Creating helpful and motivating motion games for active breaks in a sedentary work environment

Motiverande och hjälpande rörelsespel för aktiva raster vid stillasittande arbetssmiljö

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Upphovsrätt

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Abstract

One major issue that office workers face in their daily lives is a large amount of sedentary behavior. To help alleviate this, researchers at Linköping University are developing a collection of motion games to create natural and motivating active breaks named Liopep. This thesis presents the development and evaluation of one new game being added to Liopep called BoatSim. In BoatSim, the player makes real rowing motions in front of a webcam to row a virtual boat between various islands, where they can grow crops, raise cows, etc. BoatSim was created in the game engine Godot, with a motion controller powered by Mediapipe Pose. The game was evaluated by repeated playtesting where data was gathered to determine how much movement was achieved by a player interacting with the various different parts of the game, and comparing these to each other.
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1 Introduction

Spending too much time in a sedentary position, as in at a computer, has many harmful ergonomic implications. This is a major risk to many people working office jobs, where they might spend the majority of their average workday sitting still at a desk. The Public Health Agency of Sweden\cite{16} advices that taking regular short breaks to move around can help counteract this risk. In practice though, few office workers abide by these guidelines on their own. To help the workers get into the habit of taking regular movement-breaks, researchers at Linköping University have developed a program called Liopep\cite{1}, which is a collection of motion games controlled through a regular web-camera. The program encourages users to regularly take a break to play a game or two, where they have to move their bodies to complete the games' objectives. This paper describes the creation of one such motion game to be added to Liopep; a game called BoatSim, where the user moves a boat between islands by repeatedly performing rowing motions to row, and stepping side to side to steer.

1.1 Motivation

Sedentary lifestyles easily lead to issues such as back pain or neck stiffness. This is a problem serious enough to be recognized by the World Health Organization\cite{14}. One of the main causes of sedentary behavior is office jobs, where workers spend up to 40 hours per week at a computer. While things like exercise do help to counteract this, the sedentary activities ultimately have to be broken up to eliminate the risk. To negate the sedentary nature of office work, The Public Health Agency of Sweden states that taking a short break every 30 minutes to move around is beneficial\cite{16}. To this end, just about any movement is good movement; the important thing is to stop sitting still for a short time. Liopep presents a motivating way to do just that, utilizing motion games. Motion games, when developed with intense movement in mind, provide both the body movement of exercising and the addictive fun-factor of video games. To create a long-term motivating environment that utilizes many different muscles, Liopep seeks to present a wide variety of motion games controlled by many different movements. To this end, BoatSim can be considered an important addition to the program, as it presents not only a new control-scheme not seen in other Liopep games, but also a unique game apart from the movement. BoatSim has the player row a boat between islands, where they can gather resources such as water and seeds, which can be used in different islands to plant and water crops, which when harvested can be sold for profit or
fed to cows for milk. The game carries an aesthetic comparable to titles like Stardew Valley, Animal Crossing, or Farmville, which are games that draw an audience of players that do not necessarily play many other video games. This is part of what makes BoatSim such an important game for Liopep, as it may attract players that feel uninclined to play many of the other games.

1.2 Motion Games

Motion games that make the player move their body can provide various levels of exercise. Several studies have been conducted on the topic, and Biddiss and Irwin collected and reviewed many of them. They found that some motion games hardly provide less sedentary behavior than playing traditional video games, while others can provide a proper workout. This suggests that motion games can be employed to break up sedentary behavior, but only if implemented with non-trivial movement in mind.

1.3 Liopep

Liopep is a program developed by researchers at Linköping University to combat sedentary behavior among office workers. The program displays an interface with a timer counting down until the user’s next recommended short break. When the timer reaches zero, the user is encouraged to stand up and play a motion game for about two minutes. The timer is then reset back to its original value (usually 30 minutes) and the countdown starts anew.

Liopep hosts a collection of motion games all developed for the express purpose of combating sedentary behavior. The games present in Liopep mostly require different body motions to play, which is important to encourage users to activate all of their muscles throughout the day.

1.4 BoatSim

This paper presents the completion of the game BoatSim. The foundation of the game had been created prior to the beginning of the project. This early stage of the game included basic mechanics for movement between islands, planting, watering, and collecting apples from trees, feeding and milking cows, collecting water from a well, and trading items at a merchant. These mechanics were all displayed within a demo of the game, although they featured multiple programming bugs, and lacked many aspects pertaining to positive player experience. Most notably though, the game at this stage used a simple motion controller which made the boat move when the player performed a deep bowing motion. This motion was not only unintuitive to the act of rowing, it also strained the user’s neck as they repeatedly tilted their neck backwards to look at the screen in front of them as their body was perpendicular to the ground.

Originally, BoatSim was intended to be controlled by the user making rowing-motions, but implementing such a motion controller in practice was difficult, as the body tracking provided by Mediapipe Pose is very imprecise in terms of z-coordinates. That is to say, within the frame of the BoatSim project that uses Mediapipe Pose, it is very difficult to detect when the user is leaning forward towards the camera or backwards away from it. Therefore, the original plan for the motion controller was laid aside in favor of the simpler forward-bowing motion. This did mean that the code at the beginning of the project contained traces of the prior attempt at implementing the more advanced motion controller.

BoatSim was to become an important part of Liopep for two reasons. First, Liopep didn’t have any games controlled by a rowing motion where the elbows are pushed backwards to contract the shoulder blades, which is a very ergonomically sound exercise. Second, Liopep didn’t have any games featuring long-term progression. Most of the games in Liopep use
scoring systems as their main motivators, meaning that every play session is evaluated and
given a score, which is compared to previous record scores on a scoreboard. Boatsim on the
other hand, instead opts to motivate players by letting them progress through the game over
time, gradually expanding their territory by unlocking new islands, and filling their islands
with new content. Nijhar, Bianchi-Berthouze, and Boguslawski\[13\] suggests that players find
motivation for motion games in one of two categories: relaxation and achievement. They
explain that competitive players play games to challenge themselves, obtain high scores, and
defeat other players, whereas other players play to have fun or relax. Liopep users who draw
motivation from competitiveness likely enjoy the score-based systems of previous Liopep
games, but the ‘just for fun’ users might have more trouble finding a game that motivates
them. To this end, BoatSim should help fill the gap as a relaxing farming game. As an added
bonus, Nijhar, Bianchi-Berthouze, and Boguslawski also found that players who play to relax
are more likely to use the motion controller as intended and not search for ways to ‘cheat’
and get away with different motions than instructed. In the case of BoatSim, this means that
users may be more likely to perform the rowing motions as intended, granting them good
exercise.

1.5 Aim

The purpose of this project is to investigate how well playing BoatSim and executing repeated
rowing motions and side-stepping motions can assist in breaking up sedentary behavior.

1.6 Research questions

The following research questions will be answered in this paper:

1. How can a farming-based exergame be developed to reward high levels of player move-
ment?
2. How do the different segments of the game (moving forward, turning, navigating
menus, etc.) affect the level of movement achieved by the player?

1.7 Approach

To answer the research questions, a semi-finished version of BoatSim will be further devel-
oped to completion, and made to gather data detailing the player’s movement while playing
it. Data will be gathered using an almost-finished version of the game, and analyzed to draw
conclusions about which features of the game contribute to different kinds and amounts of
movement. The game will be created using the game engine Godot, as this is the basis for all
Liopep games.

The Liopep environment adds some constraints to the project. The game has to function
in an office environment with limited space, be intuitive without necessarily being able to
output audio, and it has to be able to properly register the movements of people with different
body shapes and sizes. It should also be at least somewhat different to other games in Liopep,
both in terms of game design and motion controls.
Many studies have been conducted on the topics of sedentary behavior and motion games, and this chapter presents some of the most relevant ones to the topic at hand. Little to no prior research exists on explicitly designing motion games to encourage short active breaks in sedentary behavior, so instead theory regarding sedentary behavior and the breaking up thereof, as well as general motion game design, is reviewed here.

2.1 Sedentary Behavior

It is no news that large amounts of sedentary behavior. Ekelund et al[4] summarize data from various studies to correlate sedentary behavior, physical activity, and mortality rate. They find that high amounts of sedentary behavior, particularly TV-viewing, leads to increased rate of all-cause mortality; furthermore, they found that physical activity can attenuate this increased rate, or even eliminate it entirely with enough exercise. High amounts of TV-viewing in particular seemed more dangerous though, as even high amounts of physical exercise could not entirely eliminate the increased mortality rate associated with it. It is unclear why TV-viewing appears more harmful than other forms of sedentary behavior; it might be affected by typical TV-related habits such as watching in the evenings or snacking, but it could also tie into a different study by Hagger-Johnson et al[6]. They also investigated the correlation between sedentary behavior and all-cause mortality, but they also took fidgeting into account, and found that fidgeting behaviors (moving one’s hands or feet while the rest of the body is sedentary) can alleviate or eliminate the increased risk of death associated with being sedentary. Perhaps Eklund et al’s findings about TV-viewing are related to a decreased amount of fidgeting while watching television.

There have also been various studies on breaking up sedentary behavior by taking active breaks. Peddie et al[15] and Brocklebank et al[13] conducted studies showing that regular activity breaks during otherwise sedentary behavior can lower postprandial glycemia. Larsen et al[9] conducted a similar study where they showed that breaking up sedentary behavior with light activity can reduce resting blood pressure in overweight adults.
2.2 Guidelines for Motion Game Design

Isbister and Mueller [8] presents three clusters of guidelines for designing motion games, and speaks of the implications to the broader Human-Computer Interfacing community. They establish these guidelines through a multistep process of reading theory, writing drafts, and consulting experts for feedback on said drafts. The first guidelines cluster presented speaks of how motion games require particular feedback for the input motion. Among other things, the ambiguity of movement is highlighted, and presented as something developers should embrace. Human motion is not precise like keyboard input is; our movement comes with a lot of swaying and shaking that isn’t necessarily intentional. The cluster advises that these ambiguities of movement should be embraced rather than fought against. The second cluster presents how various bodily challenges that come with movement can be utilized. This include how fatigue can be used as a game mechanic, where all or part of the challenge of a game is built on performing a strenuous exercise for as long as possible. Another challenge presented by the cluster is risk handling. Motion games typically come with some risk of hitting or bumping into things around the player, or falling over; in terms of motion games played in a local multiplayer setting (several players in the same room playing simultaneously), there’s also a risk of players colliding with each other. These risks can be turned into something positive with a bit of clever game design. As long as the players are made well aware of the risks involved, they can find much enjoyment in pushing or holding each other to disturb the other’s gameplay. Finally, the third cluster is about the kinds of fun that are associated with movement. Perhaps foremost of these is rhythm. Motion games that center around the player moving in rhythm, oftentimes to music, can be tied both to better performance and enjoyment.

Hara and Ovaska [7] establishes a set of 13 heuristics for motion game design. These heuristics were developed by examining various game reviews pertaining to games played with the motion controllers Kinect for Xbox 360 and Move for PlayStation 3. The resulting 13 heuristics of motion games presented were:

- Diversity: "Design diverse motion paths and avoid repetitive movements."
- No fatigue: "Beware of requiring strenuous movement."
- Challenge: "Keep the game control simple but challenging enough."
- Realism: "Strive for movements that match reality, and use motion control only for tasks that associate with moving."
- Guidance: "Instruct about the correct motion paths and rhythm at the beginning and when needed."
- Feedback: "Give immediate visual or aural feedback about the movements: is the player performing them correctly?"
- Robust recognition: "Pay attention to detecting the movements reliably."
- No false positives: "Make gestures diverse enough to be recognized reliably in all occasions."
- No delicate gesturing: "Do not require overly small movements and precise motion control for selection and movement."
- Natural mappings: "Make mappings natural and precise so that motion paths in the game world and in reality match, making it possible to reach the game goals."
- Tempo: "Make game pace and tempo of movement suitable for motion control."
- Multiple players: "Support many simultaneous players."
2.2. Guidelines for Motion Game Design

- Space: "Adjust game play to the space available."

Note that some of these heuristics seem contradictory to other related material. For example, Isbister and Mueller’s research presented above shows that fatigue can be an interesting game mechanic when implemented correctly, but here the ‘No fatigue’-heuristic indicates that strenuous movement is something to be avoided. This is likely because the heuristics were based on game reviews, most probably including those of games where fatigue isn’t taken properly into account by the developers. The reviews used for the heuristics were leaning more towards negative than positive, so it’s possible that the reviews praising fatigue usage in the more thought out motion games were left out, leaving only the negative reviews of motion games that implemented fatigue poorly.

Mueller et al. [12] presents a framework to analyze motion games. The framework is split into multiple perspectives, both on the body and on gaming.

The framework is divided into four body perspectives:

1. Responding: heart rate, thermoregulation, weight and development of muscles.
2. Moving: the activation of muscles, often to reposition body parts and moving weight.
3. Sensing: equipment and environment such as golf club and living room.
4. Relating: social interactions with others.

The framework is divided into three gaming perspectives:

1. Rules: the motion of body and equipment is hard to predict which leads to uncertainty. Feedback from games can change users’ awareness of their motions to influence their motivation.
2. Play: players can self-express themselves while playing. The expressions are not necessarily contributing towards game goals. The game can cause motions to happen as a rhythm.
3. Context: with motion comes risk. Enacting in physical activities enhances one’s understanding of one’s body.

The framework can be used as a tool for designing and evaluating appealing motion games. Although its main purpose is games, it can be useful when working with other interaction systems which have interfaces that the user interacts with using their body.

Sinclair, Hingston, and Masek [17] presents a collection of success factors for motion games, based on prior studies in related fields. These success factors are chosen with a focus on granting players proper exercise, beyond simply going past sedentary gaming. The factors are split into attractiveness and effectiveness. Attractiveness describes how to make exergames fun to play, and is presented along with the idea of ‘gameflow’, a state of mind where a player is fully engaged in playing a game. Effectiveness is about achieving health benefits through exercise. This can be partially integrated into gameflow, as fitness can be considered a skill, and challenging personal skills is one aspect of gameflow.

In practical terms, the paper presents a set of generic guidelines for aerobic exercise and a model of gameflow, again taken from prior research in the respective fields. Aerobic exercise is presented as warranting a 5-10 minute warmup, 20+ minutes of exercise at 77%-90% of maximum heart rate, and a 5 minute cooldown. Gameflow is described as requiring a set of conditions to be met, consisting of:

- Warranting and enabling concentration
- Being appropriately challenging to match player skill
- Enabling player skill growth
2.2. Guidelines for Motion Game Design

- Letting players feel in control
- Giving the player clear goals
- Giving players feedback for their actions.
- Helping the player get immersed in the game
- Helping the player socially interact with others over the game.

The paper then proceeds to present a "dual flow" model, where high skill is met with high challenge to create psychological flow, and high fitness is met with high intensity exercise to create physiological flow.
3 Method

To answer the research questions, data had to be gathered describing the movement expended by at least one experienced player playing through various parts of a complete or almost complete version of BoatSim.

3.1 BoatSim Development

At the start of the project, BoatSim was in a functional demo state, but lacked many desired features, along with a proper motion controller.

3.1.1 Development Software

BoatSim, as well as every other game within Liopep, was created using the Godot game engine[5], specifically Godot version 3.4.4. Godot is a free and open source game engine for cross-platform development in both 2d and 3d environments.

The motion controller was created using Mediapipe Pose[10], which provides body tracking by converting an input video feed into a set of 33 3d-coordinates. Mediapipe[11] is a collection of tracking software developed by Google. Among other things, it contains programs for body, face, hand, and eye tracking through nothing but a video feed, without the need for any special equipment. These solutions are available on various platforms, varying by program.

The coordinates provided by Mediapipe Pose represent landmarks on the body of a person visible in the video feed. Mediapipe Pose does provide some ready made functionality, such as rendering a basic skeleton based on these landmarks. For more specific problems, developers using Mediapipe Pose are able to extract the landmark coordinates and manually build their programs around them.

There are two sets of landmarks provided by MediaPipe Pose, each containing matching sets of 33 coordinates. One is called the Pose Landmarks and the other World Pose Landmarks. Pose Landmarks contains body landmarks with coordinates relative to the camera in use. World Pose Camera on the other hand contains coordinates relative to the central body of the user. This means that a user moving sideways would offset the X-coordinates of all of their Pose Landmarks, but it would not affect their World Pose Landmarks, because those
3.1. BoatSim Development

3.1.1 Landmarks

Always display their hips as coordinates around (0, 0, 0) and every other landmark is relative to that center. What’s more, while Pose Landmarks do provide Z-coordinates, these are hardly functional and users are instead advised to use the Z-coordinates provided by World Pose Landmarks. Both sets were used in the BoatSim project, as both valid Z-coordinates and camera-relative X-coordinates were desired.

3.1.2 Motion Controller

A new motion controller was created and added to BoatSim, letting the player control the in-game boat’s movements by performing rowing motions instead of bowing motions. The old and new motion controllers can be seen in action in Figure 3.1 and Figure 3.2. This new controller was developed iteratively, with four different prototypes being created and tested by different individuals. The final motion controller involved using Mediapipe Pose’s z-coordinates (towards or away from the camera) of the players hands and elbows to detect when their arms are stretched forward, and using the x- and y-coordinates of the player’s elbows to detect when their arms are pulled back. This lets the game know when the player is “pushing” and “pulling” the oars. This new motion controller was an improvement over the previous one for several reasons. In part because bowing forward deeply made it difficult to see the screen, hurting the game’s opportunities to provide feedback on the player’s movement (feedback being very important to motion games[7][17]). In part because a rowing motion where the elbows are pushed to the sides and backwards to contract the shoulder blades is a motion that was requested of Liopep. And partly because having player-movement that matches the in-game context supports player enjoyment and helps players get immersed[7][17].

![Figure 3.1: rowing the boat with the original motion controller using bowing motions](image)

To adapt to different players, the motion controller was made to remember the recent "best" movements, i.e. the furthest forward the player has pushed their arms recently, as well as the furthest they’ve pushed their elbows apart. These record movements are then set as the new goal, and any motion that’s close to them is considered a good motion. To handle faulty readings from MediaPipe, if these records aren’t matched for some time, they start to decrease, making it easier for the player to set new records and refresh the goal. Furthermore, even if the player does not come close to matching the goal movement, as long as they perform part of the desired rowing motion (stretching their elbows apart, but not as
3.1. BoatSim Development

Figure 3.2: rowing the boat with the new motion controller using rowing motions

wide as they can), the boat still moves forward, albeit at a reduced pace. This all made the motion controller rather lenient, which can be considered a positive as human motion tends to be very ambiguous, which should be embraced by the motion game[8].

To turn the in-game boat, the player can move sideways to perform rowing motions from a different x-position relative to the camera. This largely remained unchanged from the original motion controller, except for some sensitivity tweaking.

3.1.3 Boat Movement

At first when the player made a motion that was accepted by the motion controller (initially a bowing motion), the boat would gain a bit of speed, and if the player did this repeatedly, the speed would add up. Having no limitations or guidelines for how fast the motions should be performed meant players were at risk of hurting themselves trying to move too fast, having their motions ignored by the camera which didn’t necessarily record images at a very high frequency, or they could simply end up moving very slowly without anything guiding their pace. To counteract this, an upper limit to the boat’s movement frequency was added, such that after the player performed a (now) rowing motion, the boat would gain a bit of speed as before, but then it wouldn’t be able to receive a new burst of speed until a small amount of time had passed. This was displayed to the player by animating the oars of the boat at a set pace. Now when the player made a rowing motion, the boat’s oars would move at a set pace and the boat would gain a bit of speed, and then the boat would refuse any new input by the player until the oars had finished moving. This created a sense of rhythm, as the player was encouraged to learn the maximum rate of movement the boat would accept and try to perform motions at that rate to move at the maximum speed. This is very relevant as previous studies have shown that rhythmic elements in motion games can be tied to both better performance and enjoyment[8].

3.1.4 Features and Progression

At the beginning of the project, the game’s features were limited to rowing the boat between four different islands. One island had apple trees, one had cows, one had a water well, and one had a trader. The project work included altering the game features as follows:
Adding more Plants

New kinds of plants were created, for a total of three different fruit trees, three different field plants, and two different berry bushes, all with different graphics and mechanics. Seeds to plant all of them were also created. Visuals for the old and new plantation systems can be seen in Figure 3.3 and Figure 3.4. Figure 3.5 also shows how seeds are used to plant crops.

Figure 3.3: managing trees with the old system. Only apple trees existed and could be planted indefinitely without costing any resources.

Figure 3.4: managing trees with the new system. Different kinds of trees with different behavior.
3.1. BoatSim Development

Figure 3.5: Consuming wheat seeds to plant wheat.

Altering the Traders

At first, traders only provided the player with a small amount of preexisting trade options. This was altered so that any item the player had could be sold for money, and money could be spent to buy seeds of any kind. The old trading system is shown in Figure 3.6, and part of the new system is shown in Figure 3.7 and Figure 3.8.

Figure 3.6: The old trading system allowing for a limited amount of predetermined trades.
3.1. BoatSim Development

Figure 3.7: The top-level menu for the new trading system, letting the player choose to either buy or sell items.

Figure 3.8: a lower-level trading menu letting the player buy seeds for field plants.

Making Islands Editable
At the beginning of the project, there were a few set islands the player could interact with, all of predetermined types. The ability to turn an empty island into any type (plants, cows, trader) was implemented.

Altering Cow Behavior
Originally, cows ate grass and produced milk, but there was no way for the player to grow grass themselves, instead having to trade for it. This was exchanged for a system where the cows would demand to be fed a randomly selected crop, and would not produce milk until
the player grew and fed them that crop. A new random crop was then selected for the cows to request; this created something of a “quest” system.

Progression Saving
Originally, the game behaved the same every time it was started. Nothing was saved from one session to the next, so any progress the player made was reset to the beginning each time the game was restarted. This was exchanged for a system where the states of the player’s islands are loaded at the start of each game session, and saved at the end.

3.2 Data Gathering
Near the end of the project, the game was made to gather and log data about the player’s movement while playing. This data included at which timestamps the player completed a rowing motion, how qualitative the system interpreted the motion to be (distance between shoulders and elbows in the xy-plane), what state the game was in (rowing the boat or accessing menus), and at what x-position the player was standing at the time.

Data was gathered across 16 game sessions of different length, averaging 217 seconds. Normally game sessions would last exactly 2 minutes, but BoatSim did not have its in-game timer set up at the time, so instead game sessions varied in duration. A total of roughly 2000 rowing motions were performed in various in-game contexts. All of the data was gathered by one player, the author of this thesis, using one game “world”, such that progress was made and retained through all of the sessions.
Results

The data from the playtesting shows how player movement does in fact differ across the different segments of the game. Figures 4.1-4.5 showcase typical movement achieved by the test player in the various game segments, highlighting what makes the segments unique in terms of player interaction. Figure 4.1 and Figure 4.2 show how the test player typically moved while rowing the in-game boat. When rowing, the player is encouraged to move in a constant rhythm to maintain top speed, and the player also has to steer left and right by sidestepping to avoid obstacles and reach their destination. In Figure 4.3, we instead see typical test player movement when landing on a fresh island and converting it to a planting-island. The player here makes a couple of menu-choices to get the island set up, then repeats the same motion over and over to plant crops one by one, before leaving the menu. Figure 4.4 shows typical test player behavior while trading. In this case the player stands still and rapidly makes motions to sell items one by one, then begins moving left and right to navigate the menu and occasionally stopping to buy a few copies of an item. Finally, in Figure 4.5 we see the test player’s behavior when feeding cows. In this case, the player had a lot of different food-items in their inventory, so whenever the cows requested new food, the player was immediately ready to feed them. Therefor the player was able to alternate between the ‘milk’ button and the ‘feed’ button for a while, creating a sidestepping pattern.

The data also yielded average values for movement in the different game segments, as presented in Table 4. The first row of the table shows how frequently the test player performed rowing motions with their arms; actually rowing the boat around is what yielded the most rowing motions in a given time frame. On the other end, interacting with the cows is what yielded the fewest rowing motions. In the second row, we see how much the test player moved sideways on average between rowing motions, and here interacting with cows yielded the most movement, almost doubling the amount of sidestepping performed when trading. The final row shows the average peak distance between the shoulders and the elbows in the xy-plane (where the z-axis faces the web camera) achieved by the test player. This value is used by the game to evaluate the quality of the rowing motions that are performed by the player. If the player pulled their elbows very far apart, it is considered a high-quality motion, and if the player only moves their elbows apart slightly, it is considered low-quality. This metric was chosen as a quality measurement because it represents both how much the player is moving their arms in general, and also how well they are contracting their shoulder blades. The data shows that rowing the boat yielded the highest-quality motions, while
Table 4.1: Average movement data in different game segments

<table>
<thead>
<tr>
<th></th>
<th>Rowing</th>
<th>Plants</th>
<th>Trading</th>
<th>Cows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of movement (rowing motions per second)</td>
<td>0.9096</td>
<td>0.7545</td>
<td>0.6196</td>
<td>0.5317</td>
</tr>
<tr>
<td>sideways movement (difference in x-coordinate between rowing motions)</td>
<td>0.0394</td>
<td>0.0360</td>
<td>0.0301</td>
<td>0.0598</td>
</tr>
<tr>
<td>elbow movement (peak distance between shoulders and elbows in xy-plane every rowing motion)</td>
<td>0.1481</td>
<td>0.1326</td>
<td>0.1259</td>
<td>0.1262</td>
</tr>
</tbody>
</table>

Trading yielded the lowest-quality. Note that the elbow coordinates used to generate the final row of data, though good enough to be of practical use, are less reliable and more prone to noise than other metrics. Also note that the units for the second and third rows are based on MediaPipe Pose’s internal coordinate system and thus not particularly human-readable. As such the numbers are merely meant to be compared to each other.

Figure 4.1: Typical test player behavior while rowing
Figure 4.2: Different example of typical test player behavior while rowing, featuring sharper turns

Figure 4.3: Typical test player behavior while planting crops
Figure 4.4: Typical test player behavior while trading

Figure 4.5: Typical test player behavior while feeding and milking cows
5 Discussion

5.1 Results discussion

The results showcase that different parts of the game do in fact give rise to different amounts of movement, and it’s not just rowing versus menus, different menus also affect player movement differently. The boat rowing yielded the most player movement, possibly because the test player didn’t have to stop and think as much as when navigating multilayered menus, but it could also be because of the rhythmic element of rowing. Multiple sources state that highlighting a comfortable rhythm of movement in exergames can have a positive effect.[8][12]

One thing that might affect the results is that the test player often stopped at a plantation island merely to water the crops there, or to harvest crops that don’t require replanting (trees or bushes); this meant the player only needed to press one or two menu buttons before being ready to leave the island. Such interactions likely increased the average x-movement of that island category while reducing the average rate of performing rowing motions. Similar scenarios also arose with both the cow islands and the traders, where the player would feed and milk the cows once before leaving, or purchase only one or a few seeds from the trader.

The reliability of the data itself can also be questioned, as only a small amount of playtests performed by only one person were logged. The data that does exist was manually investigated and deemed without obvious fault though.

5.2 Method discussion

BoatSim could have been developed in a few different directions, but given that the project began with an incomplete version of the game, many of the biggest design choices had already been made. Much of the project time was spent on the motion controller, new game mechanics, and the progression system.

The motion controller was important because the main point of the project was to create something helpful for office workers, and the previous motion controller was not sufficient. Having the player perform actual rowing motions to row the in-game boat is good because having the in-game motions match the real-life ones helps maintain immersion and feels natural[7][17]; however, due to various constraints the same motion is also used to press buttons in the game’s various menus, which not only harms the player’s immersion, but it
also causes issues by reducing motion diversity and causing fatigue\cite{7}. Adding more motions for the player to learn would risk making the game more complex to play though, and would likely increase overlap in motions with other Liopep games.

The new game mechanics were important to make the game interesting to play. The existing gameplay loop at the very beginning of the project allowed for no creativity or decision making by the player, and the game did not last long at all before the player had seen all of the content. With the larger amount of islands, 8 different plants, cows demanding randomized treats, and traders selling every type of seed, the game has a lot more to show the player before it runs out of content. Even more importantly, the player gets to grow their own plants, and get to choose for themselves which crops get planted on which island. This opens up for the player to express some level of creativity, which can be a motivating factor for many.

Lastly, the progression system was important to set BoatSim apart from other games in Liopep and create a motivating experience for players who might struggle to find motivation to play the other games in the collection.

5.3 Sources discussion

Sources cited in this thesis are either scientific sources in the form of articles or conference proceedings, guidelines by WHO or the Swedish Public Health Agency, or simple websites used to prove existence. The scientific sources have been deemed trustworthy. The WHO and the Swedish Public Health Agency are authorities on their topics. The Swedish Public Health Agency uses WHO as their main source, and largely parrots what WHO says. WHO in turn do extensive research and back up their claims with plenty of scientific sources themselves, and are thereby deemed trustworthy. The websites for things like Mediapipe or Godot hold little to no scientific value as sources, but are used in this thesis solely to prove existence and give readers a place to go for more information.

5.4 The work in a wider context

BoatSim, as well as Liopep as a whole, is a research project at Linköping University, with the aim of counteracting sedentary behavior among office workers by creating motivating movement-breaks in their work life. This serves to improve the health and well being of the office workers involved.
Conclusion

The research questions posed in chapter 1 were as follows:

1. How can a farming-based exergame be developed to reward high levels of player movement?

2. How do the different segments of the game (moving forward, turning, navigating menus, etc.) affect the level of movement achieved by the player?

The first question is broadly stated, and such can only receive a broad answer. In the case of BoatSim, player movement can be further rewarded by emphasizing the parts of the game that require high levels of movement. The results presented in chapter 4 showcase that, for instance, rowing the boat yields a higher amount of movement than trading, both in terms of performed rowing motions and sidestepping. Given this knowledge, the game can be improved on in terms of achieved player movement by minimizing the time the player spends trading and instead having the player spend more time rowing (perhaps by adding menu buttons to purchase or sell many copies of an item instead of trading them one by one, or perhaps by adding a rhythmic element to the trading menu to encourage players to trade at a steady pace). Another way to reward high levels of player movement could be to make rowing the boat inherently more rewarding, possibly by increasing the distance between islands, or by making the further-away islands yield more crops when planted on. It is worth noting that the rowing segment that seems to yield the best player movement is the only segment with a rhythmic element to it, which is in line with Isbister and Mueller’s findings. This could also tie into Hara and Ovaska’s heuristics where they state that player movements should match a real-life scenario; meaning that players might find more motivation to perform the rowing motions when they actually correlate to in-game rowing as opposed to performing the same motions to navigate menus.

The second research question is strictly about BoatSim, and is answered by the test results in chapter 4. Different game segments yield different amounts of player movement. On average, players make more rowing motions when rowing the boat than when navigating menus, and they make comparatively few rowing motions when interacting with cows. On the other hand, the player performs a lot of sidestepping when interacting with cows. The player also performed the highest-quality rowing motions when rowing the boat. In gen-
eral, the player performed the most movement in most categories when rowing the boat, and underperformed in most categories when trading.

6.1 Future Work

There are still many improvements that can be made to the BoatSim game. Right now there is not much for the player to do once they have amassed enough in-game currency; adding more expensive items for the player to save up for and purchase would add a greater sense of progress. A way to show off one’s island system to other players would also be good, as it would enhance the social aspect of the game. The study itself could also be improved upon, as a greater amount of data, preferably with a greater amount of players involved would yield more precise and trustworthy results. There are also various metrics that were not taken into account in the current dataset. For instance, the data does not make any distinction between rowing the boat between two islands next to each other with no obstacles in between them, and rowing the boat between two far-away islands with plenty of obstacles. As this and many other things are left out of the data, there could be unknown factors affecting the results without being accounted for.

As for future studies on the subject of motion games for combating sedentary behavior, there has been plenty of research showing that active breaks have a positive effect on countering the risks of sedentary behavior, but it is still largely unclear to what extent, and how different kinds of movement differ in this regard. There is also still very limited research on how motion games help to motivate people to exercise.
Bibliography


