Linnæus University
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Bachelor Thesis

# Usability Analysis of 3D Touch Technology in the Context of Mobile Gaming

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## Abstract

This study researched users' ability to control the new input technology known as 3D Touch that is a pressure detection implemented in the new generations of iPhone. The purpose of this study was to research users ability to control the technology in a context of mobile gaming. An application was created to test participants' ability to match and control the pressure of 3D Touch at different forces. The result was then analysed and used to create an endless runner game included with the 3D Touch technology. The game was used in a usability test to investigate the user experience of the 3D Touch technology in a real gaming situation. The experimental results indicated that users have more difficulty to control the pressure of 3D Touch at higher forces. It also indicated that more stressful game situations can make it even harder to control the force of 3D Touch.

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# Contents

# 1 Introduction

## 1.1 Motivation

How players experience game interaction with different input controls is something that has been researched earlier for TV consoles, computer games and mobile phones (Lenzi, 2008, Fritsch et al. 2008). Historically have the primary input interaction for computers and TV-consoles been controlling games with physical buttons, such as hand controllers, keyboard and mouse. When the first recognized games for phones, like Snake and Tetris, were released in 1997 the mobile game interaction followed the same path with buttons as the primary interaction type. With the release of the first Apple iPhone in 2007, the way games are played on mobile devices was about to change. The multi-touch screen made touch gestures like swipe, drag, spread and rotate possible, and together with the implementation of additional sensors, such as accelerometer or gyroscope, it changed the way users were able to play games. Nine years later smart phone games have rapidly changed because of the devices powerful processors, larger displays and increased graphics capabilities. That is one of the reasons that mobile gaming is the fastest growing gaming experience at the moment. At the end of 2015, the yearly revenue of mobile games was 25 billion making mobile gaming represent 30% of the global gaming market revenue, and to have 1.5 billion players over the world (EEDAR, 2015). With the release of iPhone 6S and 6S Plus the gaming with phones is said to take another step in interaction possibilities. This is because a new technology named 3D Touch has been introduced. 3D Touch is an improved pressure detection and unlike Force Touch, which has been included in the new releases of Apple Watch and MacBook, has better detection of force allowing more "levels" of actions based on how firmly you press (Mchugh, 2015). Games that once were created for PC and consoles are now available in mobile versions and have a higher claim to have more game interactions. The technology has therefore been said to be exciting for the mobile gaming industry making it easier to get more complex game interactions (Leack, 2015).

## 1.2 Problem Specification

Because the 3D Touch technology is new and at this point only exists in the newest iPhones, the research on usability of 3D Touch, and how a user can control it, is rather unexplored. Gameloft Global Platforms Director Guilherme Lachaut said in an interview with the game website prima games (Benyamine, 2015) that the company would use 3D Touch when it makes sense. He also stated that they had started to include 3D Touch in their game where they thought it would be the most obvious use of the technology. However, it did not work out as expected and was included in other more unexpected places. One of the problems that Kim et al. (2014) discuss in their study about creating a text input system using pressure, is the lack of an established reference of different pressure levels. As a developer, you have to know how the user can control the force with their fingers to be able to create functions that are usable. In earlier research about force matching with fingers, it was shown that users ability to have accuracy when pressing, when not having feedback, was lower at higher force (Prasad et al. 2014, Harsimran et al. 2009). However, in these studies, the applied force levels have been decided after a maximum voluntary contraction (MVC), which is the maximum force the subject can press and not the maximum value of 3D Touch technology. Another problem is how a user experiences the 3D Touch as an input choice in a gaming situation. There is earlier research about game interactions with mobile phones and when to use different inputs (Hürst et al. 2013, Lubitz et al. 2012). However, the studies are concerning the difference between multi-touch, tilting and graphical buttons as an input method. None of the studies researches the new possibilities with 3D Touch, and how the users experience it in a gaming scenario.

## 1.3 Purpose and Research Questions

The purpose of this study is to research the users' ability to control different levels of pressure. Furthermore, it is of interest how users experience 3D Touch from a gaming perspective. The research questions are:

- How is the user able to control continuous isometric force using 3D Touch?
- How is the user able to match a specific pressure level on a single touch using 3D Touch?
- How do users experience interaction with 3D Touch in a gaming scenario?

## 1.4 Proposed Approach

The study is divided into two different parts. The first part is to answer the question about how the user can control the different forces (levels) of pressure with the 3D touch technology. For this question, an application with various touch tasks is created and used in a usability test. The test makes it possible to sample data about the participants' ability to match pressure at different forces.

The second part is a smaller study that is applying the indications from the first study and put it in a real gaming situation. The study includes the creation of a 2D endless runner game that is used in a usability test applying the think-aloud protocol. The participants play for 10 minutes, providing insights on how they experience it when using the technology.

## 1.5 Limitations

In this thesis, the experimental procedures were conducted in a calm test environment. The result takes no considerations of using the technology in different, more vibrant environments, e.g., sitting in a car. For the conducted study, just one gaming genre and one type of gaming interaction were tested. Endless runner games in the genre arcade were chosen because of their popularity as the most popular game genre after puzzle in mobile gaming (EEDAR, 2015).

# 2 Foundation

## 2.1 Touch interaction technology

This section explains some of today's input technologies that are being used to interact with applications on touch screens.

### 2.1.1 Multi-touch

Multi-touch is today's most common and accepted way to interact with mobile phones. It had its big breakthrough with the release of iPhone in 2007 and has spread to numerous devices ever since. Multi-touch makes it possible for the device to recognize more than one point of contact on the touchscreen or trackpad (Techopedia). It makes it possible to use touch gestures like tap, swipe, pinch, or spread to perform different actions when interacting with applications.

### 2.1.2 Force Touch

Force Touch is a touch technology first included in the Apple watch and the 2015 version MacBook. It is an evolution of the multi-touch interaction, making the trackpad or touchscreen able to feel how much pressure the user is applying (Apple, The Force Touch). It is sensitive enough to determine if the user tap or press on the surface. It makes it possible to use a touch trackpad the same way as a trackpad with physical buttons. An example of what the Force Touch can be used as is a digital drawing tablet. If the user presses harder at the trackpad, it creates thicker lines, and if she presses softer, it creates thinner lines. Force Touch uses a technology called Taptic Engine which makes it possible to give the user a haptic response when pressing. The Taptic Engine is mounted underneath the touch area on the device and starts when a touch pressure event is detected (Briddock, 2015). The Taptic Engine creates a vibration to make the user not only able to see what is happening, but also feel it (Apple, The Force Touch).

### 2.1.3 3D Touch

With the release of the new iPhone models iPhone 6s and 6s Plus Apple included the new technology named 3D Touch. It is said to be the next generation multi-touch making the phone be able to determine the amount of pressure pressed on the touchscreen. Unlike Force touch, which could detect two levels of pressure in a tap and press, 3D Touch can feel a third level of pressure. The third level makes the technology able to feel harder force against the surface. Two new ways to interact with the phone were added to the original multi-touch gestures, called peek and pop. An example of peek is to show a preview of a website just pressing the URL, if releasing the pressure it automatically goes back to the site with the URL. Pop is when a user instead of releasing the pressure, press with a higher force and that, if using the example, moves him to the URL site.

When looking closer how the 3D Touch technology is working when a user is pressing the touchscreen, you can say that instead of a touch, it is more like a push. When pressing the touchscreen the glass bends in a slight degree making the distance between the glass and the capacitor sensors underneath smaller (iFixit, 2015). This data together with accelerometer and even a calculation of gravity creates the pressure value with some complex algorithms (Apple, The innovation beneath 3D Touch). Underneath the glass, screen and sensors the Taptic Engine is included just like in the force touch technology. It makes it possible to give vibration feedback to the user when pressing.

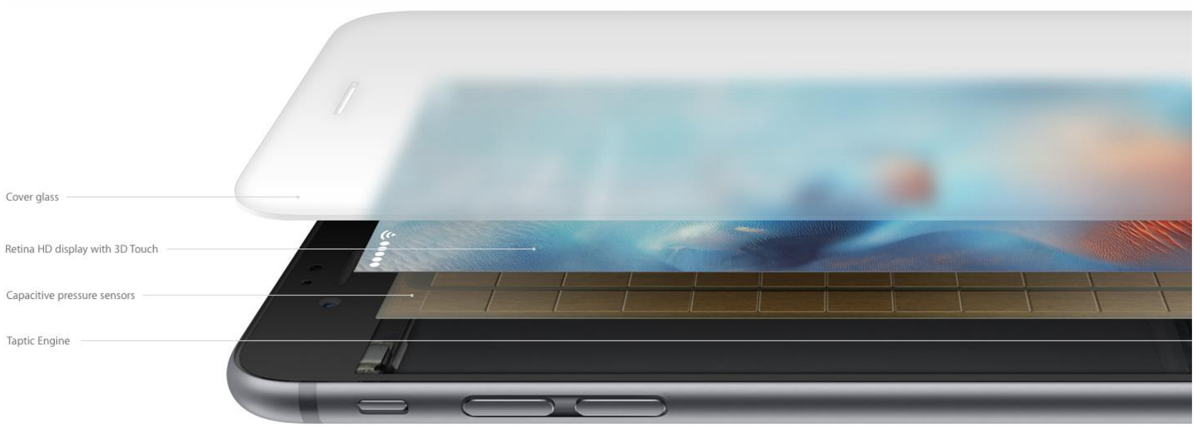


*Fig. 1, Layers of 3D Touch technology, From: Apple, "3D Touch. The next generation of Multi-Touch".*

**2.1.4 Limitations of 3D touch technology**

No confirmed values have been released from the iPhone API or Unity API on the limits of the 3D Touch technology. However, in an investigation of the Unity API and the creation of an application built in debug mode from Unity, it showed a maximum and minimum value at the moment of pressure on the screen. The value the 3D Touch was able to detect ranges from 0.0 to 6.66667 on the iPhone 6s device.

## 2.2 Related Work

This section shows results from earlier research related to the current study.

### 2.2.1 Finger Force Precision

There is some earlier research about the ability to control isometric force for finger pressure. Harsimran et al. (2009) investigated the differences in force accuracy, force variability and muscle activity with and without visual feedback. The test was made pressing the index finger at a button under a continues time aiming at five different pressure levels. For around 24-30 seconds the participant had to press. Following this period, the visual feedback shifted from hidden to visible. The result showed that without visual feedback the pressure had a high standard deviation in force, but the variability had little difference. Visual feedback also indicated to give more accuracy at higher force levels. For lower force levels the test indicated that variability was not significantly influenced.

Another way to test different pressure levels is to have a targeting reference point. Prasad et al. (2014) tested the accuracy of index finger pressure on both hands when one of the hands were provided with visual feedback. The other hand used the first hand as a reference point to match the pressure. The visual feedback was different colors from red to green that randomized were showed to the subject. The colors represented six different force levels, from soft to hard. The result revealed that users accuracy when pressing, and not having feedback, was lower at higher force. This is also the result of Kilbreth et al. (1992) study when investigation fingers possibility for different weight matching. The study was made using the index finger, but also the thumb. The experimental design was similar to Prasad et al. where the subject had a reference point of the weight in one hand, and should determine the weight of the same weight in the other. For the index finger, the result was the same as Prasad, that at higher force levels the accuracy decreased without visual feedback. However, for the thumb the result showed good accuracy remained at all pressure levels.

In all these studies the applied force levels have been decided after a Maximum voluntary contraction (MVC), which is the maximum force the subject can press, and have been a starting task for the subject to get the right pressure levels for every individual subject. None of the studies had their test made at a touchscreen. One of few pressure testing studies made at a touchscreen is Kim et al. (2014) study. They were creating a pressure sensitive text input system for the Korean language at a touchscreen to expand the ability to reach more letters and get faster access to more letters when typing. The result showed that a pressure sensitive system was 10% faster than normal touch input for typing. The problems with the system were that the participants different pressure matching made it hard to establish a good reference for different pressure levels.

### 2.2.2 Interaction in context of mobile gaming

There are some earlier studies about using different controls when interacting with games. However, most of the studies before 2008 are about game interfaces for computers or consoles and not mobile devices. This may be explained by the large progress of the mobile games since the iPhone release in 2007.

Hürst et al. (2012) are comparing different ways to navigate 2D and 3D virtual worlds in mobile games. They tested touch gestures, on-screen joypad implementation, and tilting gestures to research to see which one that enables them to create better interaction experiences. The test was made by creating two games where the user should navigate between different rooms in a 2D and 3D world. Participants did the test with all three interaction methods and the data sampled was both statistical analysis of the performance and user feedback with a questionnaire. Even if the expected result was to see clear trends between the different interactions, the result showed no such trend. The result revealed that tilting had a higher error percent but at the same time some users enjoyed that it appeared to be more "challenging". A conclusion of the result was that the test probably looks different on different tasks and no universal conclusion on what input method that works best can be found. A study that is more focused on a single task is the study by Lubitz et al. (2012). This study researched three different input methods used in a jump and run game. Input methods were tilting, one finger input and multi-touch input. For the study a game with three actions was created, jump, run left and run right. A test where participants were playing with the different controls was constructed and ended with a questionnaire. The result showed that titling and multi-touch were getting more negative feedback than one finger input. Apparently it was more demanding for the player to use the controls. Moreover, demands are something that Skalski et al. (2011) have researched in their study about naturalness in game controls. When a player is playing a game, the more natural the a controller feels, the better the experience of the game is.

### 2.2.3 Today's gaming interaction using 3D touch

Even if the 3D touch is a new technology in mobile phones, there are games that have been updated or created with the technology. In the iOS Appstore, there is a category with the name "recommended apps for the 3D touch". The category includes the games and apps already available using the 3D touch technology. When analyzing some of the games in the category, it can be seen how they are using the 3D touch as an interaction mode. The analysis focused on what way the 3D touch is used as an interaction mode and was not looking at how the interaction worked from a gaming perspective. All games were played for a time around 10 minutes and analysed by the basic gameplay. Possible later use of the technology in the games was not prioritized. The analysed games included z.Tsunami, Kill Shot Bravo, Phoenix HD, AE 3D Motor and Badland.

**Kill Shot Bravo** and **Phoenix HD**
In these games, the 3D touch interaction was used to start an attack. In both games, the attack started with a hard press on the screen. None of the games was using the 3D touch for interaction at more than two levels of pressure.

**z.Tsunami**
z.Tsunami is a jumping game where the user, depending on the level of pressure on the screen, jumps higher or lower. Users must be able to know how to feel different pressure levels to be able to jump in the different heights.

**AE 3D Motor** and **Badland**
Both used the 3D touch to make the user hold a specific level of pressure for a continuous period. Users are able to feel what pressure level they are holding. An example in Badland is where it uses continuous pressure is used to make the character fly at an even height for a longer period.

When analysing the different games, two main interaction modes could be identified:

- The user has to be able to control force over different pressure levels for a continued period of time.

- The user has to be able to press a specific pressure level on a single touch.

## 2.3 Endless Runner Games

Endless runner games are some of the most popular games that users play on their mobile phones. They are the most played genre on cell phones after puzzle games in 2015. The popularity of the genre is shown in the result from EAAC mobile research (2015).

### 2.3.1 Canabalt
Canabalt is one of the most classic endless runner games and is sometimes named as the game which popularized the genre. It was released as a flash game in 2009 by Adam Saltsman who had an idea to create a one button game where the complexity was in the environment instead of the controls (Rigney, 2011). The game is, because of its popularity, released to many platforms. In the game, the user controls a person who is trying to escape from aliens and therefore must jump

from a building to another building to survive. As long as the person is not bumping into any obstacle the speed keeps increasing and with that the degree of difficulty to manage to time the jumps. The goal of the game is to stay alive as long as possible. Jump mechanics work in the way that the longer the user touches the screen, the higher the jump gets. If the user touches the screen with a short tap, the jump gets short and a longer touch gives a higher jump. Saltsman (2010) explains that the functionality is implemented in the way that a timer is started when the user is first touching the screen, making the player increase it is vertical value as long as the timer has not hit the max value of 0.35 seconds or the user has released the touch.

# 3 Methodology

To gain a better understanding of how users can control, and how they experience the 3D Touch technology from a gaming perspective, two different studies were conducted. This section will give a better understanding of how the studies were conducted and how the result was analysed.

## 3.1 Study overview

The first study focused on how a user can control and match different force levels when using the 3D Touch technology. It was divided into two iterations with two tasks in both. The tasks were derived according to the results of the background game analysis (see 2.2.3). The reason for two iterations was to be able to use the first iterations result and indications, and implement these to the next iteration. It was also because of the lack of existing studies around the 3D Touch technology.

The second study is based on the results of the first two study iterations and aimed to investigate these results in the particular context of mobile gaming. A game was created and used in a usability test to see how users experience the 3D Touch technology when interacting with it in a real gaming situation.

## 3.2 Study 1: Usability study

### 3.2.1 Experimental Design

An application to test users ability to control 3D Touch was created in the game engine Unity 5. From the result of earlier game analyses in section 2.2.3, the application was implemented with two different tasks intended to test the users ability to interact with them. The application also had an introduction page.

*Task 1*

Task 1 (see Fig. 2) was intended to answer the question how users can hold different levels of pressure over a continued period of time. It was implemented with a bar with a marker, which allowed the users to see how much pressure they were touching the screen at the current moment. The bar was filled with different colors that gave a visual view of the areas of pressure levels. The levels were spread out from 0 to 100 % of the maximum 3D Touch value. When starting the task, the user got represented with a randomized color/pressure level that showed how hard the user should press. The round continued for 10 seconds before changing the color.

*Task 2*

This task (see. Fig 2) did not show any help on how much force that was currently applied on the screen, and was intended to answer how users can press a specific pressure level on a single touch. The bar with the different colors/pressure levels from task 1 was still visible, but no indication in between what pressure levels the participants pressed was displayed unless the user hits the maximum value and the button changed color to dark red (as a security measurement to not physically break the device through applying too much pressure). When starting the task, the user did get represented with a randomized color/pressure level that showed how hard they should press. The round continued for 2.5 seconds before changing color.

*Introduction page*

The introduction page had a button that was changing color gradient depending on how hard the user was pressing the screen. The colors changed gradient from green to red. The purpose of the page was to give participants the chance to get more familiar with the 3D Touch technology.

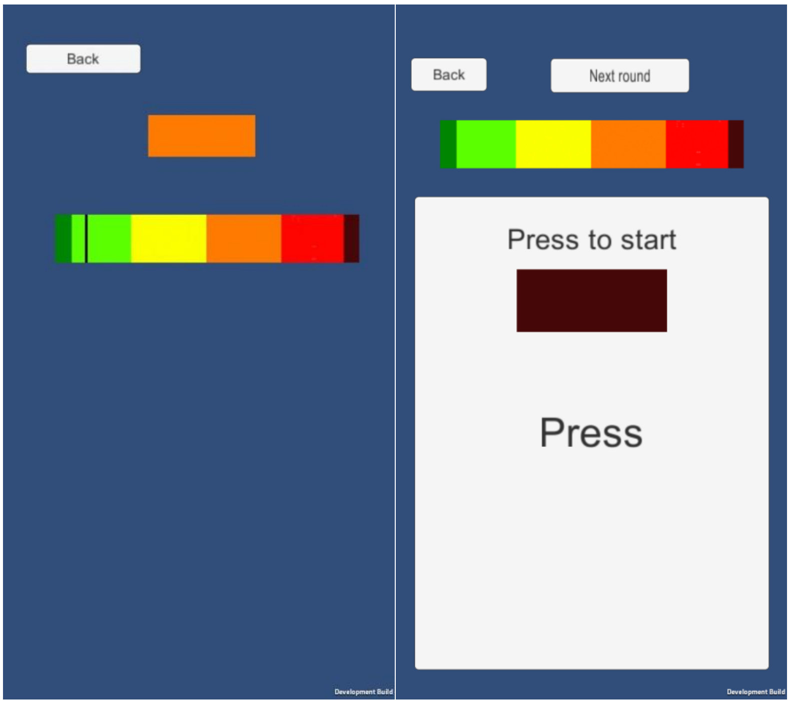


*Fig 2: The visual view of task 1 (left) and task 2 (right) in study 1. Task 1 had a marker showing how hard the user was currently pressing.*

*Data collection*
All data from the tasks was sent to a database using MySQL. The data was first validated with a PHP script on a server before it was sent to a database. To have the data in the database made it possible to access it from a connected web application. For the tests, a web application was created, that contained different charts illustrating the pressure data from the database. For task 1 the data was collected in the background of the application 10 times every second, making it a total of 100 times over a 10 seconds period. For task 2 the data was collected 50 times every second, making it a total of 250 times over a 2.5 seconds period. The higher number of data collected every second in task 2 was because the importance to get a more exact value of the highest value reached.

### 3.2.2 Experimental Procedure

As a device, the iPhone 6s was used. The test started with a brief explanation of what 3D Touch is and an explanation that the test was to research how the user can interact with the technology. The test participants then answered two questions regarding their earlier experience of 3D Touch.

Questions:
Have you heard about 3D Touch?
Have you used the 3D Touch before?

All testers were sitting in an up straight position holding the iPhone in either the right or left hand. The finger used for the test was the thumb. This was because earlier research showed differences at force matching in fingers (KILBREATH, 1992), and the thump is the most used finger to interact with a multi-touch display (Hoober, 2013). When first starting the application the tester had time to test the 3D Touch at the introduction page. This served as a possibility for the participant to get a feeling of the maximum and minimum pressure, but it also worked as a damage control to prevent the tester from pressing unnecessarily hard on the screen. When finished, the participants were starting with task 1 and then continued with task 2.

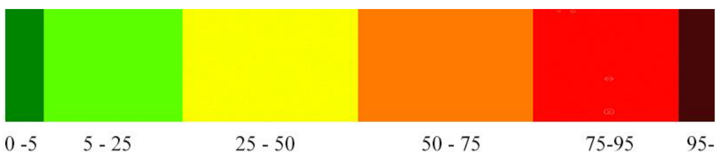


*Fig 3: Appearance of the bar used in study 1, iteration 1. Showed the colors of the level and between which percentages of 3D* Touch *max value the level area included.*

*Task 1*

Task 1 was tested with five different pressure levels (see Fig. *3*) that the participants should try to press continues until the time was over. Before the test started, the participants had one learning round to get familiar how the test worked. The task then started with showing a randomized color that the participants had to reach with the help of visual feedback from the bar. When they reach the pressure level, they were told to hold the marker as accurate and consistently as possible inside the pressure level area until the time was over. Every pressure level was pressed two times each in a randomized order.

*Task 2*

Task 2 was tested with five different pressure levels (see Fig. *3*) that the participants should try to match in a single touch, without any visual feedback showing how much force they were using. The only visual feedback given to the participants was when pressing maximum force and the button changed color to dark red. At first, the participants had an introductory round where they could get a feeling where the maximum value of the 3D Touch technology was and how to do the test. Then they were asked to reach the different pressure levels shown in the bar. All pressure levels were tested in a randomized order, four times each.

### 3.2.3 Analysis of the Result

The result by task 1 was analyzed in two ways.

**The time to reach a steady pace at the pressure level**

A steady pace was true if the user had been able to hold the pressure continuously inside a pressure level for 0.6 seconds. The time until this statement was true was the result and was performed for each pressure level. The mean of all participants result in seconds was shown as a result for each pressure level. The reason for this was to research if there are any significant differences between the hardness to reach pressure levels at different forces.

**The ability to match the force to stay inside the pressure level**

When steady was true, the remaining seconds left were analyzed by the ability for the participants to stay inside the pressure level area. The result was counted in seconds. If a participant was steady at the level after 3 seconds the remaining 7 seconds was analysed to see how much of the time the participants could not hold continuous force inside the level area. These numbers were compared to the other pressure levels. The reason for this analysis was to see if there was any difference to hold a specific force at a continues time at different forces.

In task 2 the result was analyzed in two ways.

**Number of succeeded attempts to match a pressure level**

The number of succeeded attempts occurred at each pressure level was added together for each participant. The mean of each pressure level was then shown as the percent of the number of succeeded attempts. A one-way ANOVA was conducted on the result of the succeeded attempts to see if there was any statistically significant difference between the different levels. ANOVA was made to be sure that no level was lower or higher just because of chance. If ANOVA showed a p-value over 0.05, the result showed no statistically significant difference.

**At what pressure levels unsucceeded attempts occur**

The number of unsucceeded attempts at each pressure level was analyzed to see at what different pressure levels they occurred. The reason for this was to be able to see if there were any paths showing that users unsucceeded attempts often matched softer or harder pressure levels.

## 3.3 Study 2: Game study

To be able to test the first study result in a real game situation a second smaller study was conducted.

### 3.3.1 Experimental Design

A game with the name *JumpMan* (see Fig 4) was created in the game engine Unity 5. The game was an endless runner game and was inspired by one of the most popular in the genre, Canabalt, explained in more detail in section 2.3.1. The game had three different levels of pressure that the user could press to make the character jump in different heights. In the game the player should try to stay alive as long as possible, jumping between platforms. Both small obstacles that decreased the players speed if hitting them and tunnels that got smaller over time were implemented in the gameplay.

The force needed for the different jumps was derived from study 1 results. In Canabalt, a small jump is a soft touch on the screen and is depending on the length of the touch. In JumpMan, it was a pressure level between 0-10% that made the small jump. The pressure level was derived from task 2 in iteration 2, where 86% had succeeded attempts at pressure level 0.-10%. For the second jump, which was a longer jump in the game, the force needed was 10 - 60%, derived from three levels of pressure in iteration 2. For the last, and the jump that had the most height in the game, the force needed was from 60-100%. All jumps are shown in Fig 5. The reason to have three jump heights was that study 1 indicated that this was the highest number of levels that still showed great success at all pressure levels (see results described in 4.2.3).

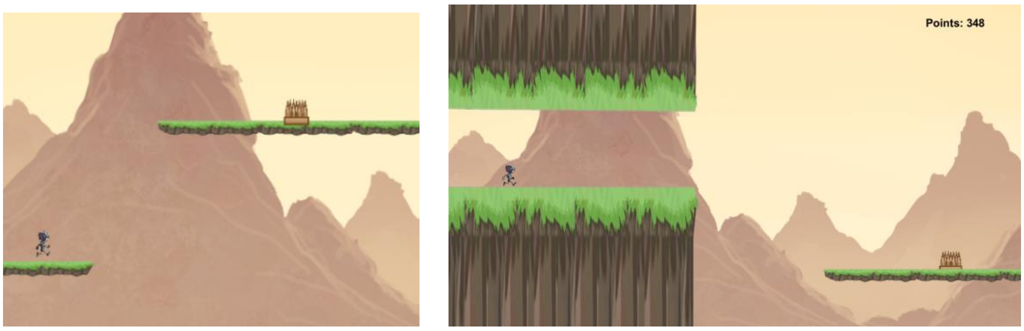


*Fig 4: Screenshots from JumpMam. The images show the platforms to jump at to survive (both images) and obstacle boxes which slow the speed of the player when hitting them (both images). A cave (right image) is a big obstacle that collapses when the player runs inside it..*

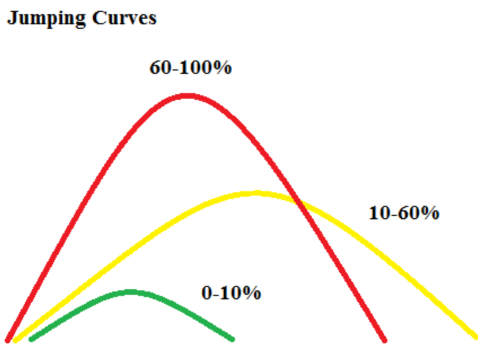


*Fig 5: Jump curves for all three jumps in JumpMan. Numbers are between which percentages of 3D* Touch *max value the user need to press to make the jump.*

### 3.3.2 Experimental Procedure

As a device, the iPhone 6s was used. The test started with brief explanations of how the game worked and how many different jump heights were available. The test participants then got to answer two questions regarding their earlier experience of 3D Touch and about mobile gaming. Have you used the 3D Touch before, and how often do you play mobile games.
Participants were holding the iPhone in either the right or left hand. The finger used for the test was the thumb. They were then asked to play the game while using the think-aloud protocol. The game session lasted for 10 minutes.

### 3.3.3 Analysis of the Result

The result of the game study was analyzed in qualitative user statements and observations by the participant gameplay and comments

# 4 Usability Analysis of the Design Application

This section presents the results of the two study iterations conducted to investigate the user's ability to interact with the 3D Touch technology using the mobile application and experimental setup as described in 3.2.

## 4.1 Iteration 1

### 4.1.1 Participants

Eighteen participants took part in the study, half of them started with task 1 and the other half with task 2. The participants were between 18-40 years old with most (13) of them in a range of 20-24 years old. Three of the participants were women. Half of the participants did not know what 3D touch was, only two had earlier experience of using 3D touch.

### 4.1.2 Results and Analysis

*Analysis of task 1*

The time to reach a steady pace at a pressure level was higher at pressure levels that needed more force, for level 50 -75 it took 3.15 seconds and for 75-95 it took 3.17 seconds. The lowest time to reach the level was at level 5-25%, were participants needed 0.95 seconds. Level 0,1 -5% and 25-50% showed a similar result of 1.6 seconds. The ability to match the force and stay inside the pressure level showed the highest value at pressure level 75-95%, with 6% of the time outside the pressure level. The other levels had a small difference, with 50-75% a bit lower with 0.80% of the time outside, saying that close to none of the logged data had been outside.

| Pressure Level | Seconds before stable on level (holding bar 0.5s inside level) | Seconds outside level ( after being stable) |
|---|---|---|
| 0,1 - 5% | 1,67 | 0,24 |
| 5 - 25% | 0,95 | 0,18 |
| 25 - 50% | 1,6 | 0,13 |
| 50 - 75% | 3,15 | 0,05 |
| 75 - 95% | 3,17 | 0,45 |

*Table 1: Iteration 1, task 1 result. Shows what level (left column), the mean of how long it in seconds took for the participants until they held pressure steady inside the pressure level area (middle column), and the seconds of the existing time the participants where outside the level area after they were steady (right column).*

*Analysis of task 2*

For task 2 the data showed that the mean of succeeded attempts on every level was higher at pressure levels that needed less force. In this case, a one-way analysis of variance (ANOVA) on these pressure levels showed statistically significant difference among conditions, $F(4,60) = 4.55$, $p = 0.002$. A post hoc Tukey-Kramer test showed that pressure levels 0-5% (M = 61.54%) vs 50-75 and 75-95 (M = 20.51%) differed significantly at $p < 0.05$. Between other levels the difference was not significant but showed a lower p-value, $p = 0.38$ for levels 25-50 (M= 46.15%) vs. 50-75 and 75-95.

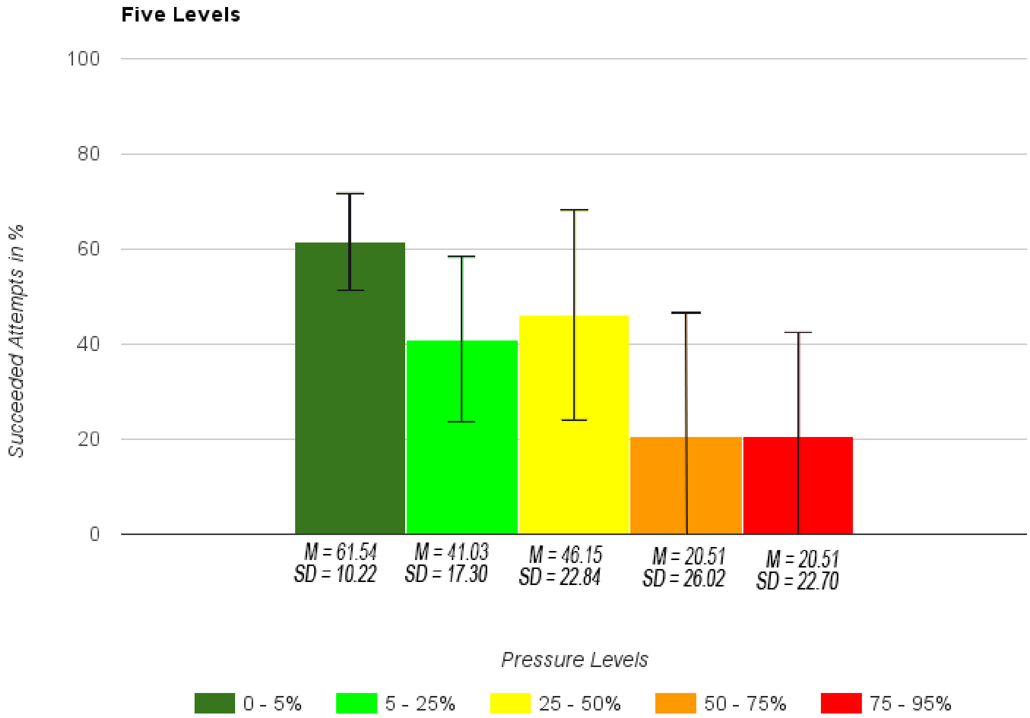


*Fig 6: Iteration 1, task 2. The diagram shows the mean of succeeded attempts at each pressure level. Also shows the standard deviation for each level.*

**4.1.3 Discussion**

The purpose of the study was to research how users can control different forces of pressure with 3D Touch. The study focused on two types of controls. The first one was that the user has to be able to control isometric force over different pressure levels for a continued period of time, and was tested in task 1. For these findings, the different pressure levels did not differ significantly. There were some tendencies that users found it more difficult the more force they needed to use. Participants had more time outside the pressure level (6%) at the highest level but the difference was small compared to the others. Observations from the test also confirm that most of the participants felt they had no problem to hold the force inside the pressure levels area. One reason for this could be that the pressure levels had a too wide area, and therefore gave the participants the opportunity to shift force and still be inside the pressure level area.

Another type of control was that the user had to be able to press a specific pressure level on a single touch and was tested in task 2. The result from this study indicated that users are more successful to match forces at lower pressure levels, and that they have a hard time to match at higher force. Only the pressure level that needed less force had a mean over 50% of succeeded attempts. All the other levels showed a small number of succeeded attempts. A reason for this could be that five levels of pressure are too many to establish a difference between them. Another reason could be the lack of visual feedback if they succeeded to match the pressure level, and therefore couldn't correct the force to next attempt.

## 4.2 Iteration 2

### 4.2.1 Changes made from iteration 1

From the indications at the first iteration, some changes were made for iteration 2.

**Changes made for task 1**

For task 1 the pressure level bar used as a visual reference for the participant, was changed to have smaller areas for all pressure levels. For iteration 2 they all had the same size of 3% of the maximum 3D Touch value.

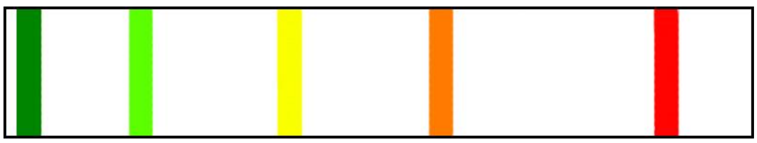

*Fig 7: Bar used for task 1, in iteration 2. Every pressure level had an area of 3% of 3D* Touch *max value.*

**Changes made for task 2**

*Visual feedback*

Changes for task 2 were that users had visual feedback on what pressure level they matched after the press. In the first iteration, the participants did not have any direct feedback on if they succeeded or not when trying to match a pressure level. In this iteration, this change was executed to simulate how a game works. In a gaming situation, the user gets some feedback when to interact with the game, and therefore also have a chance to correct errors and get better.

*Four new bars with different numbers of pressure levels.*
In the first iteration, there was only one bar with colors representing different pressure levels. In the second iteration, there were four bars with different areas of pressure levels. This change was made to get a better understanding of how many pressure levels a participant can use, and also at what forces the participants are better or worse to match them. All bars were tested in a randomized order, and every pressure level was tested four times each.

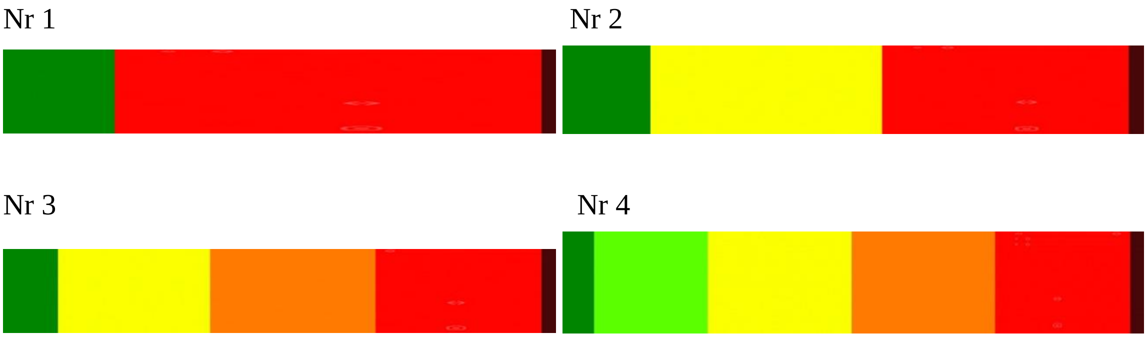


*Fig 8: Four new bars used in iteration 2, task 2. The pressure level areas had new sizes, and there were different numbers of pressure levels at each bar.*

### 4.2.2 Participants

Eleven participants took part in the study. Their age was between 18-30 years old with most (9) of them in a range of 20-24 years old. Two of the participants were women. Only two had earlier experience of using 3D Touch.

### 4.2.3 Results and Analysis

For task 1 the result was +1% on both minimum and maximum value of all pressure levels, making it a total of 5% area. The reason for this was because of the visual marker had a size of 1% of the 3D Touch max value and therefore, the user could have been inside the pressure level area visually when they actually were outside the edge.

*Analysis of task 1*
The time to reach a steady pace at the pressure level showed no big difference from iteration one and no big difference between the different pressure levels. The ability to match the force and stay inside the pressure level showed much higher values at the higher pressure levels. Level 86

- 91% had 2.91 seconds outside the pressure level, close to half of the time, 6.16 seconds that where remaining of the 10 second limit. For level 56-61% the number also showed to be higher (1.71 seconds), and the same with level 36-41% (1.24 seconds). For the two softest levels the values were smaller, with the force close to all time inside the pressure level area. The Standard deviation of the mean values can be found at the Appendix, in section 9.3.

| Pressure Level | Seconds before stable on level (holding bar 0.5s inside level) | Seconds outside level ( after being stable) |
|---|---|---|
| 1 - 6% | 1,56 | 0,28 |
| 16 - 21% | 2,16 | 0,19 |
| 36 - 41% | 2,18 | 1,27 |
| 56 - 61% | 3,1 | 1,71 |
| 86 - 91% | 3,84 | 2,91 |

*Table 2: Iteration 2, task 1 result. Shows what level (left column), the mean of how long it in seconds took for the participants until they held the bar steady inside the pressure level area (middle column), and the seconds of the existing time the participants where outside the level area after they were steady (right column).*

*Analysis of Task 2*

The section includes the analysing of succeeded attempts at each pressure level. This to answer the question of the interaction mode “The user has to be able to press a specific pressure level on a single touch”. A one-way ANOVA with $p < 0.05$ was conducted to see if the mean compared to all pressure levels had a statistically significant result. If that was the case, a Tukey-Kramer test was conducted to see in between which levels it was significant differences.

**Two Levels**

A one-way ANOVA was conducted to compare succeeded attempts at the bar with the two pressure levels (bar Nr 1 in Fig 8), dark green and red (0-20% and 21-97.5%). Means at both dark green ($M = 97.73$) and red ($M = 93.18$) were high with most of the attempts succeeded. There was no statistically significant difference between them, $F(1,20) = 1.17$, $p = 0.29$. The unsucceeded attempts at both levels had 100% of the values inside the higher pressure level.

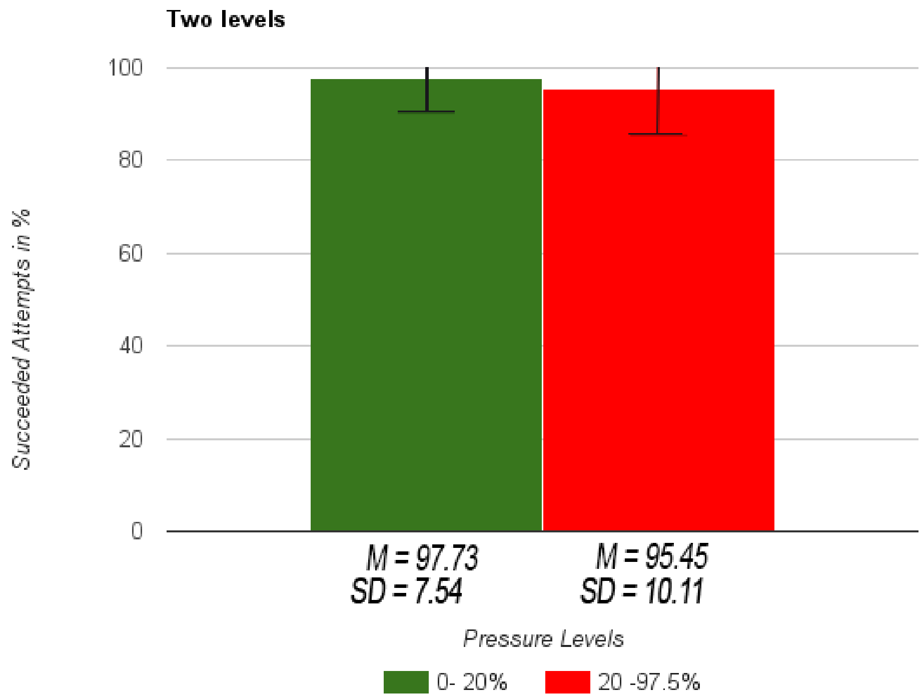


*Fig 9: Iteration 2, task 2. The diagram shows the mean of succeeded attempts at each pressure level when the participants tried to match levels at the bar containing two levels (bar Nr.1 in Fig 8) Also shows the standard deviation for each level.*

**Three Levels**

A one-way ANOVA was conducted to compare succeeded attempts at the bar with the three pressure levels (bar Nr 2 in Fig 8) dark green, yellow and red (0-15%, 16-55 and 56-97.5%). The means of dark green (M = 88.64) and yellow (M = 81.62) showed were high succeeded attempts. At red the number was a bit lower (M = 68.18). ANOVA showed that there was significant difference between them, $F(2,30) = 3.79$, $p = 0.03$. The big difference was seen between dark green and red, $p = 0.029$. The majority of the unsucceeded attempts at both dark green (75%) and red (62.5%) level was inside the yellow level. For yellow level 87.5% of the unsucceeded attempts was inside the red level.

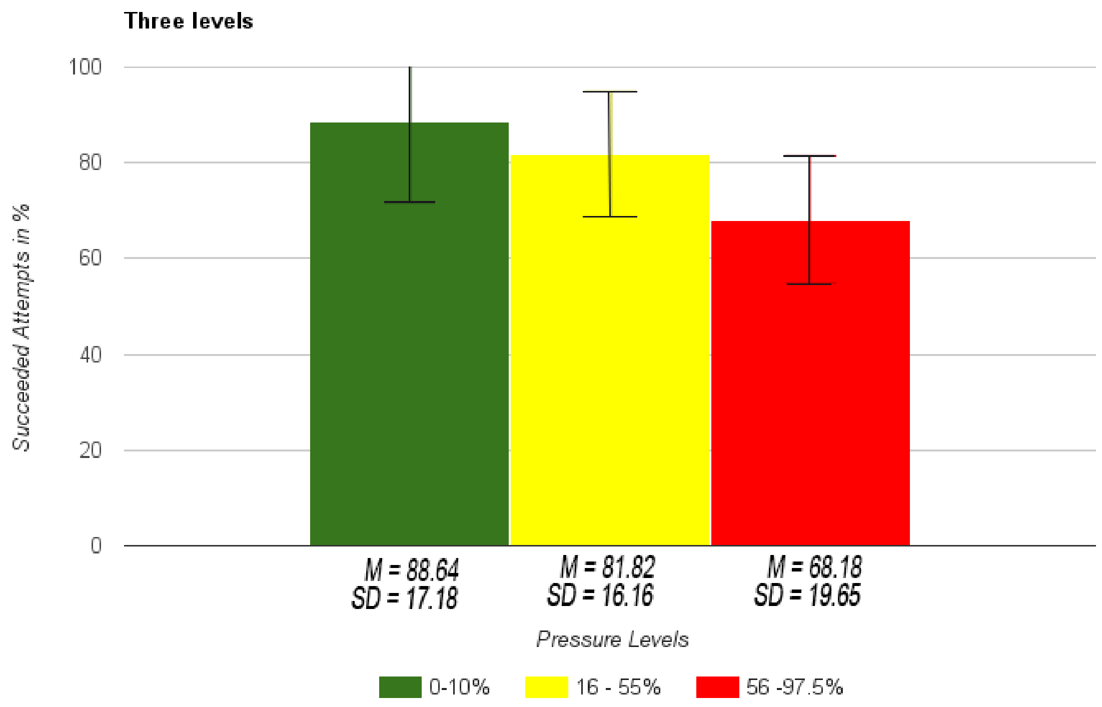


*Fig 10: Iteration 2, task 2. The diagram shows the mean of succeeded attempts at each pressure level when the participants tried to match levels at the bar containing three levels (bar Nr.3 in Fig 8). Shows the standard deviation for each level.*

**Four Levels**

A one-way ANOVA was conducted to compare succeeded attempts at the bar with the four pressure levels (bar Nr 3 in Fig 8) dark green, yellow, orange and red (0-10%, 11-37.5,37.6 - 67.5 and 67.6-97.5%). The means of dark green (M = 86.36) and yellow (M = 79.55) showed a high value of succeeded attempts and low difference. At Orange the number was a bit lower (M = 52.27), and even lower at red (M = 31.82). There was significant difference between levels $F(3,40) = 15.34$, $p = 0.0000008$. Even if so, the orange and red did not show any statistically significant difference, $p = 0.25$. The big difference was between dark green and yellow compared to orange and red, were the difference in all cases was, p = < 0.01. Both dark green and yellow pressure level had 100% of their unsucceeded attempts at one level higher. Orange had 75% of unsucceeded attempts at yellow level. Red pressure level had 50% of unsucceeded attempts inside the yellow level.

The difference in all cases was p = < 0.01. Both dark green and yellow pressure level had 100% of their unsucceded attempts at a one level higher. Orange had 75% of unsucceeded attempts at yellow level. Red pressure level had 50% of unsucceeded attempts inside the yellow level area.

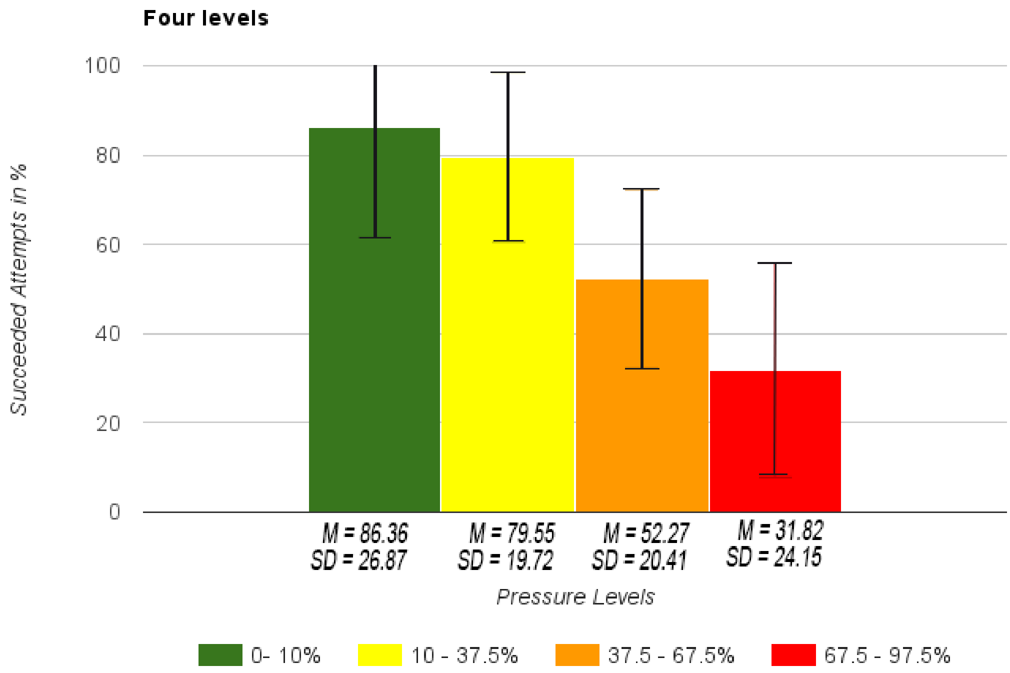


*Fig 11: Iteration 2, task 2. The diagram shows the mean of succeeded attempts at each pressure level when the participants tried to match levels at the bar containing four levels (bar Nr.3 in Fig 8). Shows the standard deviation for each level..*

**Five Levels**

A one-way ANOVA was conducted to compare succeeded attempts at the bar with the five pressure levels (bar Nr 4 in Fig 8) dark green, light green, yellow, orange and red (0-5%, 6-25, 26-50, 51-75 and 76 - 97.5% ). All levels showed less succeeded attempts compared to the other bars and the statistical difference was $F(4,50) = 12.85$, $p = 0.0000002$. The dark green level was the only one with a mean over 50% ($M = 72.73$). There is also a significant difference between dark green and all the other levels with $p =< 0.2$ between all. For all levels without red, the majority of the unsucceeded attempts occurred at the light green, and yellow level.

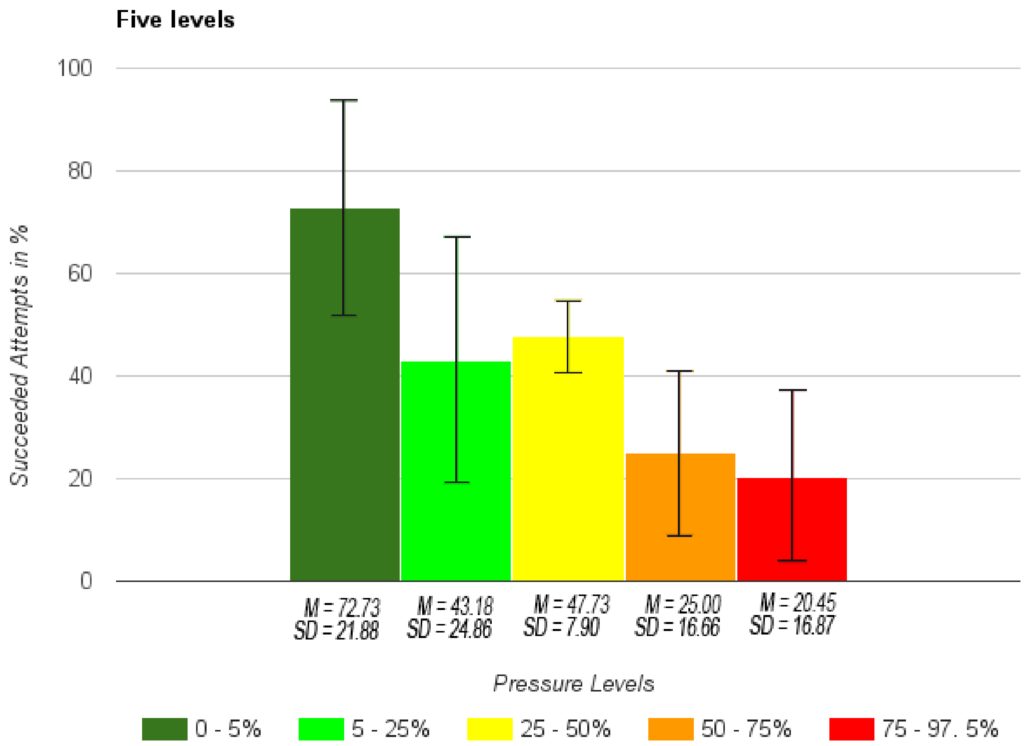


*Fig 12: Iteration 2, task 2. The diagram shows the mean of succeeded attempts at each pressure level when the participants tried to match levels at the bar containing five levels (bar Nr.4 in Fig 8). Shows the standard deviation for each level.*

### 4.3.4 Discussion

*Task 1*

The purpose of the study was to research how users are able to control different forces of pressure with 3D touch. The study focused on two types of controls. The first one was that the user has to be able to control isometric force at different pressure levels for a continuous period of time, and was tested in task 1. For these findings, the different pressure levels did differ significantly between the pressure levels which needed more force and the ones needed less. At the pressure level that needed most force participants had the marker close to 50% of the time outside the area. The time to be steady at a pressure level showed more difficulty at levels using more force. Hairsimans et al. (2009) showed that without feedback, accuracy was less accurate at higher force, but did not differ significantly at lower forces. That result is likewise confirmed by the result of this study, in such way that users showed big problems to control high forces of pressure. If using these results from a gaming perspective, changes in force can be used to adjust difficulty. An example would be to use less force early in a game, and when difficulty gets higher, the force required to control the "game object" could be increased. To be taken in consideration in this task is the short amount of time the participants had to familiarize with the pressure levels, and that the majority of the participants had no previous experience using the 3D Touch technology.

*Task 2*

Another type of interaction was the ability for a user to press a specific pressure level on a single touch and was tested in task 2. The result from this study indicated similar result as iteration 1. Participants were more successful to match forces at a lower force and had less accuracy to match at higher forces. For the bar with two pressure levels, the participants had no problem to match the different pressure levels. The same result was showed at three pressure levels. At four pressure levels the number of succeeded attempts was lower, and levels using little force versus higher force showed a big difference in succeeded attempts. At five pressure levels all pressure levels, without the one needed least force, had a number of succeeded attempts under 50 %. An interesting observation was at five levels participants often shown frustration and said that they did not feel like they had control, something that did not occur at tests with fewer pressure levels. When looking at the results from a gaming perspective, the result indicated that three levels of pressure are the maximum number of levels when a new user still has control to match all levels. To be taken in consideration in this task is the short amount of time for the participants had to familiarize with the pressure levels, and that the majority of the participants had no earlier experience using the 3D Touch technology.

# 5 Analysis of Game Mechanics

This section provides suggestions for possible areas the 3D Touch technology can be used in future game mechanics.  The suggestions will be backed up by the result from iteration 2 in study 1. It will be suggestions from the result of users ability to hold isometric force over a continuous time, and suggestions when pressing a level at a single touch. In the following text four different examples of fictitious games will be explained, and in what way the 3D Touch technology can be used in them. The games are fictitious, but are inspired from existing ones.

*Rocket launcher*

Rocket launcher is a 2D endless runner game where the player controls a rocket that is trying to avoid obstacles. In this game, the 3D Touch makes the rocket fly higher or lower depending on how hard the player is pressing at the screen. If the rocket should stay at a constant height, the user presses continuously at the same pressure. The longer the player survives it in the game, the higher the difficulty gets. As indicated in task 1, users have a harder time to match levels at a higher force and therefore the longer the user stay alive, more pressure is needed to be able to control the rocket.

*Faster Racing*

Faster Racing is a racing game where the player is driving a car that is chased by the police. The police are building obstacles in the way to try to stop the car. For the player, the mission is to avoid obstacles, but do not slow down too much. In Faster Racing 3D Touch is used as an accelerator which makes it possible for the player to self-choose the exact speed of the car. In similar games, like Driving School 2016, the interaction with the car has been with two touch buttons, were one increased speed and the other decreased.

*Fighter Legend*

Fighter Legend is a fighting game where the player battles against another contender. The game includes several attacks that the player can use to beat the opponent. In similar games, like Street Fighter IV, the mechanics often uses virtual pads, that is visual buttons shown on the screen, to control the game, but that takes a lot of the screen size. With 3D Touch, you could instead have all the attacks at different pressure levels, saving both screen size and giving the ability to trigger them everywhere at the screen. It would even be possible to click on a specific place at the contender in a fight, and from there choose the wanted attack at the right pressure level. If using the result of task 2, three attacks would be possible as standard attacks. However, the possibility to use more rare attacks could be implemented at levels that need higher force, which showed to be less accurate for users in task 2.

*JumpMan*

JumpMan is a 2D endless runner game where the player controls a man who jumps at platforms to stay alive as long as possible. In many of todays endless runner games, the height of jumps is depends on how long time the user touches the screen. In JumpMan, the 3D Touch is controlling the different jump heights depending on how much force is used. If using the result of task 2, three levels would be possible for standard jumps, but an increasing of jumps could be possible at higher difficulty in the game.

As an example to see how the user experiences the 3D Touch in a real gaming situation, the game JumpMan is created as a real prototype and tested, as explained in more detail in sections 3.3 and 6.

# 6 Game Study

This chapter presents the result of the gaming study explained in section 3.3.

## 6.1 Participants

Six participants took part in the study. The age was between 20-25 years old. All the participants were men. Only one had earlier experience with 3D Touch. Five played mobile games often. The study was made in a calm environment with the participant sitting down on a chair.

## 6.2 Result and Analysis

This section presents the user feedback and thus qualitative data gathered through observations of the participants playing the game JumpMan.

When playing the game, all of the participants showed a tendency to press to hard in the first couple of game rounds and therefore did die early. After a while, the players got familiar how to use the different jumps. The jump needed the least force took the longest time for participants to get familiar to use. Observations showed that after a while of gaming the participants had control over the different jumps in more relaxed sections in the game, as in the beginning and between obstacles. However, at more stressful situations in the game, like a fast jump to avoid an obstacle, the participant sometimes mistook the force, using too much force when pressing the screen. This was something that happened repeatedly and was not something that the participants learned how to handle in the short period of time they played.

Participants positive comments regarding the 3D Touch, whitin the game sections, included “It feels cool to actually use force in a game”, “It got easier to use the different jumps after while”, and “When learning to use the smaller jump, the game got easier”. Negative comments about the 3D Touch were “I am sure I pushed the little jump, something is wrong”, and: “It is frustrating; I forget that it is the force and not how fast I touch”.

## 6.3 Discussion

The major goal of this study was to be able to see how the user is able to interact with 3D Touch in a real game situation.  I expected to observe users be able to use pressure levels from the indications from task 2 in study 1.  Observations also indicated that this was true, as they got more familiar on how to use the force, and how to control it, after some rounds of playing. However, there were some interesting observations in stressful situations where participants had to make fast decisions. When they thought they had pressed for the smallest jump, the force they used was too much, and the jump became too high. The fast decision had led them into doing a higher jump then they were considering, and this lead to frustration. This is something that developers that are creating a game should take into consideration when choosing the numbers of pressure levels. In a more stressful game, fewer and bigger levels would be a better choice so that users have more room for mistakes. But if instead creating a less stressful game more and smaller pressure levels are more likely to be successful.

# 7 Conclusion

### 7.1 Summary

This thesis researched users ability to control the 3D Touch technology, and how the user experience to use it. A usability application was created to evaluate the users ability to control the 3D Touch. The application had two tasks that tested both the users ability to hold continues isometric force and the users ability to match specific pressure levels. The application was tested in two iterations with two tasks in both. The second iteration used the result from the first to make changes to gain further, more detailed, insights in the user's ability to utilise the 3D Touch technology. Experimental results indicated that users had less accuracy to control 3D Touch continuously when they had to use higher force. It also indicated that when users try to match pressure levels, they are more successful at levels that required less force.

### 7.2 Conclusion on Research Questions:

- How is the user able to control continuous isometric force using 3D Touch?
- Users show a good ability to control 3D Touch at low forces, at higher forces indications show that the accuracy and control decreases. When trying to stay steady inside larger pressure level areas, as 20% of 3D Touch max value, the difference between different forces is small. However, at smaller pressure level areas, as 5% of 3D Touch max value, the ability to stay steady inside an area for a longer time show less accuracy at higher forces.

- How is the user able to match different pressure on a single touch using 3D Touch?
- At lower forces users show good accuracy to match the requested force. At higher forces the accuracy decreases. Users show good accuracy to match up to three pressure levels, when using more pressure levels the accuracy decreases at the levels needed higher force. When trying to match five pressure levels users showed frustration that they did not have control. Pressure levels at 60% and upwards of the 3D Touch max value showed a low number of succeeded attempts.

- How is the user experience interaction with 3D Touch in a gaming situation?
- Users show positive feedback using the 3D Touch in a gaming scenario. However, it takes some time for a new user to be able to control it. Stressful situations in a game can make the user press too hard, and that leads to frustration when users think they pressed the level they wanted, but they pressed too hard.

### 7.3 Future Work

This research gave indications of how users control 3D Touch when they used the technology just a short period of time. It would therefore be interesting to see a study researching users' ability to control the 3D Touch when using it for a longer time. Longer use could probably lead to a better matching of different pressure levels when the users learn how to control the pressure. Study two showed indications how the users experience the use of 3D Touch in a gaming situation. Experience in gaming situations is something that could be investigated further, with more game genres, and also comparing 3D Touch against another input functionality to see in what gaming situations the technology works better or worse than other input methods. The size of different pressure levels used in bars in the usability applications is something that could be researched further. Using another combination of level sizes to investigate which pressure level sizes that fits various games the best. Something that was a limitation in this research was the calm test environment. In tests the users were sitting in a up-straight, stable position. What happens when the user is lying down or is in a less calm environment (e.g. in a moving car/bus)?

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# 9 Appendix

## 9.1 ANOVA

In this study ANOVA is used to show statically significant differences between succeeded attempts in study 1 iteration 2, explained in section 3.2. ANOVA is the analysis of variance (Laerd statistics). It is used in a statically analysis to examine if the means of several groups are equal. ANOVA can test several means at the same time, unlike T-tests that only examines two means. If an ANOVA gives a significant result the chance that the means differ from something else then the chance is 95%. If this is the case, a post hoc test can be conducted to examine between which subgroups the difference is significant. One of these tests is the Tukey-Kramer test, that examines if two different values have significant difference.

## 9.2 Unity

Unity is used to create applications for this study. It is a game development system/engine that makes it possible to create games in a 2D and 3D environment. It can build and publish games to most of the big platforms like Windows, Mac OS X, Android, iOS, and all from the same source code ("cross-platform compiling"). This means that as a developer you do not have to write applications in different languages, all can be written in C# or JavaScript, and debugged directly in the Unity graphical user interface (GUI). Unity also provides the developer with a GUI that makes adding properties to different game object possible by drag and drop them on the desired object. This kind of properties can be physics, colliders, explosion force, animations and more. All built into the Unity API.

## 9.3 Addition to Study 1

### Study 1 iteration 1

### Task 1

| | | | | | |
|---|---|---|---|---|---|
| To get steady at level | | | | | |
| Pressure Level | 0,1 - 5% | 5 - 25% | 25 - 50% | 50 - 75% | 75 - 95% |
| Mean( in seconds) | 1,67 | 0,95 | 1,6 | 3,15 | 3,17 |
| Standard deviation( in seconds) | 0,76 | 0,45 | 0,54 | 1,12 | 0,86 |
| | | | | | |
| % outside area after steady at level | | | | | |
| Pressure Level | 0,1 - 5% | 5 - 25% | 25 - 50% | 50 - 75% | 75 - 95% |
| Mean( in %) | 0.24 | 0.18 | 0.13 | 0.05 | 0.45 |
| Standard deviation( in seconds) | 0.42 | 0.28 | 0.23 | 0.12 | 0.58 |

*Table 3: Task 1 iteration 1, first table shows the mean in seconds and the SD to be steady at the pressure level. The second table shows the time in seconds and SD of how much time they were outside the pressure level area after they were steady at level.*

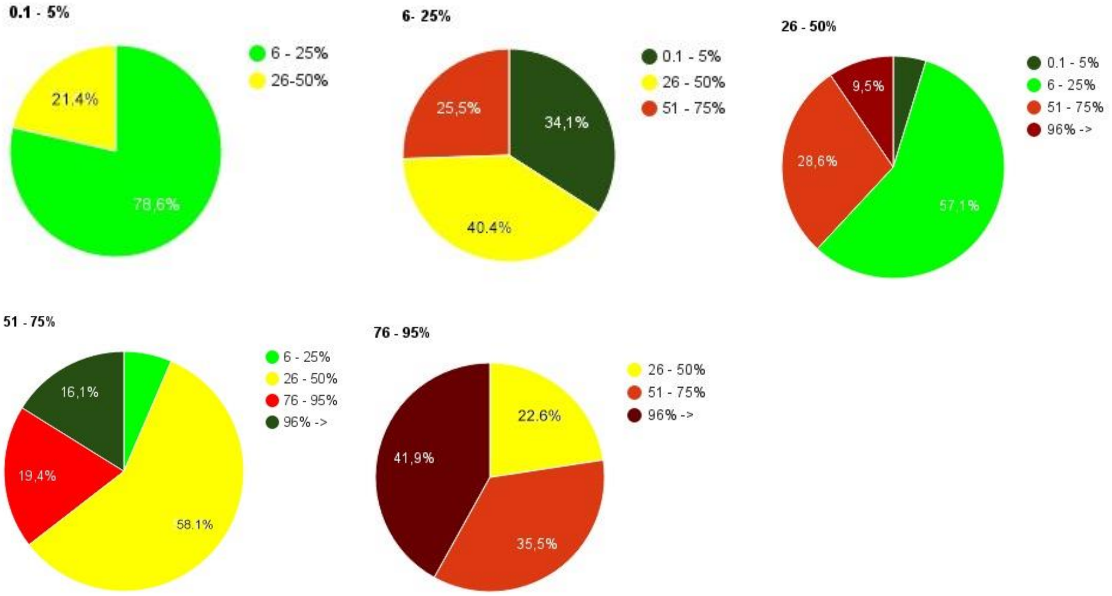


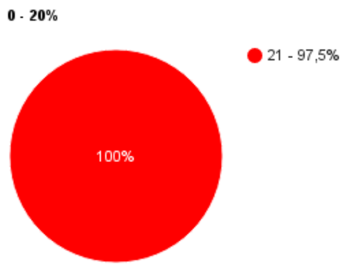

*Fig 13: The pie charts show at what pressure levels, at 5 levels, the unsucceeded attempts at each pressure level did occur.*

## Study 1 iteration 2

## Task 1

| | | | | | |
|---|---|---|---|---|---|
| To get steady at level | | | | | |
| Pressure Level | 1 - 6% | 16 - 21% | 36 - 41% | 56 - 61% | 86 - 91% |
| Mean( in seconds) | 1,56 | 2,16 | 2,18 | 3,1 | 3,84 |
| Standard deviation( in seconds) | 0,52 | 0,74 | 0,41 | 1,04 | 0,92 |
| % outside area after steady at level | | | | | |
| Pressure Level | 1 - 6% | 16 - 21% | 36 - 41% | 56 - 61% | 86 - 91% |
| Mean( in seconds) | 0.28 | 0.19 | 1.27 | 1.71 | 2.91 |
| Standard deviation( in seconds) | 0.48 | 0.14 | 0.72 | 1.5 | 1.35 |

*Table 4: Task 1 iteration 2, first table shows the mean in seconds and the SD to be steady at the pressure level. The second table shows the time in seconds and SD of how much time they were outside the pressure level area after they were steady at level.*



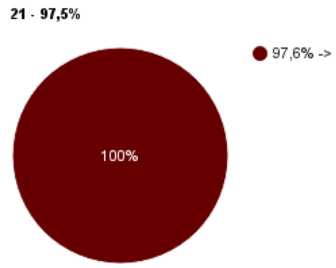




*Fig 14: The pie charts show at what pressure levels, at 2 levels, the unsucceeded attempts at each pressure level did occur.*

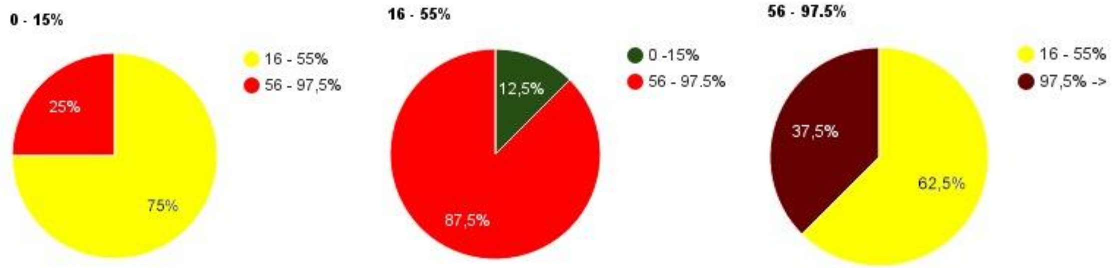



*Fig 15: The pie charts show at what pressure level, at 3 levels, the unsucceeded attempts at each pressure level did occur.*

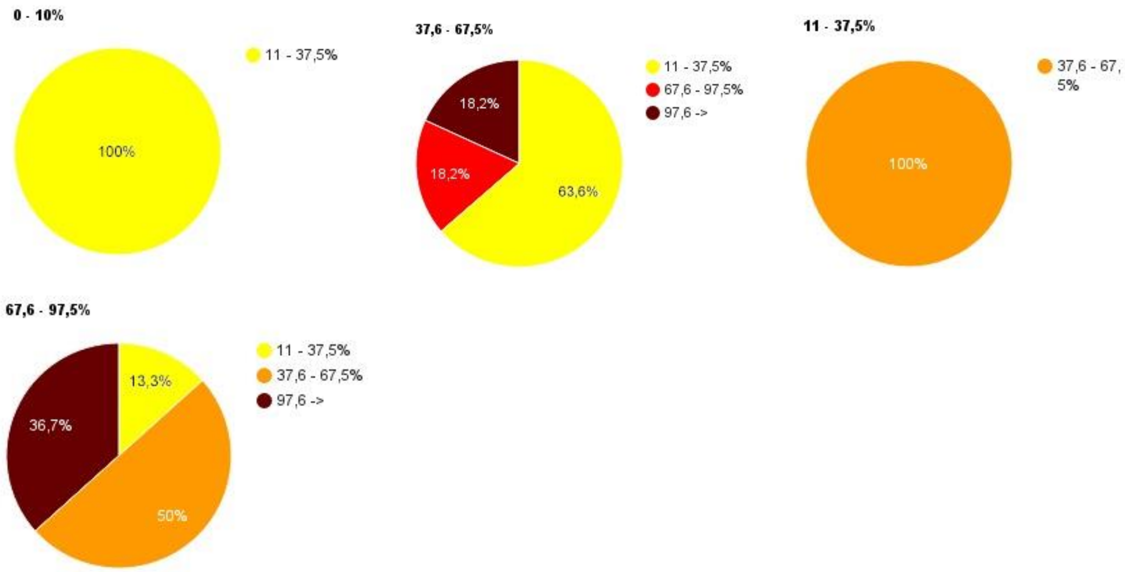



*Fig 16: The pie charts show at what pressure levels, at 4 levels, the unsucceeded attempts at each pressure level did occur.*

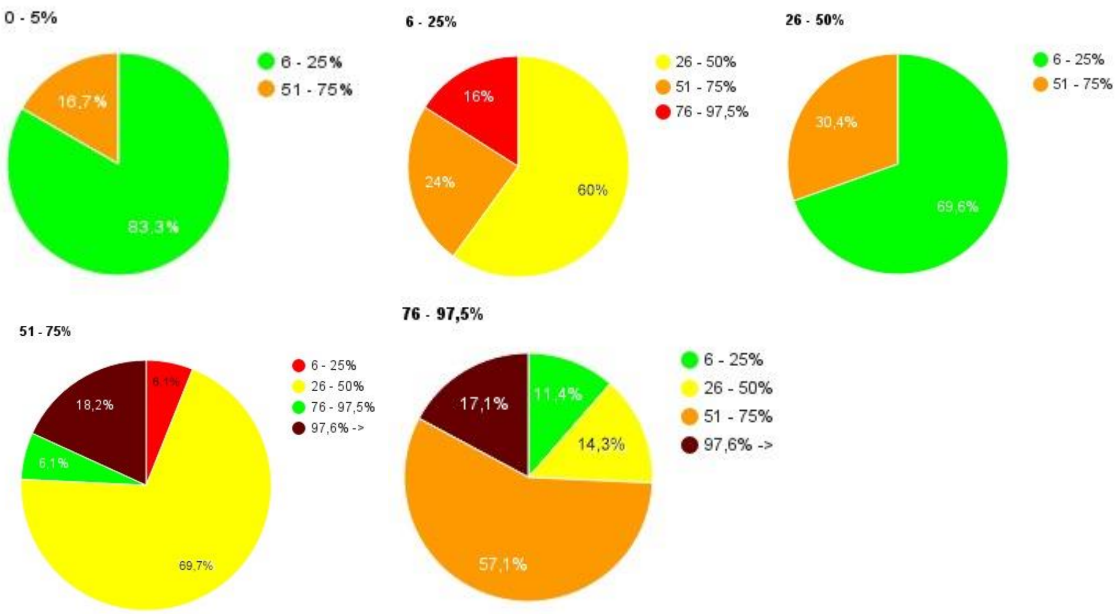



*Fig 17: The pie charts show at what pressure levels, at 5 levels, the unsucceeded attempts at each pressure level did occur.*