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BALANCE TRAINING WITH A MOBILE PHONE ACCELEROMETER

Finding the baseline parameter settings

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BALANCE TRAINING WITH A MOBILE PHONE ACCELEROMETER

Finding the baseline parameter settings

The purpose of this thesis was to develop a game for improving proprioception by using a balance board as a controller, and to find default values for several in-game parameters. The reason for this study is that there are many groups of people who could benefit from improving their proprioception and sense of balance in a more enjoyable way than regular fitness training.

In the game, players control an in-game platform by manipulating a physical balance board. The aim is to manage the tilt of the physical board so that the ball doesn’t fall off the virtual track. The game was developed with the Unity game engine, using C# language and a mobile phone accelerometer as the device that calculates the physical balance board tilt by having the phone lie on the balance board.

The mobile phone accelerometer sensitivity to physical movement can be set with three different parameters, namely maximum tilt angle, tilt speed and tilt multiplier. This thesis attempted to determine the most suitable default values (or baseline) for these parameters so that the game difficulty level for healthy (not suffering from any balance impairment conditions) individuals could be set.

Results were gathered using two different testing methods. Each method recorded different data, one for player preference and the other for in-game success. Gathered data shows that the preferred settings are not the same as the settings where players get the furthest in the game.

KEYWORDS:

Accelerometer, mobile phone, proprioception, balance, Unity game engine, game development, exergame

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TASAPAINON KEHITTÄMINEN MATKAPUHELIMEN KIIHTYVYYSANTURIN AVULLA

- sopivimpien muuntujien löytäminen

Tämän opinnäytetyön tarkoitus oli kehittää tasapainolautaa peliohjaimena käyttävä peli, joka auttaisi liikeaistin harjoittamisessa sekä löytää pelin muuttujille sopivat oletusarvot. Tutkimuksen syynä on se, että on olemassa monia eri ihmisryhmiä, jotka hyötyisivät liikeaistin ja tasapainon kehittämisestä normaalia fitness-harjoittelua mukavammalla tavalla.

Pelissä pelaaja ohjaa pelin alustaa seisomalla tasapainolaudalla. Tarkoituksena on kontrolloida pelin alustan kallistusta niin, että pallo ei tippuisi radalta. Peli on kehitetty Unity-pelimoottorilla käyttäen C#-ohjelmointikieleltä ja tasapainolaudan kallistus saadaan matkapuhelimen kiihtyvyysanturia käyttäen asettamalla matkapuhelin tasapainolaudan päälle.

Matkapuhelimen kiihtyvyysanturin herkkyys fyysiseen liikkeeseen voidaan asettaa kolmen eri muuttujan, maksimikallistuskulman, kallistusnopeuden, ja kallistuskertoimen avulla. Tämän opinnäytetyön tavoitteena oli määrittää oletusarvoja näille muuttujille, niin että peliin voitaisiin asettaa peruslinjainen vaikeusaste terveelle yksilölle.

Tuloksia varten käytettiin kahta eri testausmenetelmää. Kumpikin menetelmä keräsi eri dataa, ensimmäinen keräsi pelaajan henkilökohtaista mieltymystä muuttujien arvoihin, kun taas toinen keräsi pelaajan onnistumista eri muuttujilla pelin sisällä. Kerätty data näytti, että muuttujien arvot mieltymyksissä eivät täsmänneet arvoihin, joilla pelaaja pääsi pisimmälle.

ASIASANAT:

Unity-pelimoottori, tasapaino, liikeaisti, liikuntapeli, pelinkehitys, matkapuhelin, kiihtyvyysanturi

CONTENT

FIGURES

TABLES

LIST OF ABBREVIATIONS

Wi-Fi	Wireless-Fidelity
LAN	Local Area Network
DDA	Dynamic Difficulty Adjustment
DL	Double Leg
SL	Single Leg

1 INTRODUCTION

Fall injuries are common among the elderly and are very closely tied with bad proprioception and balance. Fall deaths in the U.S. increased by 30% from 2007 to 2016 (CDC, 2019) and training proprioception is increasingly important to prevent injuries, and even deaths. Training balance and proprioception is also commonly used for rehabilitative training for all patients, including athletes and elderly. This study aims to increase the knowledge about proprioception and balance in general, why they need to be trained and the different methods for training them. Moreover, this study sets out to develop and tweak a balance training environment using game technology.

Training proprioception and balance is commonly done with the help of professionals at start and continued alone at home or in group sessions. Finding motivation to continue home training can be difficult, but with the help of exergaming, patients can now train in their home environments in fun and engaging ways.

Using the Unity game engine and a mobile phone as controller, this thesis set about making an exergame for proprioception training. The mobile phone was attached to a balance board that was placed on an unstable surface (sponge). The movement of the board was picked up by the phone's accelerometer and transmitted via Wi-Fi to the game. The game contained a virtual track that mimicked the real board's movement and the player's task was to control the track in such a way that a virtual ball could roll to the end of the track without falling off. The responsiveness of the virtual track to the physical board is managed by three parameters that can be set at the onset of the game. These parameters include maximum tilt angle, tilt speed and tilt multiplier and depending on the settings, the game would become easier or more difficult—more detailed explanations of the parameter effects are given later in the thesis.

The scope of this thesis did not include testing the game on those with balance impairment, but rather set out to determine the parameter settings most suited to players who have no issues with balance or proprioception. In order to find these baseline settings, the study first approached several players and asked to play with some arbitrary settings until they settled on their preferred settings. The second phase of testing used a series of six settings combinations around the previously established player-preferred settings. A new group of players (15 emergency rescue personnel) were asked to play one round (lasting 60 seconds) on each settings combination. The distance that each player achieved with the ball on the virtual track was recorded. The settings combination where most players achieved the greatest distance was considered the baseline for the game parameters.

After this introduction, section 2 of the thesis provides detailed explanations of balance and proprioception before moving onto a discussion, in section 3, about how exergaming has been addressing the training needs of those with balance impairment issues. Section 4 describes the game, the parameters and their effects on the game and the how the game was made. In section 5, the thesis describes the methods that were used to obtain the baseline parameter settings, as well as what the baseline results were. The last part of the thesis (section 6) is dedicated to a discussion of what the results mean and what the study concludes. Recommendations for further study are also given in section 6.

2 SENSE OF BALANCE

The sense of balance comes from the brain receiving multiple signals from different parts of the body, specifically eyes, ears and the muscles and touch sensors in the legs (NIDCD Information Clearinghouse, 2017). These signals are primarily channeled through the body's proprioception, which is in turn governed by the vestibular system. The next sections explain how these three systems are interlinked to give what we simply term, sense of balance. There are other body mechanics and physiological responses that play a role in balance, but since this thesis is not targeted at the science of human movement, headline discussions of proprioception, the vestibular system and balance will suffice.

2.1 Proprioception

Proprioception is the sense of the body relative to the head and strength required for moving the body. This sense enables one to move their body in a certain way without the aid of other senses like touch or sight. For example, one can close their eyes, spread their hands apart and move index finger together or at least to proximity.

The term proprioception was first used by Sherrington in 1906 describing it as feedback from the limbs to the central nervous system (Dover & Powers, 2003). Proprioceptive information is provided through a variety of mechanoreceptors, sensory receptors that respond to mechanical pressure or distortion. The main mechanoreceptors for proprioception are Ruffini corpuscle, which identifies the stretching of the skin, muscle spindle receptors, which detect changes in the length of the muscle, and Golgi tendon organ, which senses changes in muscle tension (Dover & Powers, 2003).

There are multiple techniques to measure proprioception, with joint position sense being the most common one. Joint position sense test measures the accuracy of placing a knee to a previous angle (Adachi, et al., 2002). Other techniques involve kinesthesia and sense of tension. Kinesthesia testing measures the threshold of detecting passive motion and a more specific test is about detecting passive motion direction (Riemann, Myers, & Lephart, Sensorimotor System Measurement Techniques, 2002). Sense of tension tests compare the ability to reproduce torque by a group of muscles under different conditions (Riemann, Myers, & Lephart, 2002). These three test techniques, joint position sense, kinesthesia, and sense of tension, are also regarded as the submodalities of proprioception (Riemann & Lephart, 2002).

Proprioception is integral part of controlling body movement, or motor control, and as such plays a big part in the sense of balance. Proprioception can be viewed as the trigger for corrective action that needs to be taken when the body's perceived position in space is distorted. The brain is made aware of these distortions, however insignificant they may be, through the vestibular system.

2.2 Vestibular system

The vestibular system, or the labyrinth, is a bone and soft tissue maze-like structure in the inner ear (Figure 1). The labyrinth contains three semicircular, fluid-filled, canals that are roughly arranged at right angles to one another. The end of each canal is blocked by a special membrane, cupula, that has mechanosensing hair cell organelles, stereocilia, attached to it, when the head moves the fluid within the canals moves and pressures the cupula allowing stereocilia to send a signal to brain. This signal is then processed within the brain to tell the rotation of the head.

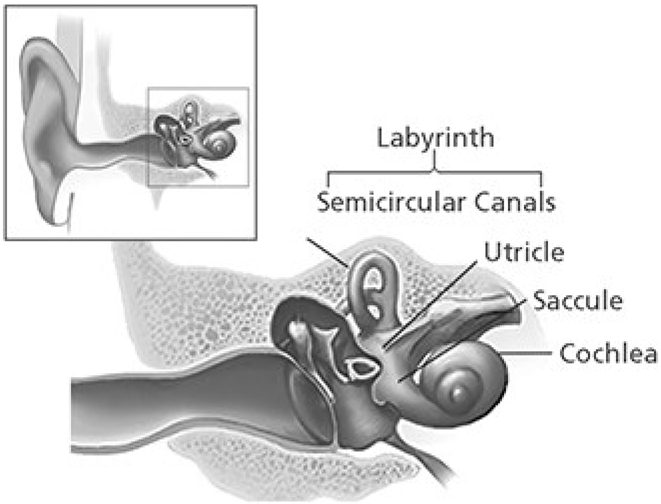

Figure 1. Vestibular system structure inside the inner ear (NIDCD Information Clearinghouse, 2017).

While the rotation of the head is sensed by semicircular canals, the sense of linear accelerations happens within two otolithic organs, utricle and saccule. These two organs are fluid-filled pouches with stereocilias lining the wall in a gel-like layer. The gel contains tiny, dense grains of calcium carbonate otoliths, when the position of the head changes, gravity pulls on these grains, moving the stereocilia and sending the signal of head's position to the brain (NIDCD Information Clearinghouse, 2017).

These internal systems and triggers for corrective body positioning are outwardly manifest in a person's muscular response to these systems. These muscular responses to brain signals are collectively seen as a person's balance and this is the area most often targeted by athletic trainers and physiotherapists when balance impairment rectification or injury rehabilitation is required.

2.3 Balance

Sense of balance, or postural control, can be categorized into two sections, static and dynamic (Wang, Ji, Jiang, Liu, & Jiao, 2016). Static balance refers to the ability to keep the body within its base of support, in static equilibrium, while dynamic balance refers to maintaining said equilibrium when transitioning from dynamic to static state (Gioftsidou, et al., 2013)).

Achieving balance requires mainly the usage of visual, vestibular, proprioceptive and somatosensory inputs (van Diest, Lamoth, Stegenga, Verkerke, & Postema, 2013). Brain uses the inputs of vestibular system, proprioception and somatosensory system and compares it to visual signals of body's position. Vestibular system signals position of the head while proprioception signals the rest of the body and somatosensory system inputs changes of the surfaces.

2.4 Training proprioception and balance

Proprioceptive training can be viewed as wide as acquiring motor skills, even skills that are usually viewed as visuomotor skills such as throwing darts (Aman, Elangovan, Yeh, & Konczak, 2015). Training proprioception is achieved by challenging its limits to strengthen its capabilities. As proprioception detects muscle tension it also means that muscle strength increases proprioceptive awareness.

Balance training aims to help achieving or keeping balance when parameters change, such as changing surface, being forced on one leg or losing one or more of the core signals. Therefore, balance training exercises usually have different stances (sitting, standing, standing on one leg, being on all fours among others), different surfaces (floor, mats, balance/wobble boards), excluding one signal, vision, and mixing all types together.

Training proprioception and balance is vital for elderly, elderly falls are a leading cause of injury and a major public health concern. Injury prevention is especially important for patients with osteoarthritis due to the increased risk and impact of falling. Balance and proprioceptive training are also a large part of rehabilitative training for all patients from professional athletes to elderly. Rehabilitative training can be done via unaffected limb if the affected limb is unable to do the exercises, this is called cross training ((El-Gohary, Khaled, & Alshenqiti, 2016). The program with best results included high dose of exercise together with challenging balance exercises (van Diest, Lamoth, Stegenga, Verkerke, & Postema, 2013).

A normal balance and proprioceptive training program last around 16 weeks with two to three training sessions per week. Program is divided into 5 phases where two initial phases last two weeks each and the rest four weeks. This training program uses wobble board/foam surface and exercise ball as equipment. First phase uses basic weight shifting exercises within patient's tolerance, in this exercise patient shifts his/her weight from one leg to another. Phase two focuses on Single-Leg (SL) standing on firm surface with eyes open and closed.

Figure 2. Double and single leg stands on foam surface and star drill pattern.

Phase three contains three exercises; Double-leg (DL) standing on unstable surface such as wobble board or foam surface (Figure 2), star-drill on SL with front-back and side reaches (Figure 2), and step-and-load with front-back and side-side exercise. Star-drill is an exercise where patient stands on one foot and move the other to a point of the star and back while keeping balance. Phase four continues with similar, but harder, exercises from phase three, SL standing on unstable surface, DL squats on unstable surface and multidirectional reaches on SL star drill. Phase five introduces SL tasks with perturbations, such as ball tossing and increased difficulty star drills with different combinations of added speed, weight/resistance and unstable surface.

With the rising costs of health care and the ability for technology to replicate the protocols of traditional balance training, there exists a trend to seek successful balance training through exergaming and rehabilitation games. Additionally, after a limited period with a healthcare professional, many patients are sent home to do continue the exercises themselves. Although these training activities are suited to unsupervised homecare, they can be quite dull, and this is another area where exergames can increase the motivation to achieve greater balance and proprioception training success.

Due to the frailty, and hence required supervisory training, of the first phases of balance training programs, this thesis is focused on the rehabilitative strategy of phases three, four and five of a typical balance training regime. The exergame in this thesis replicates these training phases by asking participants to do DL standing on a board that lies on a foam surface. Additionally, as in phases four and five, the participants manipulate the board through a series of complex maneuvers through continually shifting their body weight.

3 EXERGAMES

Exercise games, exergames, or serious games, are games where active body movement is used to control the game rather than using a traditional controller. Exergames have become popular among younger population (Gioftsidou, et al., 2013) and are increasing popularity within elderly population (Gschwind, et al., 2015).

3.1 What exergames are

Exergames are a branch of video gaming where the controller device input source is a range of movement of the body rather than button pressing that normal controllers use. This type of input opens the possibility of games that deliver engaging, non-repetitive exercises to home users.

Exergame equipment can be divided into four different categories; exercise bikes, motion sensors, foot operated pads and other physically interactive games (Sun & Lee, 2013). Exergame roots reach all the way out to 1980's with Autodesk's Virtual Racquetball and Highcycle. Exergames first became properly to home use when arcade dance machine game Dance Dance Revolution was ported to PlayStation in the late 1990's. Since then technology has advanced greatly bringing us even more equipment to use for exergaming, such as Nintendo Wii, PlayStation Move, and Kinect Xbox (Sun & Lee, 2013). The breakthrough for rehabilitation usage came with Nintendo Wii's Wii board, where players use their center of pressure to control the game, allowing balance rehabilitation for patients with such issues as knee osteoarthritis or people, usually elderly, with general balance issues.

Although, consumer games are not marketed towards rehabilitative activities, research has shown that some commercial exergames may be suitable for treating people with balance impairment issues. Researchers also often resort to creating very targeted balance and proprioception games with mostly positive results. In 2010, a study took place where the effect of a wobble board-based exergame was compared with conventional wobble board-based postural stability training (Fitzgerald, Trakarnratanakul, Smyth, & Caulfield, 2010). In the study, both groups showed similar improvements in postural stability and no real differences could be found.

3.2 Balance and proprioception benefits of exergaming

Exergames offer a vast amount of benefits such as engaging exercises and instant performance feedback, possibly increasing the motivation to exercise (Gschwind, et al., 2015).

Different exergames have different strengths and weaknesses when compared with each other. For example, step-mat game has greater effect on cognitive processing, proprioception and sit-to-stand times while Kinect game, specified in strength and balance exercises, has greater improvement in knee extension strength and visual contrast sensitivity (Gschwind, et al., 2015). This creates the need for physicians and game developers to work together to create games that fit the needs of the patients with different modes within a single game or different games all together to maximize the effectiveness of the games.

Patients using exergames also benefit healthcare professionals. With every training session being recorded by exergames, professionals have more substantial datasets to draw conclusions from, it is also possible to have fewer dedicated assessments and/or multiple functions within a single gaming task, saving time and possibly lowering patient distress and anxiety (Ellmers, Young, & Paraskevopoulos). Exergaming can also speed up the process of getting feedback from healthcare professionals as data can be gathered and sent instantly from patients' home sessions.

Having different limitations than normal sports, such as requiring less space, exergaming can be used in greater variety. One should however be mindful that exergaming can't completely replace real sports or training, though it can be used as supplementary training on both, healthy and injured athletes (Gioftsidou, et al., 2013).

3.3 Current exergames

Currently there are many commercial exergames available from authors like EA and Nintendo mostly for different consoles, but some are for PC as well. These games most often use a motion sensor system like Microsoft Kinect but games like Dance Dance Revolution use foot operated pads, or dance pads.

Dance Dance Revolution is still one of the most, if not the most, successful exergame. In this game, players step on the correct dance pad buttons shown on the screen, players gain score based on how good the timing on the correct button press was. Button presses are synced to the rhythm of the picked song, so the game also improves player's rhythm as well as proprioception, balance, and overall shape.

Just Dance is another dancing game but compared with Dance Dance Revolution, Just Dance works with either motion sensor camera system or movement tracking hand held controllers. In this game, the person is supposed to mimic the dance move choreographs seen on the screen that are associated with the heard song. Both dance games have good playability and gamification through scores and competition with friends and family, and even cash prizes on tournaments.

EA Sports Active is designed specifically for exercising. The player basically has a personal trainer that either encourages or chides depending on how well the exercise was performed. Movements are captured by a motion sensor camera system, which doesn't always work that well with all exercise movements as it lacks the ability to track through the player's body. The game lacks gamification elements, which can cause motivational issues with the players.

Next to the above non-exhaustive list of commercially available exergames, also lies a host of research-geared exergames that are struck to the confines of university laboratories across the globe. Their successes, attributed to a variety of factors, vary from unmotivating or ineffective to fully achieving a desirable training outcome. Although this thesis does not test the effectiveness of balance training, the goal is to lay the foundation for a balance training game that will ultimately be adopted by sports professionals as their go-to tool for rehabilitative balance training.

4 THE GAME

The game in this thesis is a Super Monkey Ball type of game, where the player ball tries to collect points and finish the route in time along a track controlled by tilting an unsteady platform. A mobile phone was attached to a balance board that was placed on an unstable surface (sponge). The movement of the board was picked up by the phone's accelerometer and transmitted via Wi-Fi to the game. The game contained a virtual track that mimicked the real board's movement and the player's task was to control the track in such a way that a virtual ball could roll to the end of the track without falling off. The responsiveness of the virtual track to the physical board is managed by three parameters that can be set at the onset of the game. These parameters include maximum tilt angle, tilt speed and tilt multiplier and depending on the settings, the game would become easier or more difficult. Figure 3 shows the physical setup for the game and a player attempting to control the virtual track by tilting the physical board.

Figure 3. Physical setup

4.1 Parameters

Tilt Speed increases the speed at which the in-game platform reaches the same tilt as the controller device. Tilting in the game isn't direct, but rather interpolates between the current tilt and the tilt within the device. This allows the in-game platform to tilt smoother, avoiding the sharp twists that might happen when the player tries to achieve and maintain balance.

Max Tilt limits the tilt available in-game. For example, if Max Tilt is set to 30 and the controller device tilts to 45 degrees, then the virtual platform will only ever achieve the maximum of 30 degrees. This parameter goes hand-in-hand with Tilt Multiplier to assert basic restrictions.

Tilt Multiplier directly multiplies the tilt from controlling device to virtual platform. This allows players to reach higher tilts even if the controlling device couldn't physically reach them.

4.2 Making the game

Rolling the ball happens with the in-game physics engine using the rigid body component on the ball allowing simulation of real-world physics. This approach of using similar physics as in the real world allows test subjects to get familiar with the game faster than when using made up physics. The level is made in a train track like fashion by using small individual pieces (Figure 4) to form level's gestalt. This type of approach allows the implementation of DDA (Dynamic Difficulty Adjustment) system that can create different shaped maps and ultimately, with more pieces, tracks of any shape or form.

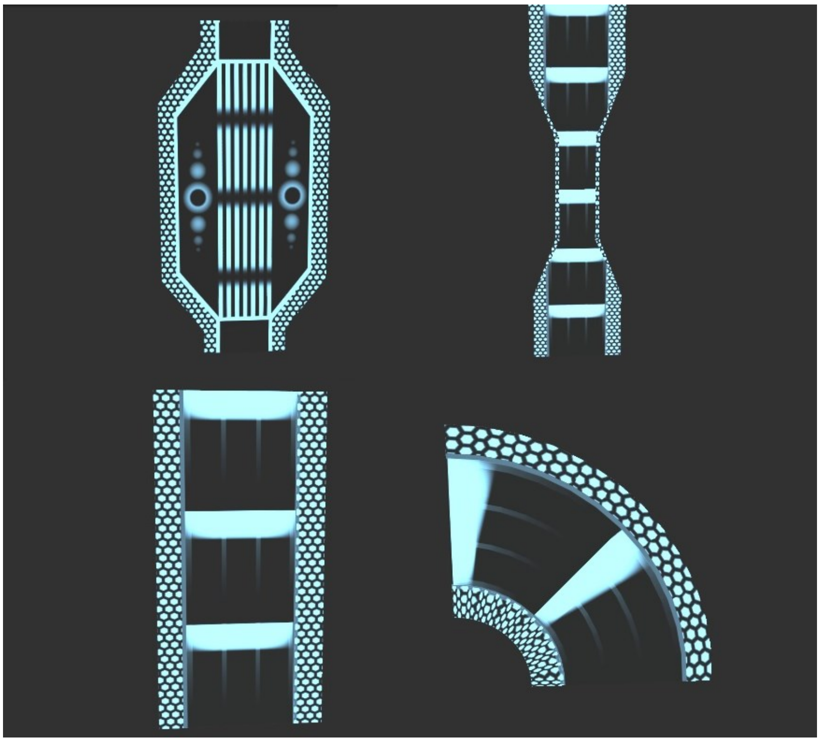

Figure 4. Example of track tiles used in the game.

Figure 5 shows the complete track used in this Thesis work. The track is divided into six sections (barrels outside the track in Figure 5) and it starts with side barriers that prevent test subjects from falling out, giving them a chance to get a feel with the settings and learn basic gameplay in case it is their first time. Once the first and most of the second section are passed the barriers stop and player is now vulnerable to fall-outs. First obstacle is narrowed passage way, followed by a small climb at top right corner of Figure 5 which can be surpassed on a level plane, but the passage is rather tight. Next part gives the test subject a little breathing room but also a chance to speed up a little bit only to arrive at a very tight turn followed by a narrow passage way into a new tight turn. This bit requires good control of both, speed and turns to complete the level.

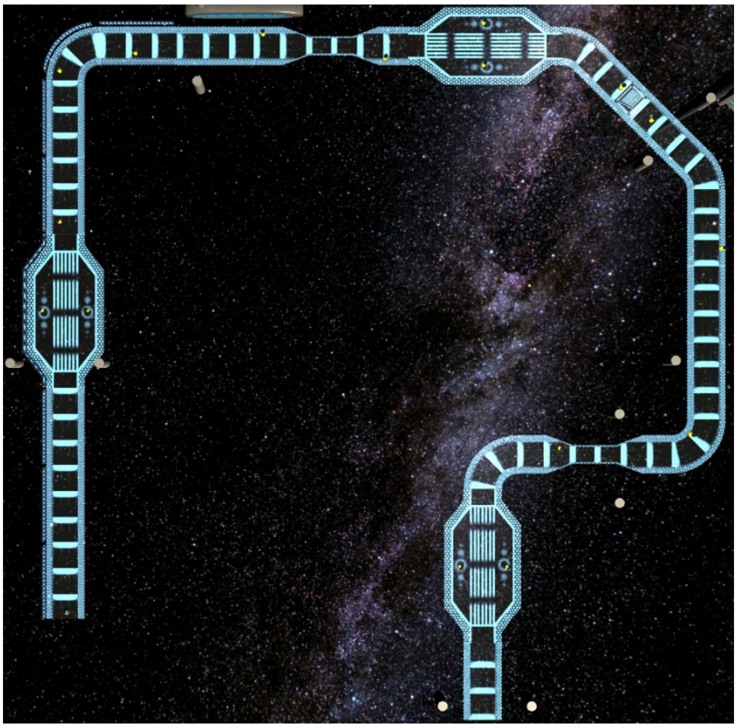

Figure 5. Complete track

The camera follows the position of the ball, always staying specific distance away from the ball in an angle compared with the normal position of the platform. Set angle allows the player to see the tilt of the platform helping with visualization. The camera also always aims to point at the velocity vector of the ball, meaning the camera follows the direction the ball is going. Using Quaternion.lerp function (Figure 6), within the camera follow code, allows the ability to soften the camera movement avoiding sudden, hard to follow movements.

```
Vector3 direction = ballRbody.velocity;
cameraRotSpeed = direction.magnitude;
direction = new Vector3(direction.x, 0, direction.z).normalized;

Quaternion tempRot = Quaternion.LookRotation(direction);
rotation = Quaternion.Lerp(rotation, Quaternion.Euler(cameraAngle, tempRot.eulerAngles.y, 0), Time.deltaTime * cameraRotSpeed);
position = rotation * new Vector3(0, 0, -distance) + ball.position;
cam.position = position;
cam.rotation = rotation;
```

Figure 6. Camera follow code

To show the visual aspect of the tilt in game there are multiple objects in distant space, such as space ships and asteroids. This helps test subjects clarify that the platform is tilting rather than just the camera changing angle because of the ball's speed. Skybox also helps with this visualization and was implemented using multiple cameras because Unity doesn't allow rotating skybox itself on multiple axes.

Balancing / tilting the platform / controls: Tilting the platform happens around its pivot point, this causes the elevation differences to be great when the ball (player) is far away from said pivot point causing problems such as launching the ball in catapult like fashion or simply going through the platform if there are sudden changes in the tilt. In order to prevent such things from happening the same trick was used as with the camera, attaching the ball to the platform as a child object. Tilting is based on the facing direction of the camera (Figure 7), this together with the camera following the ball velocity vector, explained earlier, the platform always tilts forward on the screen when the player tilts forward on their balance board. Quaternion.slerp function is also used here to avoid translating balance board "wobbling" to the in-game platform.

```
public void TiltPlatform()
{
    Vector3 targetRotation = camTemp.TransformDirection(new Vector3(xValue * maxTilt, 0, zValue * maxTilt*-1));
    rotation = Quaternion.Slerp(platform.rotation, Quaternion.Euler(targetRotation), tiltSpeed * Time.deltaTime);
    platform.rotation = rotation;
}
```

Figure 7. Platform tilt code

Client/Server connection: Basic LAN (Local Area Network) connection where phone app is the server and the game being the client. The server will only check and send accelerator data when game is ready to be played (client sends message "start" when game is started and "stop" when the game ends).

5 METHODS & RESULTS

Two test sessions were conducted using different testing methods. Method one uses a player preference style approach while method two focuses on a player success in the game. Comparing the results of these methods can help to determine overall accuracy of the results.

5.1 Method one

In method one, the test subjects were explained how the game and each variable worked together with a quick visual demonstration. Then each subject played the game multiple times, each time using two constant variables seen in Table 1 and changing the third with one of the settings seen in Table 2. After they played through most of the settings, as there was no need to test a setting they didn't like at all with different variables such as having the max tilt be extremely low, they got to pick their preferred setting and started tweaking variables further to match their preference. No other information regarding their play sessions was recorded

Table 1. Constant variable values.

Tilt Speed	Max Tilt	Tilt Multiplier
2	40	2

Table 2. Changing variable values.

Tilt Speed	1	2	3	4
Max Tilt	20	30	40	50
Tilt Multiplier	1	2	3	4

5.2 Method two

Method two took place with participants from the local rescue department and consisted of tests where the tester plays through 6 different premade settings, seen in Table 3, for 60 seconds at a time. Different from method one, is that player preference wasn't asked but rather determined by their success within the game through gathering each round's maximum distance the ball rolled on the virtual platform.

Table 3. Premade settings.

	A	B	C	D	E	F
Tilt Speed	1	2	3	2	2	3
Max Tilt	30	45	60	60	45	30
Tilt Multi	1	2	2	1	1	2

The data gathered from each 60 second session for every premade setting, consisted of maximum distance, score, section where the player falls off the platform and whether the player completes the track within the time limit.

5.3 Results

Method one

Table 4 shows the parameter preferences for the three participants in the first method. In this method players played the game several times with the option to change the parameter settings until they were satisfied with the dynamic of the game. We can see from **Error! Not a valid bookmark self-reference.** that player preferences were similar, with an almost negligible deviation in Tilt Multiplier; Max Tilt ranged from 60 to 40; and Tilt Speed ranged from 2 to 3. Although one can certainly argue that three participants is not enough to determine preferred parameter settings, the study merely used the results of this first method to guide us with the far more systematic second method.

Table 4. Player preferences.

Test subject	1	2	3
Tilt Speed	3	2	3
Max Tilt	60	60	40
Tilt Multiplier	2.1	2	2

Method two

The second method presented 6 predefined (based on Method one's results) sets of parameter settings to 15 rescue center personnel. The six sets of parameter settings are shown in Table 3. Out of 15 test subjects, only 8 played through all levels as some had to leave for work due to alarms and others didn't want to continue. We are only using the data from test subjects who played through all levels.

One of the data collected was maximum distance test subjects managed to achieve within the given time limit of 60 seconds. This is shown in Figure 8 and in here we can see that the general trend follows the number of playtimes, or levels. There are a few exceptions specifically with two test subjects who gained their best distance using level B settings.

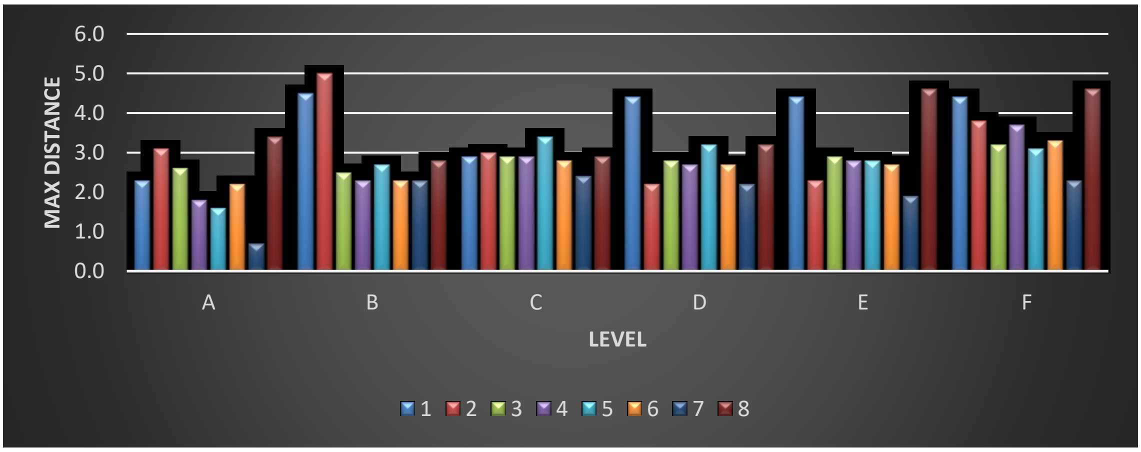

Figure 8. Maximum Distance

Figure 9 shows the number of times the player fell off the track during their play session. We can see that using difficulty levels B and C there were more fall-outs on all participants compared with the other levels, specifically for test subject 7.

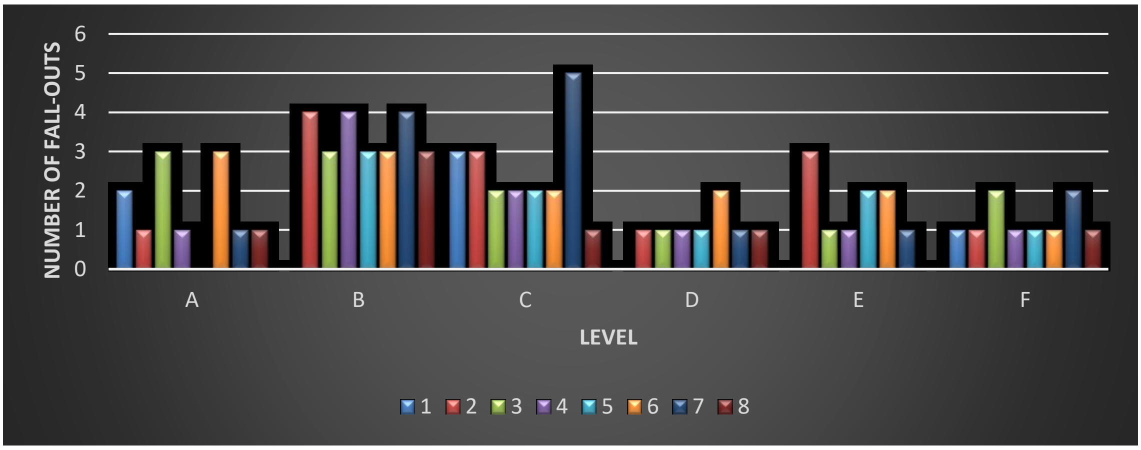

Figure 9. Total number of fall-outs

Going into more detail about the fall-outs from Figure 9, Figure 10 shows the number of fall-outs based on the section seen in Figure 5. All but one test subject had the most fall-offs overall in section 2 – 3, which is right after protective barricades are no longer on the track. Combining the data shows that with settings F (Table 3) test subjects managed to, in general, progress furthest with fewest fall-outs.

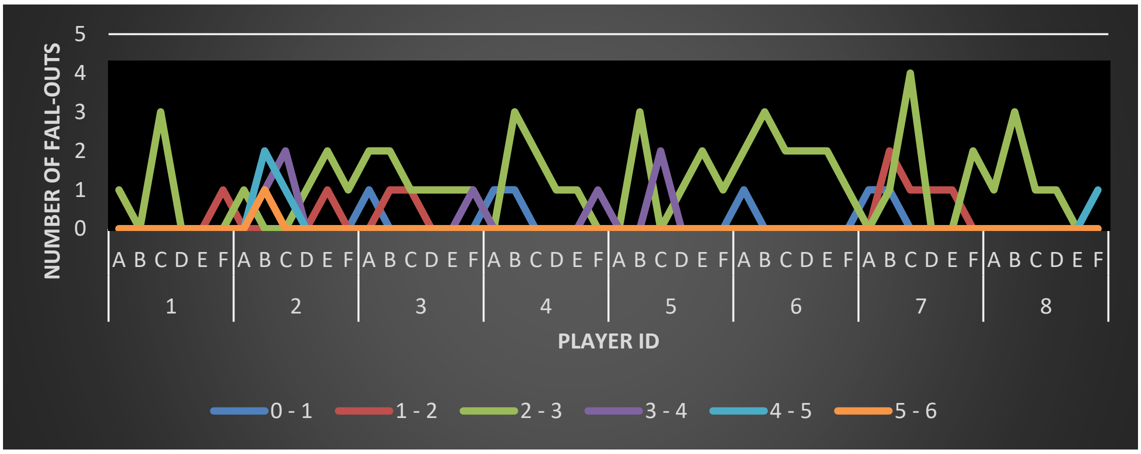

Figure 10. Number of fall-outs at certain distances

Combining the results of these 2 test methods it was concluded that there is not one set of settings that are the best for everyone since people's preferences in method 1 are different than the settings test subjects progressed furthest within method 2.

6 DISCUSSION

While getting a basic understanding about what default settings could use data from the conducted tests, there are still more aspects and some problems with the tests and the data collected. With method one, the largest problem was the amount of test subjects while with method two it was the similarity of D, E and F difficulty levels as the physical limitations of balance board didn't allow test subjects to fully feel max tilt and tilt speed with such a low tilt multiplier. Other data that would've helped with giving a more accurate result involves; test subjects basic physical health, balance and proprioception skill, and prior experience with balance boards or similar hobbies, such as snowboarding.

Another note is with the game itself, how much of a training effect people had going into the later difficulty levels compared with earlier ones.

Yet a further point of contention was the difficulty progression, or how hard was the track at certain points compared to the other points? Ideally, the track should get harder the further a player gets. However, for this version it could be that certain parts of the track were too hard, relative to the distance from the start. For example, the early narrow location (Figure 5) right after "training wheels", in the form of barricades that prevented falling-off, were removed. This would explain the number of fall-outs for that specific section seen in Figure 10.

Results gained using method 1 and method 2 were not the same. This indicates that there are settings which may get you to the end of the game more easily, but do not necessarily "feel" better. This can be related to Flow theory, which states that players will enjoy a game if they are in a constant challenge-ability balance. Settings that take you to the end of the game easily, may illicit a feeling of boredom and this hampers the overall gameplay satisfaction. The preferred settings seen in Method 1 show faster paced play than the settings that got players the furthest in Method 2. This verifies that players prefer a higher challenge, rather than experiencing boredom, even if it may mean not finishing the game.

7 CONCLUSION

This thesis set out to create an exergame to address the boredom associated with unsupervised home balance training. The study did not aim to test the effectiveness of the exergame, but rather establish a set of baseline parameter settings for healthy individuals. The thesis managed to build and test the game but was unsuccessful in categorically establishing baseline parameters. The reasons included insufficient number of test subjects, undiscernible difference in difficulty, training effect and inappropriate difficulty progression. The researcher remains assured that if these four points are adequately addressed in future experiments, a set of baseline parameters can be established. This set of parameters will, in turn, set the tone for validated testing on how effective the game is in improving balance impairment.

To truly validate default settings, one would have to use more testing methods where data, such as how good current proprioception and sense of balance are, and improvements in those after multiple play sessions. This would allow finding better default settings for players with different skill levels and find out how much improvement in proprioception was gained in comparison with normal training methods.

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