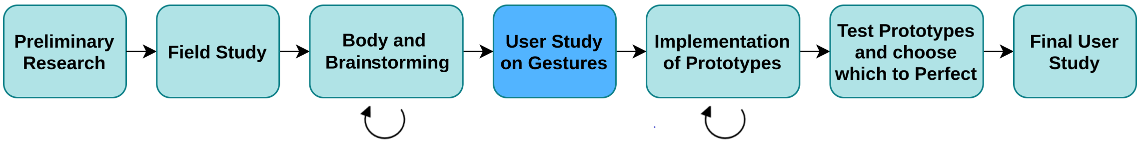


Figure 7.1: Methodology used in the report

7.1 Experimental Setup

The study let users simulate operating a jetboard with gestures. To make the users understand the scenario better, they were told that they had a smartwatch on their arm of choice, which would monitor every movement they were doing with that hand. Due to not having access to a jetboard the study would use longboards to simulate part of the challenges a user would typically experience when surfing.

7.1.1 Participants

The study involved 13 users from Sweden with ages from 20 years old to 64 years old. The age distribution can be seen in figure 7.2. Six out of the users were female, and 7 were male. The interviewees had varying board experience, but no one considered themselves a very skilled user. See figure 7.3 for their level of experience.

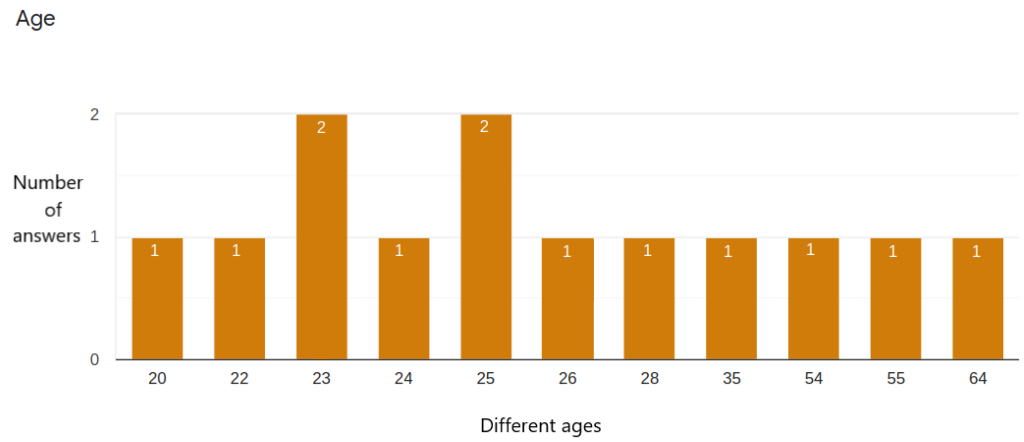


Figure 7.2: Age distribution

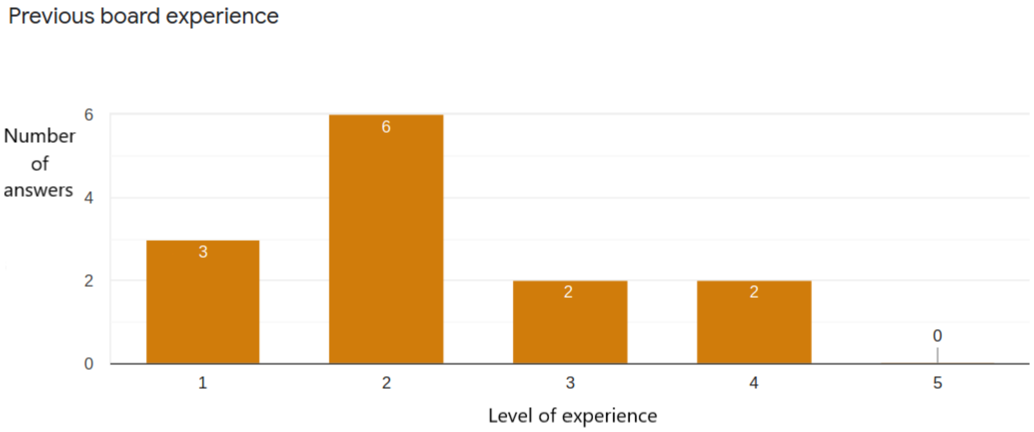


Figure 7.3: Participants previous experience with a board sport. 1 being no experience and 5 being very experienced.

7.2 Procedure

As an introduction to the format, to make users accustomed to performing gestures, users were instructed to use their hands and bodies to signal feelings such as happiness and sadness.

After that, we had a discovery phase, where users were tasked to suggest their interaction for each of the actions in figure 7.5.

Next, an evaluation phase followed where our users would rate our gestures for different interactions with postures standing up and prone position. Each of the actions in figure 7.5 had several different interactions to rate between on a scale from one to five. This procedure can be seen in figure 7.4.

Lastly, users were asked to rate four different user stories. The user stories' goal was to find out how well different interactions work together. Maybe one gesture is optimal for acceleration, and another is optimal for deceleration, but they do not synergize together. Therefore, the users rated four different user stories on a scale from one to five. The study's structure is seen in figure 7.4.

The authors derived the to-be-evaluated gestures from the 30 gestures that the bodystorming sessions yielded. An undertaken filtering procedure had all of the different gestures added to separate lists for each action. It took voice-based interaction into account. Then the thesis writers gave each interaction a score from -2 to +2. The user study examines the interactions with the highest scores. Out of the 30 gestures, three to ten gestures, and sometimes an audio command was chosen for each action.

The control actions were Accelerating, Decelerating, Connecting, Panic Stop, and Cruise Control. The end of the study would examine some of our selected gestures in more broad user cases by letting the users rate user stories filled with instructions to be done chronologically to drive an imagined scenario.

For Accelerating, gestures such as "wrist flicks", "finger snapping", "clenching fist", "pushing thumb down", and saying "go" were added to be examined in the study by the Authors' vote. Decelerating gestures got similar results, with the top-voted gestures "wave no with an open hand", "clap leg", "wrist flicks", and saying "stop". Connecting and Cruise Control actions only had a few voted-in gestures. For Connecting, "tapping the smartwatch", "saying connect", and "clapping hands", were considered. For Cruise Control (Pausing), the gestures were "wrist flicks", "finger snapping" and "holding hand still for a long time". Lastly, the gestures "jump", "punch the air with a fist", saying "stop" and "waving no with an open hand" were considered for a Panic Stop action.

A person carried out the user study, acting as both coordinator and observer. Data collection was in Google Forms with the use of smartphones by taking notes.

Figure 7.4: Procedure for Users during the study.

7.2.1 Part 1: Own Suggestions

Instructed users created their suggestions for a gesture for each of the control actions Acceleration, Deceleration, Connecting to Board, Panic Stop (Abrupt Stop), Cruise Control (Pausing Control), which figure 7.5 shows. Since it is possible to drive the jetboard while standing and prone on it, users suggested gestures for each action for both standing and prone on the board.

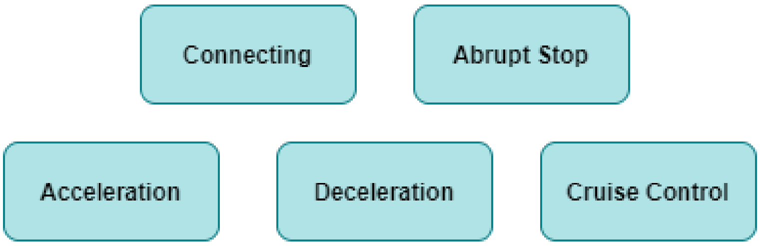


Figure 7.5: The Actions that the study tried to find gestures for.

7.2.2 Part 2: Rating Gesture

Users are given examples of different gestures for actions in figure 7.5, and are then supposed to rate them from a Likert scale, where 1 is very bad, 3 is neutral and 5 is very good. For example, “How much do you like this Wrist Flick gesture for accelerating?”. When the gestures in a set had been rated for a given control activity, we then asked about a rating for a spoken command, for example, Audio “Go” for the control action “Accelerating”. Some of the gestures used in the study can be seen in figure 7.6.

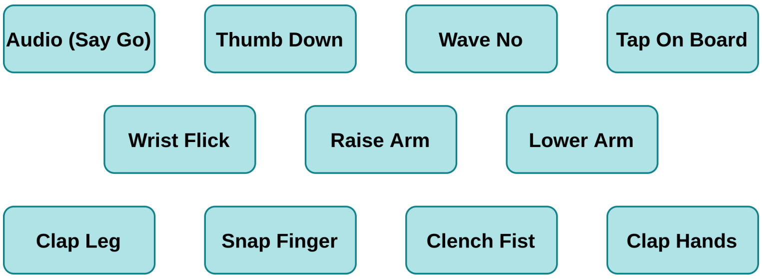


Figure 7.6: Some of the gestures that users had to rate in the study.

7.2.3 Part 3: Rating User Stories

There were four short user stories with instructions to simulate a particular real user scenario. These describe how users are exactly supposed to operate the board, from putting on the smartwatch to driving and then turning it off.

Each story was told to a user. The person was guided in acting them out from start to finish and rating the story before continuing with the next story. They then answered, "How would you rate the simplicity of the story?", "How would you rate the story overall?" and "How did the gestures work together with each other?".

Holding the hand up continuously accelerates the speed of the board. The higher the hand is held, the faster it accelerates. If the hand is lowered, it functions like before but instead decelerates the more the hand is lowered. If the hand is neither raised nor lowered, in a neutral middle position from the wrist, then the board neither accelerates nor decelerates

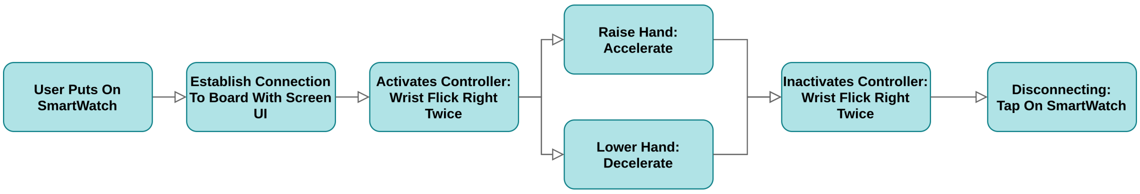


Figure 7.7: User Story 1

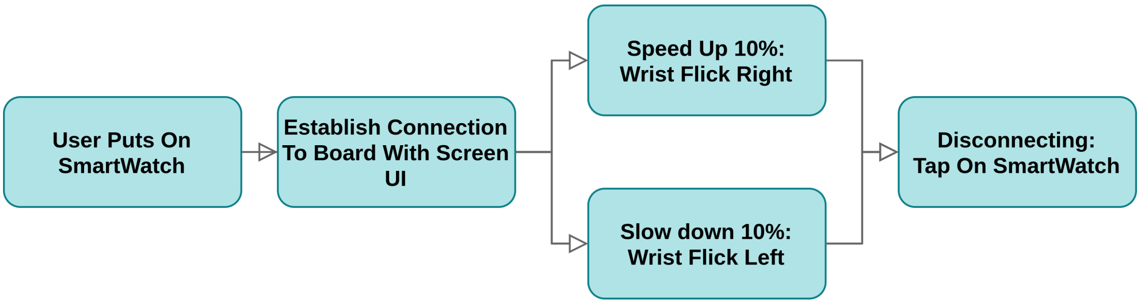


Figure 7.8: User Story 2

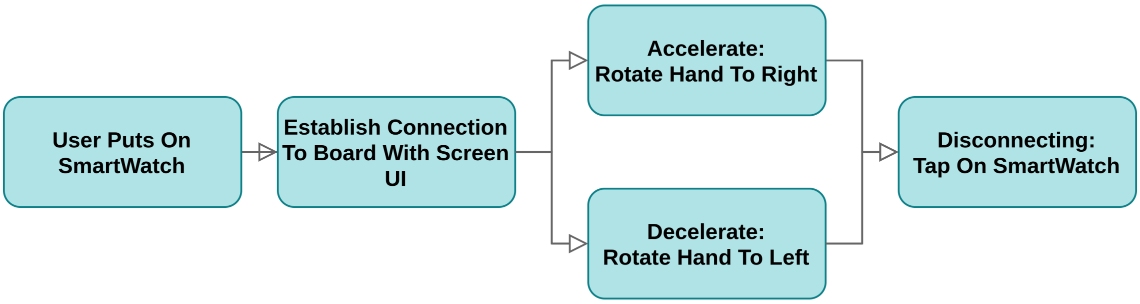


Figure 7.9: User Story 3

Note for User Story 3. Controlling is like steering a car. Holding hand at 12 o clock is neutral, with no acceleration nor deceleration. Holding hand at 3 pm will accelerate the board, holding hand a 9 pm will decelerate the board.

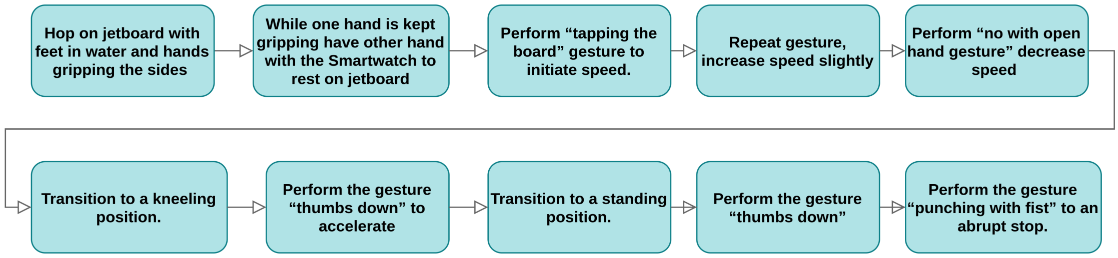


Figure 7.10: User Story 4

7.3 Takeaways

7.3.1 Part 1: Users Own suggestions

- **Acceleration gesture.** 7 out of the 13 questioned suggested moving the hand forward. 3 users suggested clenching a fist to accelerate.

- **Deceleration gesture.** 4 users suggested lowering or moving hand backward to decelerate. The rest of the users gave unique suggestions, everything from clenching a fist to waving no with hand and leaning backward with the body.

- **Connecting to board gesture.** 4 users recommend tapping on a smartwatch to connect the board with the controller. Other suggestions were, punching a fist towards the board, physically making the smartwatch touch the board, making circle motions in the air with the arm.

- **Gesture for panic stop gesture.** 3 users jump off the board. 3 other users move the whole body backward. 4 users raise their hand and mimic waving no or stop motion with their hand.

- **Accelerating when prone gesture.** 6 users point their hand forward. Some users make a swimming motion with their hands.

- **Decelerating when prone gesture.** 5 users move their hand backward. Other suggestions were rotating arm, talking with the board, clenching a fist.

7.3.2 Part 2: Rating gestures

Figure 7.11 shows that no acceleration gesture was uniformly liked by all the users. However, wrist flicks and clapping leg gestures were the two gestures that had the fewest number of dislikes in the study. Finger snapping received its low rating due to many users not being able to perform it. Using audio or thumb to accelerate resulted in a uniform rating from very bad to very good. Lastly, fist-clenching received some very positive remarks but also some negative, even though the positives were in the majority.

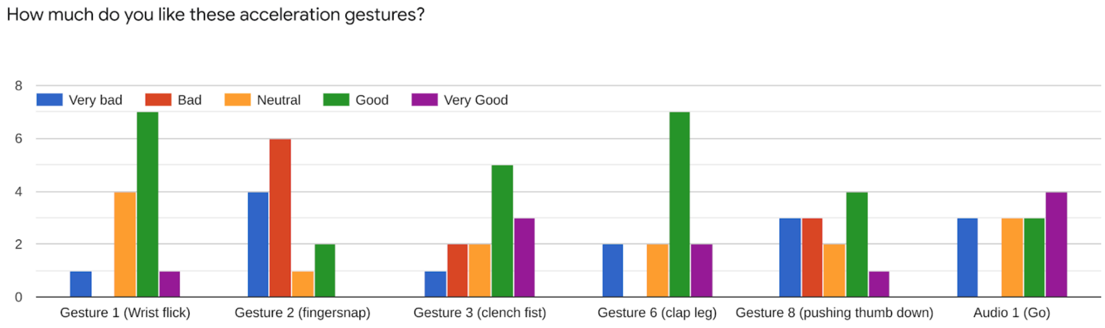


Figure 7.11: User's rating of different gestures for accelerating a jet-board

The deceleration gestures are shown in figure 7.12, waving no and saying no have the highest number of good and outstanding ratings. Clapping leg and wrist flicks have uniformly spread out votes. Wrist flicks in general, however, have no vote for very bad. Worth noting is that wrist flicking to the left gets a very low rating from the users compared to wrist flicking to the right.

Figure 7.12: User's rating of different gestures for deceleration a jet-board

Gestures performed while prone require different body movement than while standing. Resulting in some movements not being as easy to perform while prone. As seen in figure 7.13, raising hand get a very low rating from all but one user. Tapping the board stands out as a clear winner for a very good gesture while prone, with only one vote being less than neutral. As for waving no with hand, finger snapping and wrist flicks and audio give a rather ambiguous result while prone.

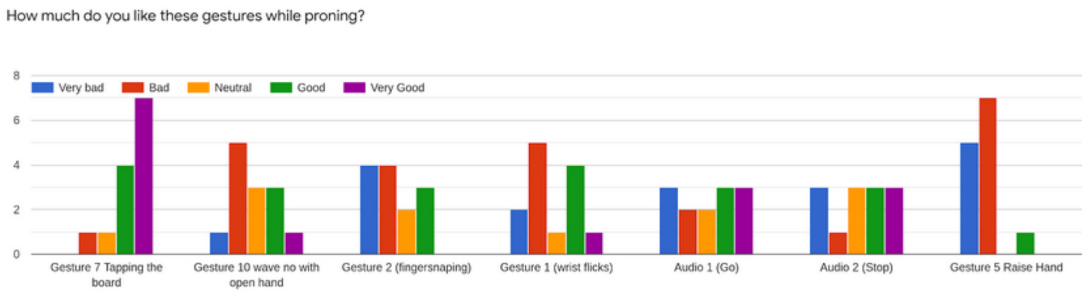


Figure 7.13: User's rating of different gestures while proning on a jetboard

Tapping on the smartwatch in order to connect with the jetboard was the outstandingly best way, according to figure 7.14. Clapping hands was liked and disliked but had no votes for very bad and very good as the gesture audio had. However, one user in the study had a problem with clapping his hand because he only had one hand.

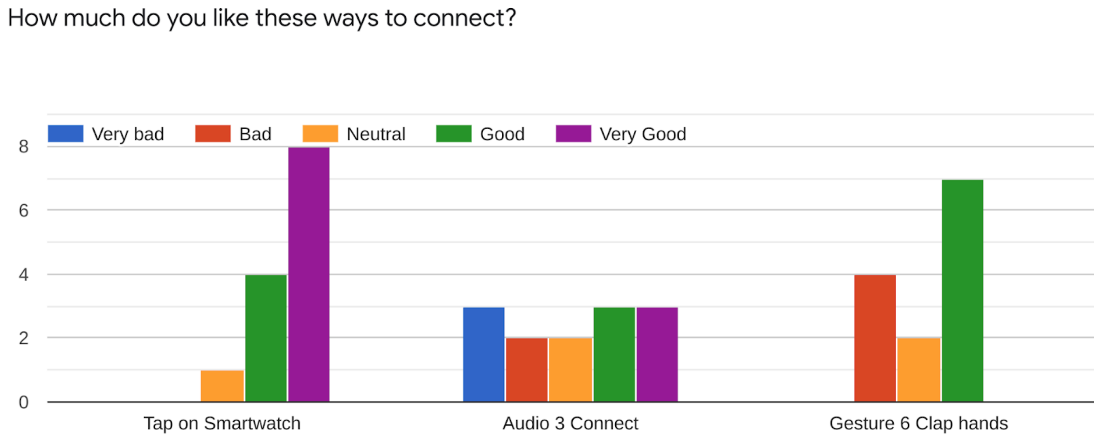


Figure 7.14: User's rating of different gestures for establishing a connection between controller and a jetboard

Wrist flick is viewed as a neutrally enjoyed gesture for pausing the controller according to figure 7.15. Doing nothing at all, just holding the hand still for a long time, has a relatively good rating but the most liked gesture for pausing the controller is finger snapping.

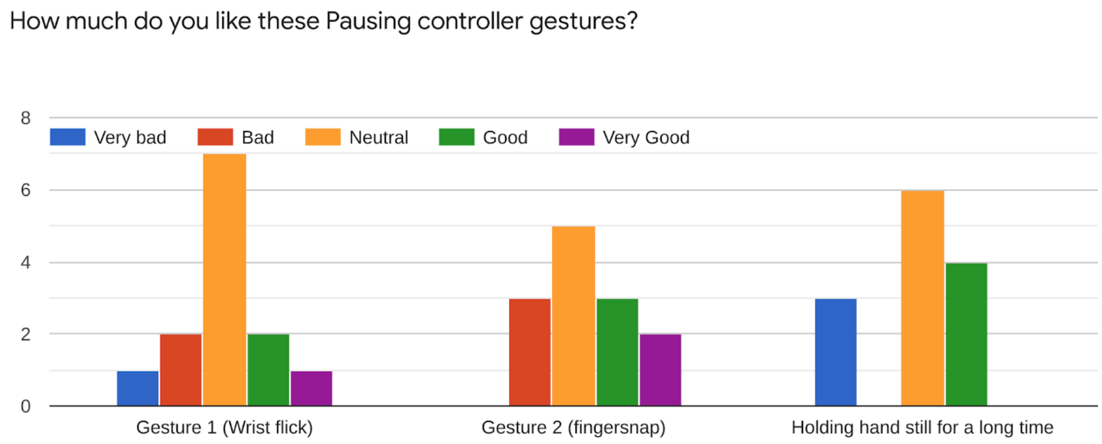


Figure 7.15: User's rating of different gestures for pausing/resuming a controller while still maintaining a connection

Figure 7.16 shows that jumping, "waving no with hand", and saying stop are liked for a panic stop of the surfboard. Punching fist is very disliked.

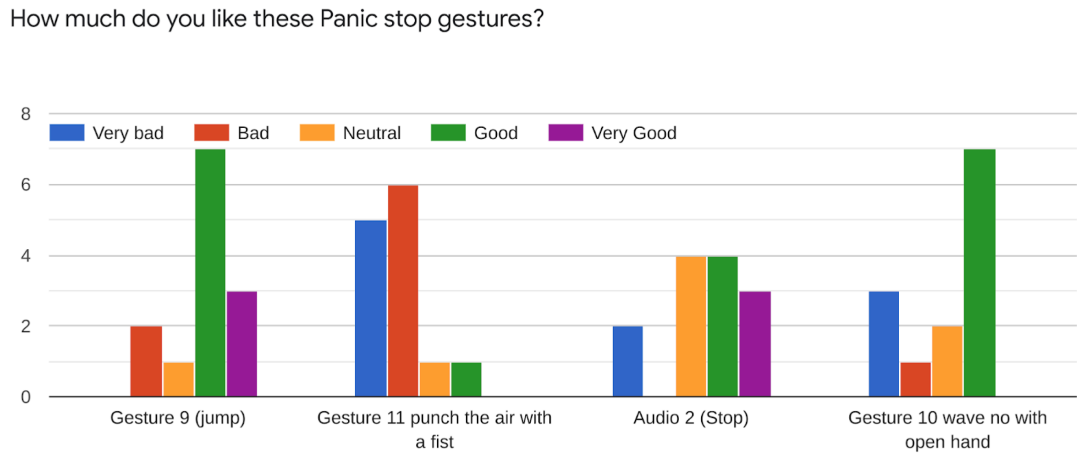


Figure 7.16: User's rating of different gestures for jetboard to perform an panic stop

7.3.3 Part 3: Rating User stories

Most users found the first user story straightforward to understand. It also received high points for the synergy between all the gestures and overall got a good rating. This can be seen in figure 7.17

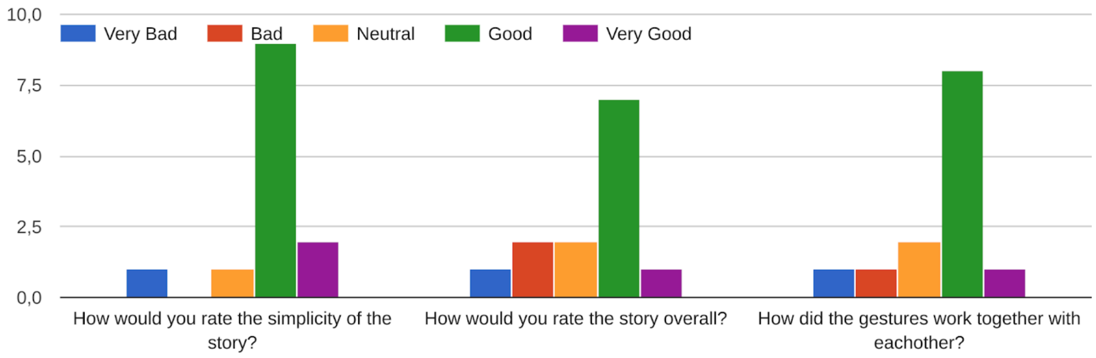


Figure 7.17: User's rating of different gestures User Story 1

The second user story results in figure 7.18 was a notch higher than that from the first user story—good simplicity, synergy, and overall score.

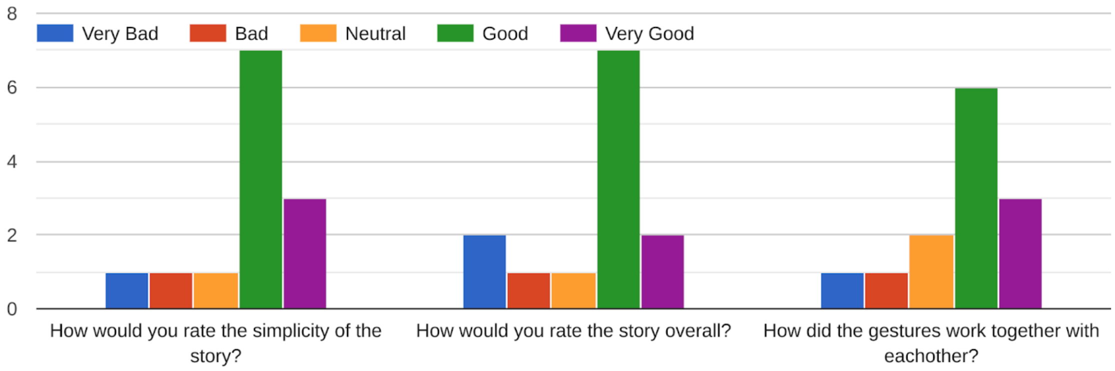


Figure 7.18: User's rating of different gestures User Story 2

User story three had a more diverse rating than the first two. Even though some users found it to be better than user stories one and two, a distinct number of users found it not so simple to understand.

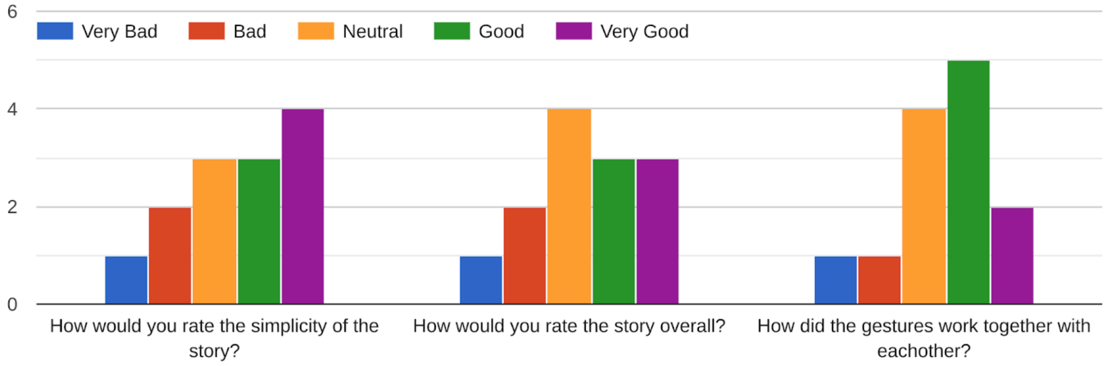


Figure 7.19: User's rating of different gestures User Story 3

User found that the fourth user story had an unintuitive nature to it. The gestures did not synergize all too well for many users. However, many still voted it to have a good overall rating. This can be seen in figure 7.20.

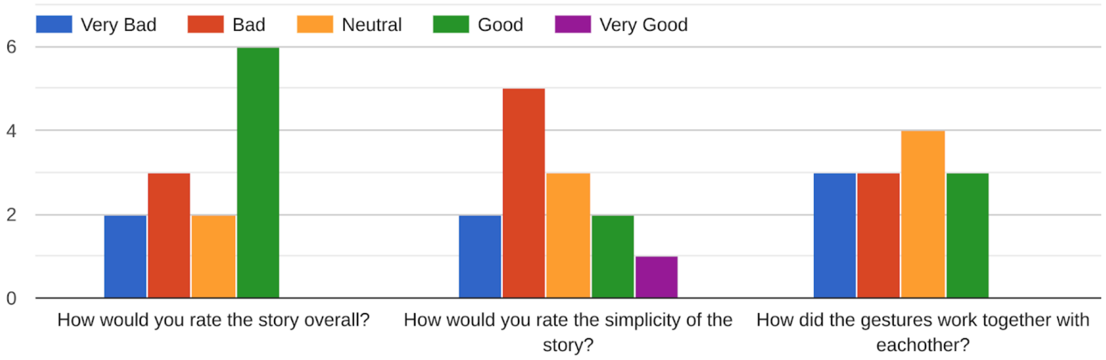


Figure 7.20: User's rating of different gestures User Story 4

7.4 Discussion

7.4.1 Part 1: Own Suggestions

Even though all users had their twists on their suggestions, some significant trends could be noted. For example, moving the arm forward for acceleration and backward for decelerating seems to be one of the most natural ways of communicating movement when both standing up and prone on the board. No clear winner was found for connecting to the board, but tapping the smartwatch was the only suggestion that several users chose independently of each other. Gestures for the panic stop were divided into two categories: moving the whole body backward or jumping off, or raising hands to wave no or stop with hands.

It also seems that most users tend to recommend according to their own experience in similar areas. For example, one user had experience riding a horse and therefore gave the suggestion that was close to how one rides a horse. Another one had experience with driving motorcycles and therefore gave suggestions for gestures that resemble controlling a motorcycle.

7.4.2 Part 2: Rating gestures

As the study found that not everyone can perform finger snapping, that gesture is ruled out as a potential implementation for all the categories.

The use of spoken words for controlling the jetboard was polarising as many liked it and just as many hated it.

Tapping the board had one of the best results in the study. However, tapping the board is only possible when prone or sitting down on the board. While standing up, it is not possible to reach down and tap the board. This variation would result in one gesture while sitting or lying down on the board and another for standing on the board, which might lead to confusion. It is to be considered if it is worth weakening some usability goals to strengthen others and lead to different trade-offs for different user groups. From the perspective of new beginners, a good similarity within the set of gestures for controlling in both prone position and standing position might increase simplicity for greater learnability and lead to a more intuitive user experience for this user group. The same pattern for gestures might be preferred for newbies. However, the confusion might also be of a minor character and should not be the driving factor for the user experience design.

7.4.3 Part 3: Rating User stories

It is noticeable that the first and second user stories had the best response according to the data. However, during the study, it was found that it is hard for users to understand how the controller operates for real. Additionally, some user stories did not involve a starting position, so it is hard to judge all from the same scope. Alas, isolating how well discrete manipulation of speed fares compared to analog by looking at user story 2 and 3, it did not generate a significant difference in the result. User story 1 made some users concerned with raising their hand for accelerating. They warned that this distinct arm movement could be perceived as a Sieg Heil, a victory salute used originally by Nazis at political rallies. People's cultural heritage poses an explicit limitation on certain gestures that collide with what is set by the culture as either unacceptable or rude.

7.5 Takeaways

It is found that there is not enough data to yet decide which gestures that fit best in with the product. There is a need for more research, which considers how it operates for real. Instead of deciding exactly how the final controller should work from this study, several different controllers will be implemented that take inspiration from the experiment. Then a new study will survey which one of the implemented devices that users enjoy the most.

Chapter 8

Gesture Controller Implementation

This chapter will go through the four different gesture prototypes that were implemented, explain some critics about them and which one that was chosen to perfect for the final user study. To get a short description of the User Interface for the smartwatch, the reader will find a chapter on it in the appendix.

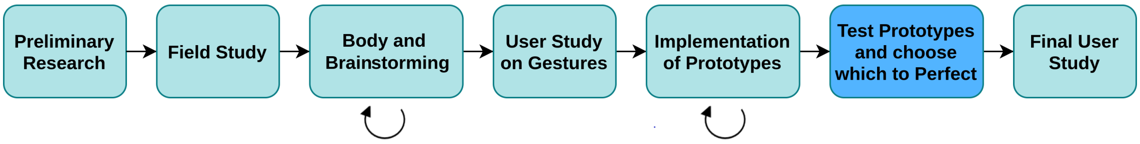


Figure 8.1: Methodology used in the report

8.1 Introduction

As concluded in chapter 6, the user study's results were inadequate to determine one single gesture controller to implement. This conclusion was due to unambiguous results in the study and users' insight not fully understanding how the controller would work while being implemented. As a consequence, this work has not focused on developing one single controller. Instead, four different prototype gesture controllers have been developed. The argument for making four controllers was a consequence of the continuous development of one controller. Once one controller was done, it was easy to tweak the controller and various versions of it. The controller technology is based on gyroscope technology to minimize the noise from the acceleration and directional velocity arriving from the board while driving. The proposed controllers have taken inspiration from our Field Study, Bodystorming Sessions, and User Study. However, due to technical limitation and time restriction, some gestures from the previous chapters were filtered out but with a good balance between the constraints and the user needs.

After implementation, the controllers were tested together with a jet board on the water to find out which controllers gave the best user experience according to the report writers, and from that, perfect these controllers for the final user study at the end of the report. Ideally, a user study should have been conducted to determine which controllers to perfect, but this was not done due to time limitations.

8.2 Controller 1

This controller was implemented mostly due to its technological simplicity. However, wrist flicks did get good results in the user study according to figure 7.11. The gesture also got good results in the user stories, as seen in figure 7.8. The operation is simple. A wrist flick to the right increments the speed while wrist flicking to the left decrements the speed. A figure describing the operation of the controller is shown in figure 8.2.

8.2.1 How it operates

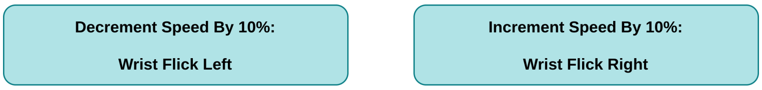


Figure 8.2: How Controller 1 operates.

8.2.2 Pros and Cons

The main drawback of this implementation was that accelerating and decelerating became tedious. To increase speed to an operating speed at about 50 percent, the user must use a wrist flick to the right five times, and then to slow down, the user must use a wrist flick five times to the left. Each wrist flick takes about one second to perform, meaning that to stop the controller from max speed, it takes ten wrist flicks, around ten seconds, to slow down entirely. Simultaneously, the board may drive at a speed of 30km/h, which is about 8 meters per second, which means that it takes at least 50 meters to stop the board, which is too slow for both the safety and user experience.

8.3 Controller 2

One finding in the user study in chapter 5 was that many users gave suggestions that mimicked moving their hand forward to move forward and move the hand back to slow down. This manipulation gesture was the original concept idea for this controller. However, due to some technical limitations, instead of moving the hand forward and backward, the user is supposed to move their hand up and down to accelerate and decelerate. Holding the hand still for a short time was chosen to act as a pause function for the controller due to its high liking in figure 7.15. A figure describing the operations of the controller is shown in figure 8.3.

8.3.1 How it operates

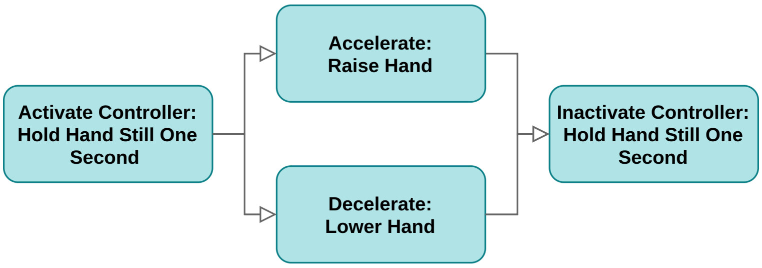


Figure 8.3: How Controller 2 operates.

8.3.2 Pros and Cons

Holding hand still to activate and inactivate the controller worked fine while operating the board on land. However, while driving the board, the body moves, resulting in hard to hold the hand still enough for the controller to trigger. The controller also suffered from some false positives, which required an additional button on the smartwatch that activated the controller. Another con of the solution was that waiting one second for activation and deactivation is too long. An optimal experience for the user requires a fast controller that easily activates and inactivates. Every delaying milliseconds for the user makes the driving experience feel unsafe.

The acceleration and decelerating gestures worked very well. It was easy for the user to have good control of the board, accelerate fast, and make small adjustments to acceleration. Even though figure 7.13 said that raising hand was a bad gesture while prone on the board, it was not the case while testing the controller together with the board. This exception was due to the board not laying horizontally on the water since the user is making the board back heavy by laying on it.

8.4 Controller 3

The rationale for this controller was to test how controller 2 worked together with another activation gesture. Instead of holding the hand still like in controller 2, the user is supposed to wrist flick to activate/inactivate the controller. This controller also was liked as a user story in the user study done in chapter 5, as seen in figure 7.17. A figure describing the controller's operations is shown in figure 8.4.

8.4.1 How it operates

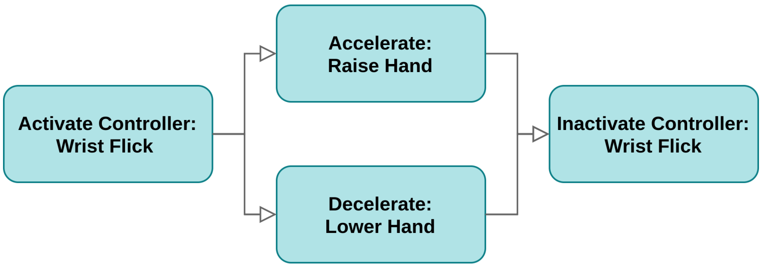


Figure 8.4: How Controller 3 operates.

8.4.2 Pros and Cons

Wrist flicks were a more optimal solution for activating/inactivating the controller than just holding the hand still. This preference was due to wrist flicks being faster and having a higher number of true positives. Most importantly, the user knew precisely when the controller was activated since it was activated when the user had performed wrist flicks.

Raising and Lowering the hand to control speed works very well together with the wrist flick gestures.

8.5 Controller 4

Holding hand was chosen for activating and inactivating the controller due to the results seen in figure 7.15. This was the most liked user story in chapter 5 and seen in figure 7.18. A figure describing the operations of the controller is shown in figure 8.5.

8.5.1 How it operates

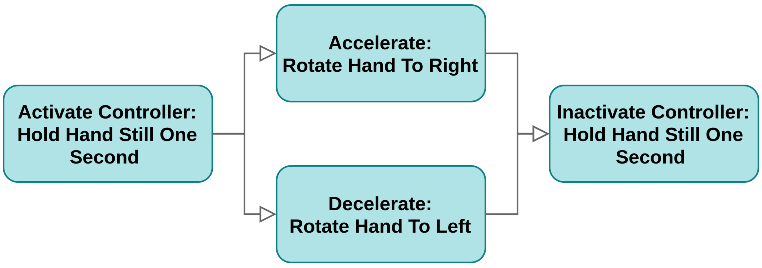


Figure 8.5: How Controller 4 operates.

8.5.2 Pros and Cons

Holding the hand still for activation was nonoptimal. Read pros and cons for controller 2 for more information. The gestures for accelerating and decelerating were promising and gave a good user experience. It was both simple to understand and control. However, it had one big problem, which also was found in the first user study. Rotating the arm to the left (inner rotation) is not a comfortable gesture for users. Some users cannot perform this gesture well, resulting in an incapability of slowing down the controller.

8.6 Takeaways

As a result of the controller testing, controller number 3 was chosen to perfect. It has simple activation and inactivation gestures, and the speed controlling gesture was also simple and intuitive for users.

The speed manipulation gestures are similar to the gestures Sofia Pescarin et al. use for free exploration in a 3D virtual place with a museum's gestural interface [3]. The designers used a raised arm gesture to move forward. To move backward, they used a lowered arm gesture. Roland Aigner et al. provide guidelines for designing a gestural interface in a substantially different setting than ours [5]. Still, let us look at their found preferences for the gesture effect Navigate, which is for their application guiding a representation that is considered similar to a mouse cursor, and for gesture effect Translate, which refers to movement or dragging of an object. The gesture effects have slight similarities with our actions Acceleration and Deceleration as our users are navigating the jetboard on the water and translating a jetboard located under their feet to move where they choose. The team found Navigate and Translate preferences that match the arm's raising and lowering in controller 3. Navigation preferences were to point in the desired direction to guide movement in a tight feedback loop between the actor's movements and the manipulated object's movements. Translate preferences included pointing in the desired direction with one hand. Raising the arm can then be explained as pointing forward for moving forward and lowering the arm as pointing downward to stay in place to match their found preferences.

Some tweaks were done on the controller used for the final study by adopting an iterative and agile programming process. The process was to implement adjustments then test with a jetboard on the water at the end of each week in sprints. The major one was that users control the velocity instead of the acceleration. This change was mainly due to tests on users, which resulted in the insight that users intuitively thought the controller controlled the velocity and not the acceleration. As a result, the product design was changed to operate the way users thought it was. Another optimization was to cater to users' necessity for gripping the jetboard while prone, as described in the Field Study chapter, and simultaneously boost with the same gripping hand holding the controller. We analysed hand angles between the water and the jetboard when a surfer is resting or gripping the front of the jetboard. The initial speed requirement for balancing considerably better and transitioning to a standing pose led to trimming the gripping hand angle's generated speed to an ideal initial speed. There were also adjustments to the UI during the process.

Chapter 9

Implementation Of SmartWatch UI

This chapter will give a brief overview of the screen User Interface made for the smartwatch. The conceptual design for the smartwatch User Interface was done using Photoshop. The rationale for this was that it gives a better understanding of how the product would look in the end compared to using pen and paper.

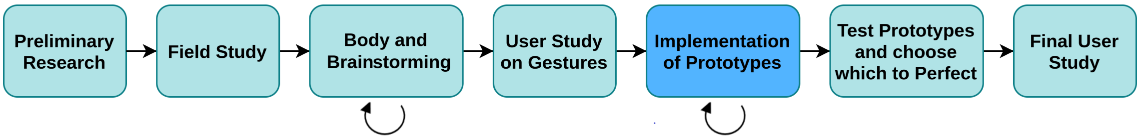
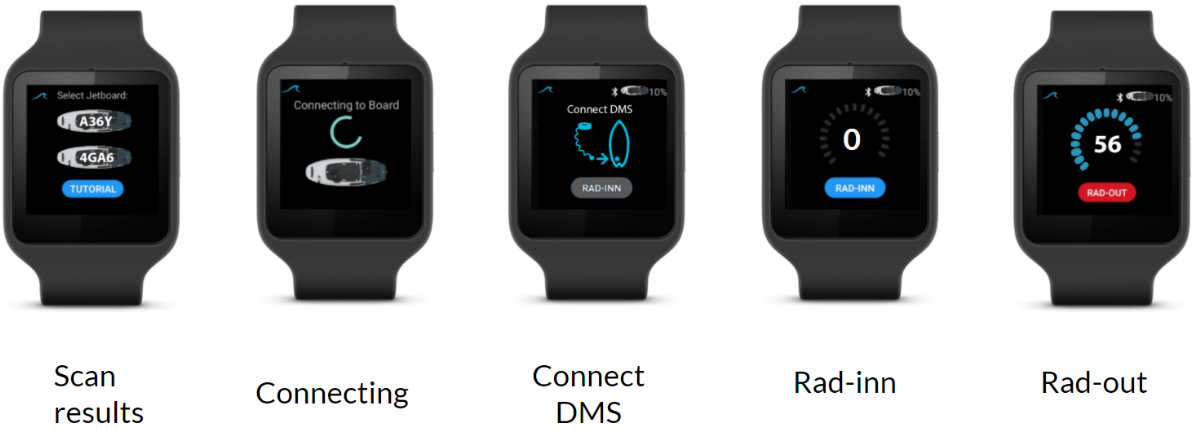


Figure 9.1: Methodology used in the report

9.1 Screen UI design

This section will show images of some conceptual UI designs as well as images of the actual implementation. Some UI did not have any conceptual designs. This is because they were added late in the development progress. View the final UI implementation in figure 9.2.



Scan results

Connecting

Connect DMS

Rad-inn

Rad-out

Figure 9.2: The image illustrates the flow of the UI from left to right. The surfer begins the session by touching a jetboard icon, presented in the nearby Scan Results, to connect. Whenever the surfer falls and the Bluetooth connection is lost, it will reconnect as the surfer swims closer to the jetboard. Connect Dead Man's Switch (DMS) view notifies the surfer if the dead man's switch requires attaching to the jetboard. Once safety is assured, the smartwatch application recognises hand gestures to activate (Rad-inn) and deactivate (Rad-out) the speed manipulation and to manipulate the speed. The UI displays jetboards in the vicinity, connection, battery, engine activation, speed, and dead man's switch statuses.

9.1.1 Scanning UI

(a) Conceptual implementation.

(b) Real implementation.

Figure 9.3: The real and conceptual implementations for scanning after a jetboard.

9.1.2 Connecting to board UI

(a) Conceptual implementation.

(b) Conceptual implementation.

(c) Real implementation.

Figure 9.4: The real and conceptual implementations for connecting to a jetboard.

9.1.3 Speed UI

(a) Conceptual implementation.

(b) Conceptual implementation.

(c) Real implementation.

Figure 9.5: The real and conceptual implementations for viewing speed.

9.1.4 Low Battery UI

(a) Conceptual implementation.

(b) Real implementation.

Figure 9.6: The real and conceptual implementations for displaying low battery after a jetboard.

9.1.5 Disconnect UI

(a) Conceptual implementation.

Figure 9.7: The conceptual implementation for disconnecting from the jetboard is shown. No real visual implementation was made for disconnecting. The smartwatch navigation to go back via swiping the touch screen is used to disconnect.

9.1.6 Connect Dead Man’s Switch

Figure 9.8: The real implementation of connecting dead man’s switch. No conceptual design was made for this

9.1.7 Tutorial UI

(a) Real implementation.

(b) Real implementation.

Figure 9.9: The real implementation for the controller tutorial is shown. No conceptual design was made.

9.1.8 Discussion

Our solution's UI's sketching began early, timewise around the time the First User Study was ongoing and after discovering the main interactions in figure 5.9. In the Background chapter, in section 1.1.1 we mentioned several flaws of the current Radinn controller. One of the handheld controller's flaws was its visibility, as its LED feedback was confusing to the user. The smartwatch application's UI goal was to improve the existing visual feedback for connection and battery status and add more information, as shown in figure 9.2. The authors made most of the final UI design choices during the iterative implementation of the gestural interface from the previous chapter 8

Chapter 10

Final User Study

A final user study was performed to compare how gesture based controllers are operated compared to Radinn's controller. A System Usability Scale and a Nasa Task Load Index survey were used for both of the controllers. After the study was performed, the users were asked to give their fair input about the products, what they liked and disliked.

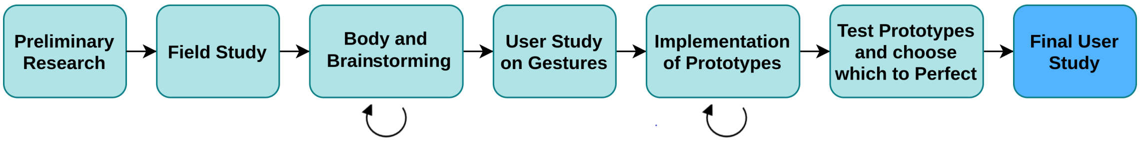


Figure 10.1: Methodology used in the report

10.1 Experimental Setup

Participants tested both Radinn's controller as well as the gesture based smartwatch controller with the electric jetboard. This test was to understand how the two controllers compared to each other, primarily how well a gesture based controller compares to the traditional handheld controller. The test was performed on land because of safety concerns for users as the weather was cold in December and the coronavirus pandemic was ongoing. Users were instructed to perform a set of tasks for one controller, then answer two surveys, System Usability Scale (SUS) and NASA task Load Index (NASA-TLX). The goal of the NASA test is to understand how the workload differs between the two controllers. Furthermore, the goal of the SUS is to measure the overall usability of the products. To avoid biases, half of the users began using Radinn's controller, and half began using the smartwatch.

The basis for testing users' workload was safety reasons and estimating gestural control's mental and physical impact on the surfing experience. Driving the board can be very dangerous. Suppose it requires a high mental load to control the board. In that case, it may cause harm to the users by seizing their cognitive capacity in extreme situations. The system usability scale was chosen due to its extensive usage in other studies and supplementing the other test to cover learnability and intuitive design. Therefore, a designer can use each controller's SUS score and compare it to hundreds of other products. As a result, a score of 68 does not just indicate a number. It indicates that it is the average product's SUS scale score, indicating that the product is average in usability.

10.1.1 Procedure

The tasks were performed once for the smartwatch and once for Radinn's controller. The tasks were divided into two assignments. The first part was setting up the device and making the board speed up, with no other instructions. These tasks' goal was to measure how much users understood from the get-go with both products.

When users finally managed to control the board using a controller. They were given a task to lay down on the board, try to speed up slightly, and then slowly try to stand up on the board with constant velocity. It is imperative to measure users' ability to stand up with constant speed while driving on board. Otherwise, the user will likely fall off the board. Therefore it was interesting to measure how easy it was for users to do this. Lastly, users were told to move away from the board, causing the dead man's switch to trigger, resulting in the board switching off. They then had to figure out how to start the board again and then disconnect the app.

A more detailed description of the exact instructions is given in figure 10.2. These instructions were given once for each controller, and after the instructions were completed, they answered a survey for SUS and NASA scores. The surveys were done directly after they tested each controller.

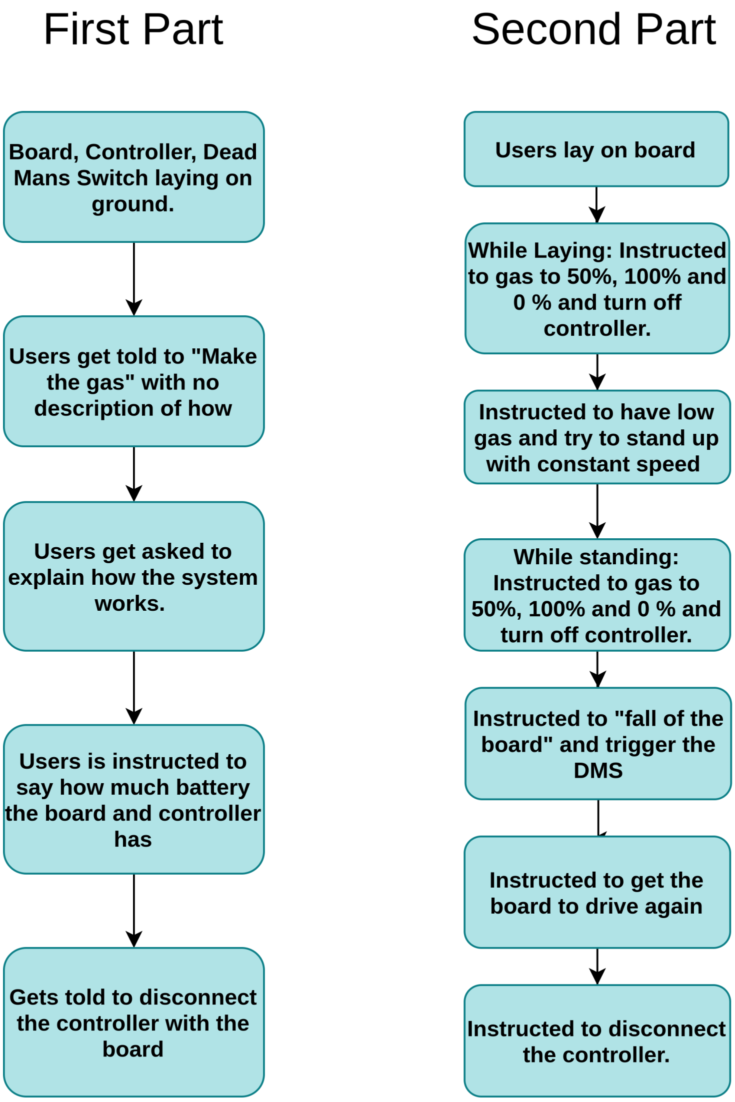


Figure 10.2: The instructions were given to users for parts one and two of the final study. After they have performed both these parts, they answered a survey with SUS and NASA TLX.

10.2 Participants

In total, 14 users were tested, all in the ages of 20 to 30. Out of the 14 users, 10 were male, and 4 were women. As seen in figure 10.3, most users had no surfing experience before the study.

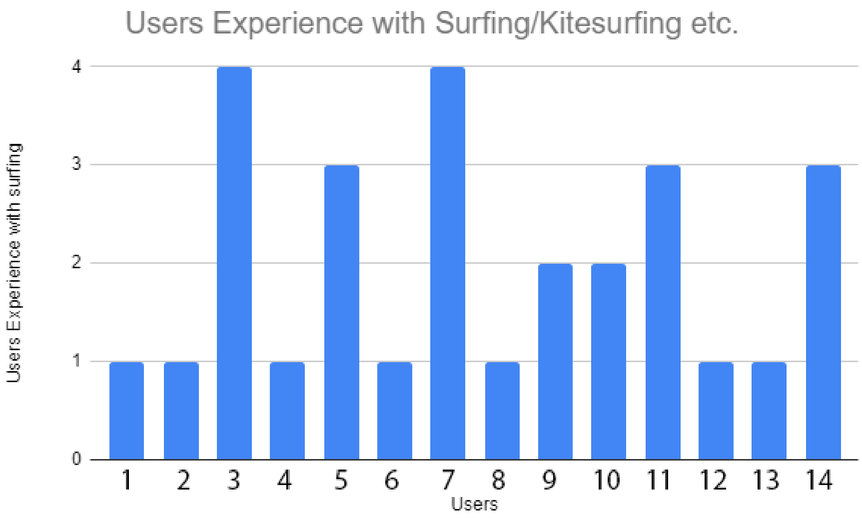


Figure 10.3: Users experience with surfing. 1 means no experience and 5 means very experienced.

10.3 Key Takeaways

- Most users had trouble understanding the LED lights on Radinns controller. Only one of all the asked users managed to figure out how much battery there was in the board and the controller, while all of the respondents figured out the battery when using the smartwatch. One respondent thought that the flashing LEDs represented a need for charging the batteries. The smartwatch users had trouble understanding the wrist flick instruction in the smartwatch as it said: "hold hand upside down". Some users then held the hand upside down and waited for it to start without flicking it back.

- Users had an easier time setting up the device using the smartwatch as it has guided instructions on the screen. Radinn's solution has no guide except for the guiding manual that arrives with the package. Despite this, Radinn's controller was more intuitive for users to understand with regard to controlling the speed. The smartwatch solution of raising and lowering the arm was hard for some users to understand.

- The comfort of having a smartwatch was more enjoyed than the physical comfort of holding Radinn's controller. However, the Radinn controller had one feature that all users liked, namely the physical feedback of the throttle button. Users did not feel any physical feedback from the smartwatch controller and had difficulty truly understanding how it operates.

- Most users have no trouble keeping constant velocity while going from prone to a standing up position on the board, neither with the Smartwatch nor Radinn controller.

- As for driving the board, users had difficulty understanding how the gesture based controller worked. Some thought that it was the height of the hand that determined the speed and not the angle. However, once they understood the controller, they thought it had superior velocity control compared to Radinn's controller, as it has a much larger span. Radinn's controller has about 2-3 centimeters of throttle going from no gas to full gas. While the smartwatch solution has about 20-30 cm instead, and users enjoyed this.

10.3.1 SUS Score

When performing a SUS study, it is desired to get a high score. Radinn's average SUS score for all users was 75, while the smartwatch solution got a 64 score. As a score of 68 is considered average, it can be concluded that Radinn's existing controller is slightly above average, while the gesture based controller is slightly below average. A SUS score of 74 compares to being in the top 70 percent of all products. While a score of 64 is better than about 40 percent of all products. For a design becoming top 10 percent, a score of 80 is needed. Which Radinn is not too far away from reaching. [9]

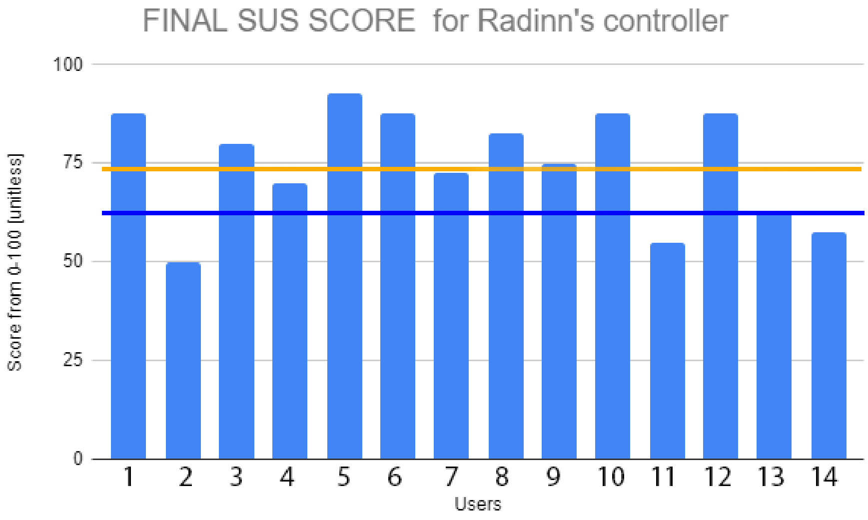


Figure 10.4: Average SUS score for each user when using Radinn's existing solution. The yellow line indicates the controller's total average score, while the dark blue line indicates the global average SUS score of 68.

It is noticeable that there are no apparent residuals or outliers in the data regarding the average score of each user. There is also hard to spot any correlation between the Radinn and smartwatch controller data, making the controllers quite different.

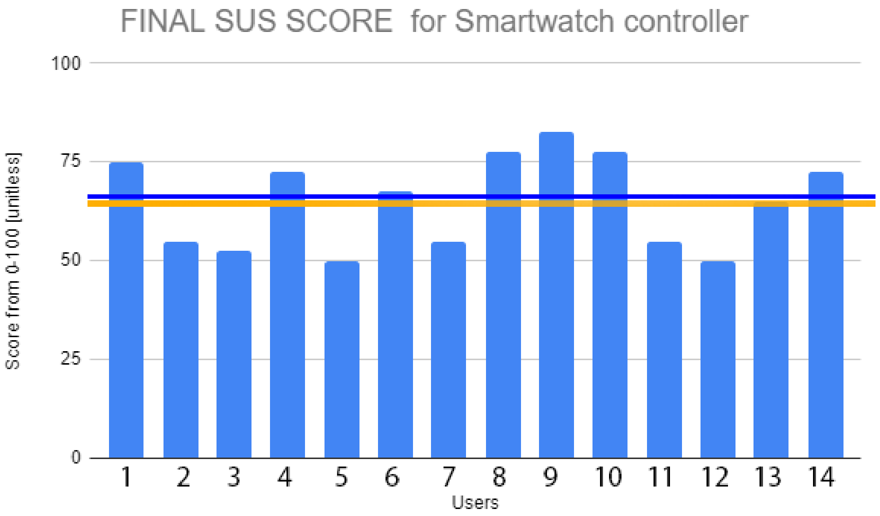


Figure 10.5: Average SUS score for each user when using Smartwatch existing solution. The yellow line indicates the controller's total average score, while the dark blue line indicates the global average SUS score of 68.

10.3.2 NASA TLX Score

The score interval for NASA TLX was from 0 to 20 for each question, resulting in a total max score of 120. As NASA-TLX is a score for measuring users' task load, it is desired to have a score as low as possible, resulting in no task load. The total score for Radinns controller was 30, as shown in figure 10.6, and the total score for the gesture based smartwatch was 37, figure 10.7. A NASA score of 10-29 is considered to have a "medium" task load for users, while a score of 30-49 is considered to have a "somewhat high" task load for users [11]. As a result, Radinn's controller can be said to have a medium to somewhat high task load for users, while the smartwatch has a clearer, somewhat high task load.

It can also be noted from the answers shown in figure 10.6 and 10.7 that the scores between users are somewhat varied. Some users give a score around 60, while some barely reach ten. It is not clear why this is the case. The same variance cannot be spotted in the SUS score ratings.

The main flaw of Radinn's controller, according to the study, is the performance category. This effect can be noted with the smartwatch controller as well. However, the other categories' average score is slightly higher, making the Performance category stand out less compared with Radinn's controller. The smartwatch controller has a higher average score for all categories, but the most notable difference between the scores is the Mental Demand. While mental demand was the next to lowest score with Radinn's controller, it jumps to the next highest for the smartwatch, indicating a high mental demand for users to understand and work with the gesture based controller.

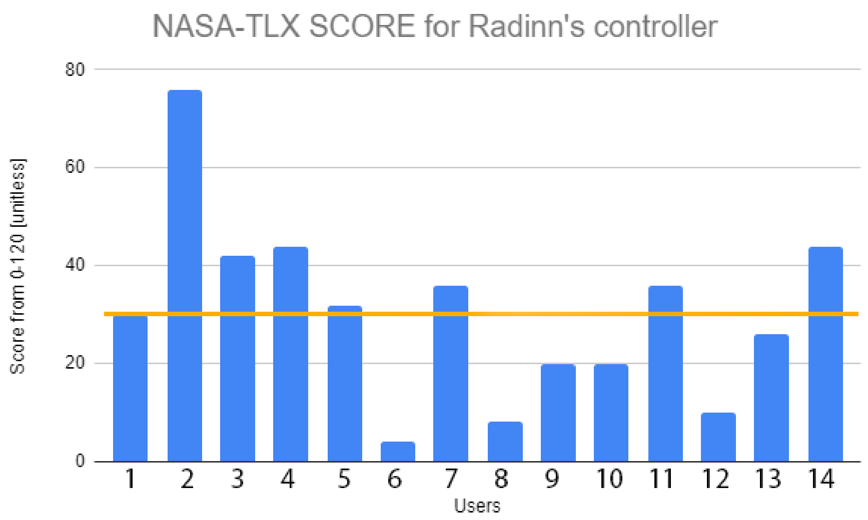


Figure 10.6: Total NASA score for each user when using Radinn's existing solution. The yellow line indicates the total average score of the controller. It is desired to have a low score.

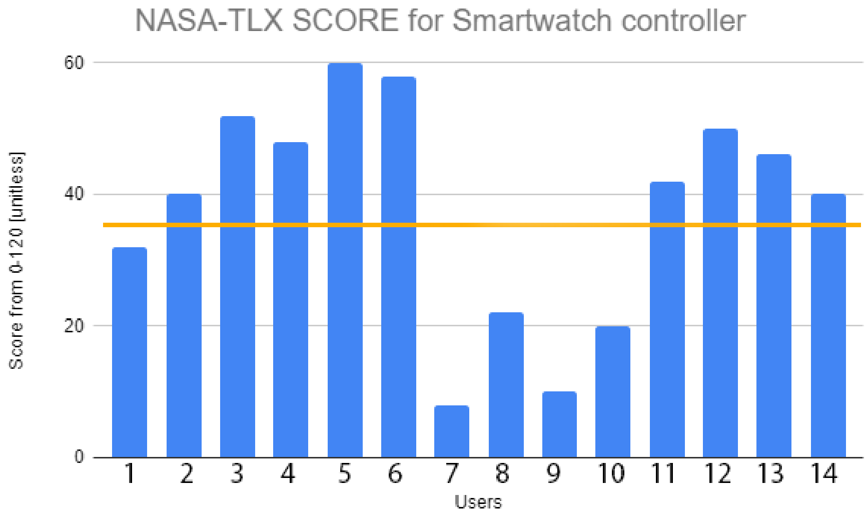


Figure 10.7: Total NASA score for each user when using Smartwatch existing solution. The yellow line indicates the total average score of the controller. It is desired to have a low score.

10.4 Discussion

A significant drawback of the final study is that there is no evaluation of how users experience the gesture based controller in water. We believe that to accurately determine the users' experience for the gesture based controller and the old controller, more user tests have to be done in the intended use case. For observing the users' behavior and experience in the intended use case, which is surfing, the users must surf with the jetboard in water to such a degree that the challenges of body pose control and human-aquatic interactivity are experienced. For precise evaluation of each controller, a repeated number of surfing sessions should be conducted so each system's learnability can be properly compared. This demand is because to learn the system; the authors had to have three sessions with a jetboard on water, as mentioned in the bodystorming section, as the task is not trivial for beginners from the get-go. Therefore, we believe that a future study with 4 sessions for each controller is preferred with users who have not learned to use a jetboard previously, so the learnability of each can be explored. We also believe that the gestural interface's visibility is increased while traveling on the water. The gesture then impacts the speed and does not hold the user stationary as on land. While traveling on the water at different speeds, the feedback of pushing down the throttle button of the old controller is felt in the surfer's legs due to braking waves with the jetboard. The rate of advancement in distance is experienced visually. Therefore, on water, the feedback is not only from the physical resistance in the button's actuation, which the gestural interface is lacking.

Chapter 11

Discussion

The master thesis is an initiation for exploring alternative interfaces and provides knowledge of users' surfing behavior and preferences that can be built on to develop the concept further. This thesis aims to compare a wearable gestural controller to a traditional throttle button controller. The scientific questions have been set to give more exact definitions of the goal and questions that this thesis intends to answer.

11.1 Scientific Questions

The scientific questions formulated at the beginning of the report are stated below. A short discussion is then held about each of them.

- **Does gesture controlling improve the usability of jetboards?**

Gesture controlling, as performed in this thesis, does not seem to improve the usability of jetboard. It has aspects that users liked, such as the broader span for controlling the board's speed. The wider span made it easier for users to speed up to the exact velocity that they wanted. Moreover, they also liked the concept of having cruise control. Users enjoyed the ergonomics of the gestural interface and its physical comfort. Nevertheless, overall, the controller did not improve the usability of the jetboard. Though, with more work, it might improve the usability of jetboards.

- **How can wearables and gesture interaction be designed to support interaction in a watersport environment that involves challenges such as body pose control and human-aquatic interactivity?**

Our working prototype of a wearable gestural interface that uses midair hand gestures for surfing is the answer to this question. We explain its design throughout the thesis. Observations of users were the key to accomplish the task.

- **Is it possible to improve the existing UI for jetboard battery and connectivity status with a smartwatch application?**

The smartwatch screen solution helped users to navigate the system much more easily compared to Radinn's UI. Users did have an easier time understanding the battery of both the controller and board. The connectivity status was also easier for users to understand with the board.

- **Does a gesture based controller enhance or reduce the mental task load for users?**

A gestural controller, as implemented in the report, raises the mental task load for users. However, this could be a result of just this controller. It might also be because gestural interaction is not commonly used today. Therefore users have no relation to such a product. Radinn's controller uses a throttle button to control the speed, a much more traditional approach that almost all users already had been in contact with before. Possibly, the mental task load could be lower for a gestural controller if this was the societal norm instead of throttle controllers.

- **Does a gesture based controller enhance or reduce the Usability of the System?**

The gestural controller in this thesis reduces the usability of the system in its primary use. The intuitive design and reliability of a simple throttle button for boosting are hard to top. Although some interaction design areas are seeing improvement, there is a need for a more polished gestural interface to recognize hand gestures reliably.

11.2 Design Process And User Studies

The Design Process has been good. The beginning Field Study successfully taught us many things about how new users understood and tried the product from scratch. Before the study, we had never thought about the concept of lying down on the board and driving it, which is a major part of the user experience that cannot be skipped. This study was a good starting point to understand how the product worked and how to develop.

The next study, namely the first user study, was good for getting input about which gestures would work for the vast majority. Early, we learned that some of our best-rated gestures needed to be skipped, namely finger snapping and hand clapping. We skipped the first one since a large proportion of the users did not know how to perform it, and the latter because of a user only having one hand. Even though the latter one is a rare exception, it is good to make the product available to as many people as possible.

As for the implementation of prototypes, we would have liked to conduct a survey after implementing several conceptual controllers and have the survey as a base to know which controller we should perfect for the final study. But due to time limitations, we could not conduct such a test. However, we let some users try the board and give feedback on the controllers, even though they were not scientifically documented while doing so. But this helped us arrive at which controller we wanted to perfect.

Lastly, the final study was initially supposed to be performed with fewer users but on the water to capture the challenges that occur when the product is used in its intended environment. Due to Covid-19, weather conditions, and safety, we opted to have the study on land. The consequence of this was that the study could be performed on a larger set of users than planned, but the users were not experiencing the real task of body pose control and human-aquatic interactivity. If the final study had been conducted during the summer period instead of in the winter, the user study could have been performed on water.

Overall, User Studies suffers from one severe flaw: the lack of users testing the board on the water. Even though the solution has been tested and tried on the water multiple times during the development phase, no user studies have been conducted on the water except the first field study. Performing user studies on water would potentially alter the results.

11.3 Limitations

The thesis's duration has had a limited time of 6 months, and the implementation of the product was three months. This time condition has also limited the development of the gesture controller. For example, we had visions of using machine learning but did not have the time to implement it in the device. Another barrier was the technical limitations of a smartwatch manufactured in 2014, a seven-year-old product when conducting the thesis. The rate of false and true triggers for gestures could have been improved upon drastically with newer equipment and better built-in sensors. Next, as all our users were in southern Sweden and our studies did not occur in other countries, the gestures' cultural aspect had implications for selecting the gesture controller. The Final User Study was also due in December, with the temperature around zero degrees Celsius and Covid-19 active in Sweden. All these safety concerns for users resulted in choosing to have the final user study on land instead of on the water.

11.3.1 Drawbacks of the First User Study

One fallacy found during this study was that since users had to make their own gesture in part 1 as described in Section 7.2.1, some of the interviewees had a bias towards gestures that had a resemblance to their own suggestion and seemed dismissive of the other options which did not match theirs.

A discrete controller works differently than an analog one. Still, this difference is hard for users to imagine and evaluate in terms of usability without the implementation of these modes of control at hand at the time of the study.

Wrist flicks to the left means inner wrist rotation for the right hand and is inflexible. Wrist flicks to the left mean outer wrist rotation for the left hand and is flexible. Thus, when rating the gesture "Wrist Flick" and "Wrist Flick to the left", the smartwatch's position on which hand played a role in the rating outcome. Still, most users simulated that they had the smartwatch on their right hand, but "Wrist Flick to the left" was meant to be inner wrist rotation.

The gestures intend to control a jetboard, but because we are present when observing and conducting the users to perform the tasks, slight mannerism of human to human dialog while users were answering us might have appeared to be a contributing factor to the responses that we collected.

Lastly, local culture might affect the users' choice of gestures and their likeness for ours since the participants were all living in Sweden.

11.4 Future Works

Future works for enhancing the gesture controller's usability are to reduce the false triggers and increase the number of times it should trigger when it is supposed to. This enhancement would make the product more reliable and thus more secure for users and improve usability. This improvement could be done by implementing Machine Learning to identify gestures more precisely than now. In 2019, Gierad Laput and Chris Harrison proposed a state-of-the-art sensing technology for fine-grained hand gestures with a wearable device in their paper "Sensing Fine-Grained Hand Activity with Smartwatches" [13]. Their example of future work is to eliminate their limitation from using large Fast Fourier Transform windows as features for Deep Learning as they incur a latency penalty of a few seconds in recognizing events. While this is acceptable for some situations as their "all users" model achieves a mean accuracy of 90.7% for 25 different activities, they explain that the latency is too great for shorter duration activities such as operating a TV remote control. From surfing with the controllers presented in the thesis, we are confident that recognising gestures for controlling a jetboard is within a similarly short time limit if the designer wants a great user experience to be had.

The smartwatch based gesture controller would also benefit from a battery symbol for the smartwatch battery charge while in the application instead of having to exit the program to view the smartwatch battery. The tutorial UI could also be improved to increase users' rate that fully understood how the gesture controller works. As for gesture based controlling systems, it would need some form of physical feedback from the gesture controller to increase the usability of the score or perhaps see if the experienced feedback of surfing faster is enough.

When the gesture controller's usability is enhanced, a further study performed on the water with users will benefit from getting more credible study results than doing studies on land.

Chapter 12

Conclusions

This thesis has covered a wide span of activities which can give insight in further developing the concept of an alternative design for operating a jetboard. First, research into the subject area and the related work about gestural interfaces was done. After that, a Field Study helped us to understand better how users operated the board naturally. The bodystorming sessions then help to find out which gestures to explore in the first user study. With cumulative knowledge from previous moments and the first user study, the implementation began. The development of several different prototypes led to one evaluated controller in the final user study.

The smartwatch solution resulted in being below average in SUS score, only being better than 40 percent of all products. Radinn's controller scored much higher and ended up above the top 70 percent of all products made. It shows a need for further development and perfection of the smartwatch solution until it reaches a level on par with Radinn's controller.

The mental load is higher for the smartwatch controller compared to Radinn's solution. The smartwatch solution has a "Somewhat High" Task load, according to the NASA TLX score. Radinns solution has a "Medium" Task Load. This difference can be significant for long time use of the controller and board. A typical ride can last for one hour.

However, Hand Gesture Based Controlling Systems still can eventually enhance usability compared to more traditional controllers. There is still much work needed for it to become a better controller than the traditional one. The main reason for this is due to the mental demand that was required for gesture based controllers. It may be due to the lack of physical feedback, false gesture triggers, and not triggering when it should. As of now, the existing solution offers substantially better usability compared to a gesture based solution.

The gestures themselves were not necessarily troublesome for users and provided a physically comfortable and enjoyable interaction. It was instead the performance issues from the controller that worsened the experience. If better implementation fixed these faults, it could eventually become a better solution than the existing one. The gestures will still be unintuitive for new users to understand. While Radinn's existing solution diminishes the complexity of boosting by pressing an intuitive physical button, the gestures must be memorized.

Even though it is not featured in the studies, due to them being conducted on land, it was noted during prototype testing that the touch screen on the smartwatch was useless when operating the board on the water. Even if the smartwatch is not wet, the wet fingers make the touch screen almost impossible to navigate. Touch screen input is not feasible to complement the gestural interface in the watersport environment. So while a screen solution can offer a better User Interface for guidance and explaining the overall system's functions, a touch screen interaction may spoil the usability when surfing. Comparing the SUS ratings for each category, the category "I needed to learn a lot of things before I could get going with this system" was lower for the smartwatch solution. It is hinting that a screen and a guiding UI may help the user to get a better understanding of how the product works compared to using only vibration and four LEDs.

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Appendices

Appendix A
Field Study Notes

Table A.1: How users operated with the board

Sex	Age	Surfing skill	Falls	Notes (Trends, patterns, etc.)
Male	47	Advanced	0	One hand is always held straight out. Waves a lot with his arms and hands to sustain balance. Right foot back, holds controller with the left hand. Right hand forward with the controller. He uses his arms to find a good balance. He tilts his body to the side he is going to turn to. He presses his left hand down when turning left. Right foot forward a lot. When it looks like he's about to lose balance, he corrects his posture by lowering his body, especially his arms. His arms are naturally positioned under the center of his body when riding. His body looks like it's falling forward, and the arms come waving forward multiple times during a short time. Waves his hands occasionally. His body is oriented more toward the side. Arms are all over their range of movement, but most of the time, they are straight

Female	46	Average	1	Drives stable with moderate speed. Hands are still and controlled, but the user sometimes waves her hand to the crowd. Hands are held down else. Right leg back and holds controller kept by the right leg with the right hand. She puts herself in a prone position when launching and accelerating slowly. Transition to a kneeling position with the right leg back before standing up. She puts her hands in a chicken wing position and falls. She presses the board with her hands to get standing. She stands with a body posture that resembles a lounge with her right leg back. Arms in front of the body. When about to rest, she puts her hands on the board first and then hugs the board with her legs wrapped around the back part. She accelerates while her arms are resting in parallel with the board's surface. When the user rides and hits a wave, her right-hand goes up and down for each wave that is hit. She fists the sky with her right hand when she is about to lose balance after slowing down.
Male	50	Beginner	2	Has trouble standing on the board. He lays down on the board and holds his hand onto the board while using his thumb to control the speed throttle. Crawls on top of the board from the water. Grips underneath the sides of the board at the top with hands and at the same time accelerates. He does the same thing after he falls. He stands on all four before trying to stand upright. Swims toward the board. Positions his hands in front of his body, around the center. He uses a body pose resembling a lounge when riding. His right foot is back with the right hand back
Male	50	Beginner	2	Begins driving by laying on the board. He falls down when he tries to stand up. His hands are in balance when he finally stands up and becomes more experienced. This person has his arms closer to the body, almost under his breast, when he is lying on top of the board. He crawls in different ways all over the board. He has his hands in a chicken wing position when riding. He is very forward-facing with his body

Male	50	Beginner	2	He lies down on the board and holds his hands onto the board. After a while, he stands on all fours, the knees and hands onto the board. He holds his hands around the frame when starting. He kneels on the board with his hands on the board. He flails around with his arms up high when he is about to fall but falls at the end
Male	20	Advanced	6	He moves his hands up and down in order to remain balanced. He lowers his whole body and moves it synchronously with the board. They act as one. Sometimes stands in a plank position on the board. He starts from a prone position, pulls his body up with hands on the board, and kneels with his legs. Rides with left leg to the back left arm back in a stance which is facing the side and in a lower position under neutral riding circumstances. Controller in the right arm in front of the board. Sometimes lowers the upper body towards the board when riding. Occasionally jolts forward and downwards with his body and then corrects his posture quickly to a more upright position. He flails around with his arms when he is about to fall but falls in the end. He uses the same technique described earlier to launch again. He Falls in front of the board with his hands up. He falls again after having arms straight out at each side like walking on a line.
Male	30	Beginner	-	He sits on the board and drives with fast speed. When standing up, he continuously falls down with his body to combat the waves. He waves his hands for balance. Mostly tries to help the next user described in the next row. Rides with both legs together or in a lunging forward position
Female	25	Beginner	-	She has a hard time with the board. She lies down for a very long time and drives at low speed. She is never able to stand up on the board. She holds her hand onto the board all the time. This user is spending most of the time trying to get on top of the board. She does not stand on top of the board. Lays in a prone position on the board with hands gripping the frame at the sides of the board.

Female	30		-	She falls down when having no speed. She stands on the board and holds her hands onto the board edges. Her hands are still, but the thumb is moving to control the board. She drives this way for several minutes at low speed. Uses left leg back. She rides the board by not standing at all. Instead, she is knelt over with hands on the middle part of the board. She turns quite good.
Male	50	Beginner	-	He stands on all fours in the beginning. He is able to stand up relatively fast. He uses his hands onto the board for stability when trying to stand up. When standing, he pointed his hands out like a Y shape.
Male	45	Advanced	2	Drives very fast, the body is stable, hands are still, positioned around the legs. Even though he is stable, his body and hands move a little up and down with the board. He loses some balance when turning. When launching, he grabs the tip of the board with his left hand while his right hand is gripping the right side. Puts one foot at a time on top of the board, starting with the right leg in the back. The body is pointing diagonally to the side. He holds his arms close to the body most of the time when riding forward. When turning, the arms go more apart from the body. The sharper the turn, the more the arms go away from the body. He tries to save himself from a fall by tilting his body downwards and forward while touching the water with his right hand. The user has straps on his board to put his feet into.
Male	28	Beginner	5	Uses hand to stabilize. He moves his hands a lot back and forth to stay balanced. He lies down on the board a lot. Most falls are from the user being propelled forward.

Appendix B

BodyStorming Gestures

Table B.1: Gestures from Bodystorming

Finger snapping
Clench Fist
Release Fist
Clap hands twice
Pushing Thumb Down
Forming an "O" with fingers
Raise Forearms
Moving arm in an infinite sign motion
Tapping leg with hand
Clap Leg
Wrist Flicks
Tapping the board
Thumbs up

Pointing

Flat Hand facing forward

Circular hand motion

Sideward flick of the hand

Smashing Fists Together

Leaning Body Forward

Wave "No" with open hand

Arm in pendulum.

Fingermovements

Head Angle

Voice

Gas pedal on Board

Touch sensing slider on board

NeuralLink to "think" of speed

Row with hands

Jumping of jetbaord

Periphery detemines speed

Tap Head

Rotate Arm to left or right

Put hands together

Tap foot on board

Show number of finger to determine speed

Wave finger tips up and down

Pinching an imagined knob and twist it

Zones in vision generates speed

Punching Fist in Air

Tap On Smartwatch

Appendix C

List of Changes