The Influence of Non-diegetic UI Elements in 3D Touch Controlled Games

Nana Tian
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Media Technology MSc program, Leiden University
Supervisor: Maarten Lamers and Edwin van der Heide
berserker0211@gmail.com

***Abstract*—3D touch technology has been introduced by Apple since 2015, and got serious attentions since the innovative pressure-sensitivity technology can bring more space for creativity. Some developers have claimed that it does not usually intuitive for beginners to use because lack of proper visual hints for pressure. Meanwhile, it could be noticed that the non-diegetic UI elements in games can direct the users a lot better than solely the instruction text. However, former researches have proven that the non-diegetic UI elements in games could reduce the level of immersion, and there is a tendency for non-diegetic UI elements to be as minimum as possible by reason of the smaller screen capacity. Therefore, it is important to figure out whether non-diegetic UI elements related to 3D touch will function positively in games while maintaining a balance of immersion. In this paper, an empirical experiment has been conducted to study non-diegetic UI elements' influence on 3D touch control and the level of immersion with a 2D shooter game called "PlaneWar". 35 participants have participated in this study to compare the two versions: 1. The game with non-diegetic UI elements demonstrating the pressure ranges in real-time. 2. The game removed the non-diegetic UI element that is relevant to 3D touch controller. The results indicate that non-diegetic UI elements indeed highly suggestive for beginners to adapt the 3D touch control. The outcomes illustrate that there is a statistically significant difference in control accuracy between the two conditions. No statistically significant difference, however, is found on the level of immersion. Finally, some implications have been made for game developers to make more effective selections when using 3D touch in games.**

***Index Terms*—3D touch, Human-computer interaction, mobile games, Non-diegetic UI elements, immersion.**

I. INTRODUCTION

1.1 Brief introduction of 3D touch

Lately, a swift evolution of advanced interaction technology has brought fresh ideas to the computing industry, particularly mobile computing. In 2014, Apple defined and innovated a brand new multi-touch technology called "Force touch", which allows the trackpads or touch screen be capable of pressure sensing and actuating. In late 2015, "Force touch" was extended by Apple to a more advanced level--"3D touch". A new dimension of interactive technology has been opened up by 3D touch. The finger movement is not only now measured from the "up, down, right and left", but also "through" [11].

1.2 What is unique about 3D touch

1.2.1 Force touch or pressure sensitive

3D touch has the pressure-sensitive feature of force touch, but a step further. The technology can distinguish different levels of forces applying from your finger, and react immediately according to the force. Imperceptible changes can be captured by the capacitive sensors and allow a precise continuous acquisition of the force exerted on a touch screen or similar display surface, and then be interpreted and reacted to specific actions or controls (based on the exact amount of the force of the input).

When using 3D touch, different levels of pressure detected from your finger would be responded with specific actions or events like preview a picture, article, and other contents on the internet. Moreover, the 3D touch has a customizable feature with which you can freely fine-tune the pressure's sensitivity so that the pressure needed to activate an event is determined by yourself. 3D Touch can even automatically adjust the sensitivity level by distinguishing from the fingers you use to press on the screen [1].

From the developer's view, the force is a continuously changing float point value, and it's perfectly linear (The maximum possible force is defined by Apple as a float number) [12]. The force detected is ranged from 0.00 to the maximumPossibleForce of 6.6666667, and the observed non-zero minimal force detected always be 0.016666666667. Moreover, the nearest power-of-two multiple to the maximum force is 512, or 9 bits according to R.kevin's experiment [35]. It is worth mentioning that these values are independent from the different models of device and personal sensitivity settings.

This technology enables a potential capability of picking up the user experience to the next level. Developer Ryan Mcleod has done research on using the pressure sensitive feature to turn the iPhone6s into a scale(Gravity). He used a spoon as the conductive medium. The graph of the force values of discrete numbers of US nickels on the metal spoon is showed in Fig.1, which indicates the force values correlated to the weight linearly. But this later has been forbidden officially by Apple for some reasons. One of the hypotheses is that

someone might be interested in testing the limits and

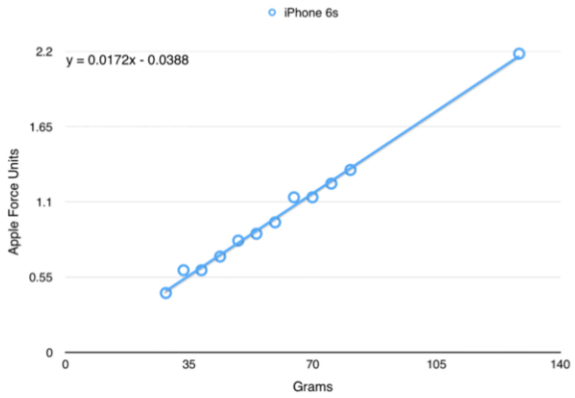

Fig. 1. The graph shows the linear relationship of the weights and force.The developer calibrated the gravity or weights in Grams.

There's another interesting research which opens a whole new realm of usabilities of 3D touch. A team of researchers from Johns Hopkins University School of Medicine implement -ed a game called Bandit's Shark Showdown using 3D touch as the controller. They used this game as part of a serious experiment. From which they want to know whether the pressure-sensitive touch screen can help stroke patients restore deftness and strength of their finger [14].

Also, there're lots of applications in creative fields like music and art using the feature " force " to trigger actions. For example, in an app called Procreate, the painting strokes are now associated with the amount of pressure. Pressing harder will get a thicker stroke. In iMaschine 2, a music-making app, the velocity or pitch of a note is defined by the pressure, changing the pressure will cause a variation in the music.

These researches and applications are much more challenging and intrinsically have more depth than providing faster access to system or app features.

1.2.2 Quick actions

3D touch is an expanded version of multi-touch. In addition to the traditional gestures like taps, swipes, and pinches, new pressure-based gestures are introduced on the iPhone 6s, 6s Plus and the newest models for in-app shortcuts called "Peak and Pop" and system-wide shortcuts named Quick Actions. Those gestures allow users a fast and direct access to the key activities and context of the application, which is more intuitive and time-saving. However, it is also controversial that the users have to discover themselves whether the application supports quick actions or not, and where the hidden menus are. Since it's a fairly new technology, not all apps apply and support it, and the users couldn't tell from the surface and there is no hint.

On one side, from the user's perspective, the peak and pop or quick actions provide a seamless way for users to preview and navigate content, the users don't need to click more buttons or links, allowing them to connect even closer to the application's content. From the developer's perspective, both the UI content and the navigation method become cleaner and simpler. On the other side, for the user experience, the new interaction method needs time to discover and adapt to use it, since the traditional multi-touch dominated the touch surface for a while. And people always need time to accept the new things.

In conclusion, 3D touch lets you get "through" into the application and reveals what's inside, but it's vague from the surface that how "deep" the application can let you look. Although there might be tactile feedbacks, but as a new user, you don't know if there's more, the only way you can do is press harder and harder. The developer might know there is a maximumPossibleForce. But users don't. How to find an intuitive way to tell the user that the 3D touch advanced functions available has become a hurdle.

1.2.3 Haptic feedback

Along with the quick actions, the new Taptic engine [9] provides a more precise haptic feedback to inform you that the pressure threshold has been reached and where the swift actions will respond. The original engine could provide more distinct tactile feedback for different events. More nuance haptic feedback could be created by the time the vibration last. These subtle changes can be only provided by the new Tapitc engine which the old vibration motor can't.

1.2.4 Other limitations

A. Compatibility

Since the 3D touch is only available in iPhone 6s and 6s Plus and the newest devices. It's competent to provide the unique experience exclusively for new iOS users to some extent. However, it can be tricky somewhat. Obviously, it's lacking compatibility. Developers and interaction designers need to create different versions of applications. For example, the developer Victor Baro [10] claims that he wouldn't design an action completely just by using this feature, and the 3D touch should just offer an alternative level of interaction. This already indicated a limitation of this feature.

B. Apple has hidden "rules"

Apple seems to set the key spirit of 3D touch as "shortcuts". The company defined the new feature to be an add-on or alternative way of interaction. The essential part of the multi-touch features remains the same for all iOS users. This might leave the developers less space to manipulate or overwrite the actions.

C. Adaptivity

The normal multi-touch has been admitted for a long time on the touch surfaces. Users are prone to tap other than pressure harder when a button or a link appears. Some users reported training themselves to get used to the new interaction of 3D touch [15].

1.3 Similar new technologies and researches.

1.3.1 Pressure sensitive interfaces

Jefferson Y. Han introduces the FTIR (Fourier transform infrared spectroscopy) based multi-touch sensing system using infrared light, but the system only provides a rough sense of pressure, the pressure does not change significantly as the user s press harder. And it very strongly depends on the resolution of the camera [2]. As an improvement research based on Han's. J. David Smith has developed a malleable multi-touch surface with pressure sensitivity. The advantage of the technology is the surface can be deformed to different sizes and with high extensibility. Moreover, It has high-pressure

sensibility and also reports to have a continuous range of pressure like 3D touch. Additionally, because the softness of the touch surface, the user can feel a tangible depth from the material itself. Furthermore, the surface is not only workable with human fingers but also other objects like brushes. But it's portability is limited comparing to 3D touch devices because the system requires a camera for the interactions and this makes the system somewhat cumbersome [3].

1.3.2 Tactile feedback on touch screen

Recently, there are modern technologies developed to support tactile feedback on touch screens. Also, some researches on vibrotactile feedback on touch screens have been made. Koji Yatani and Khai N. Truong [4] introduced SemFeel—a semantic tactile feedback system which notifies the user of the advent of objects with grammatical information. It builds up a more complex and strong vibration system which can generate different patterns of vibrations, supporting accurate eyes-free interactions [4]. Feed-Good touch is an experiment carried by Emilia Koskinen, Topi Kaaresoja and Pauli Laitinen to find the most pleasant tactile feedback for the mobile touch screens. They used both a piezo actuator and a vibration motor as the experiment subjects. The result implies that tactile feedback is significant during the interaction of touch screens and piezo actuator is slightly better than the vibration motor with a more pleasing tactile feedback. But it is not statistically important [5]. There's another research called MudPad using an array of electromagnets and magnetorheological (MR) fluid to provide an instant active multi-point haptic feedback on the designed touch screen [6]. Olivier Bau from Disney research had research on a new technology for enhancing touch interfaces with tactile feedback called Tesla Touch. The innovative technology provides different levels of stimuli according to the friction frequency. Nevertheless, it is limited to camera recognition and tracking of fingers [7]. All those above researches are more related to texture feedbacks and haven't been extensively used in normal life.

1.4 The possible implication of the 3D touch in game context

3D touch has got serious attention now, but not too many applications and games support 3D touch yet. There's a statement that 3D touch will bring real excitement when it applies to games because our adrenaline pushes us to touch the surface harder when we are fully heated [8]. From a developer's view, the most manipulative property in 3D touch feature is the "force".

There are already a bunch of 3D touch enhanced games in the app store. A racing game like Asphalt 8 uses 3D touch for the alternative steering, pressing harder when you're holding left or right enables the car into a left or right drift. AG Drive, another racing game, using the 3D touch pressure sensitivity to offer subtle increasing or decreasing of the levels of acceleration.

In "Warhammer 40,000: Freeblade", the "force" is divided into 3 levels(minor touch, press a little harder, a solid press) to change weapons real-time in the battle without interrupting the gameplay. Another first-person shooter game called "Into the dead". Pressure sensitivity is used to steer the characters. Pressing harder in either right or left makes a stronger move in each direction. The new 3D touch interactions are claimed to be tricky to use in some of those games [16].

In conclusion, how the pressure sensibility applied to the existing games depends on the game concept. But they all have a notable feature that the expression of 3D touch in those games is weak. A lot of them don't seem to significantly affect the way you play the game or you can barely acknowledge the changes even when you press harder. The 3D touch seems to dispensable in those games.

Developers are working hard to implant the new 3D touch features in games. Mainly, they're used for subtle steering, acceleration or weapon changes. Speaking of the game genres, the racing game takes a large proportion. One possible reason may be the adrenaline rush forces us to touch our screen with high pressure [8].

Being an attractive new technology, 3D touch has been designed and implemented in many games now to upgrade the experience. We've played some popular ones listed by Macworld [16] to explore how 3d touch controls applied in games. In spite of the game genre. We can basically observe and summarize the use of 3D touch in games into two categories: A.Continuous usage B. Discrete usage

A. Steering (Continuous usage)

Use 3D touch as steering controls is the most common in games. If we look into the features, we can easily find that the movement of the character is linearly and continuously changed with the pressure from your finger. Like in the game BreakNeck, the speed of the spaceship which player controls will increase linearly when player press harder on the screen. A simple graph demonstrates the relationship of the controls and character movement below (See Fig. 2).

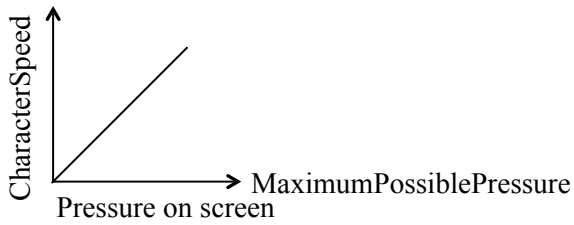

Fig. 2

B. Weapon change (Discrete usage)

Weapon change is another key interest to implement 3D touch in games. It's different from the steering fundamentally. The changes happened at certain points. The linearly pressure serves as the "quantitative change". When it reaches to some threshold value, the "qualitative change"—weapon change will happen. For example, in the game "Warhammer 40,000: Freeblade", there's descriptive text before the game for beginners to know that jam your thumb onto the screen can switch weapons. But no visual cues are designed to indicate when exactly the pressure is enough for a weapon change. It's not friendly for the beginner.

The benefit of using 3D touch as weapon change is that you don't need to discontinue the game process to switch to weapon store or item storage etc. But the disadvantage is also there, the number of weapons relative to 3D touch will be limited due to the maximumPossiblePressure and sensitivity. If you divide the pressure into too many levels to reach a certain amount of weapons, it will be too sensitive to control.

A simple graph illustrates the abstract relationship of the controls and weapon changes below (See Fig. 3).

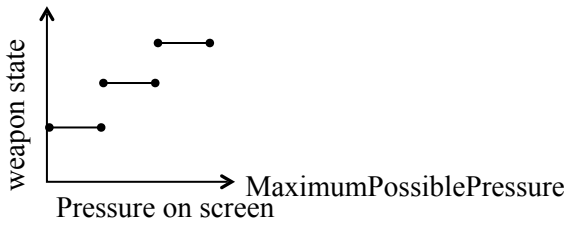

Fig. 3

Also, we have noticed that many of the games are not born for 3D touch controls. In another word, they have been released in multi-platforms before the inventive 3D touch controls. A key principle for multi-platform interactive designers is expendable game controls can only be accepted without changing game mechanics [21]. As 3D touch is exclusive to the iPhone 6s(Plus) and the iPhone newer than 6s(Plus), which leads to 3D touch with little expression in most of those games. To maintain the perfection of the original game mechanism, 3D touch controls often become chicken ribs. We can easily discover that among the top 10 games advanced with 3D touch listed by Macworld. 9 of them do not have the non-diegetic UI elements for 3D touch. As we kept playing those games , the experience varies over time. At the very first beginning, the non-diegetic UI elements did offer a more controlled controller. The pressure range provides a clear information of how hard you can press on the screen and how much you've pressed. The rest of them, on the contrary, are somehow not handy from the very beginning when you start the game. And then, after one week, the experience had turned out differently. As getting much more familiar with the 3D touch controls. The non-diegetic UI elements which jump out every time when you put you finger back again really become a distraction.

1.5 3D touch controller and game experience

1.5.1 Immersion in games

Computer games have been considerably loved by people from all over the world. From 2D pixel art to realistic 3D simulations. Now games have numerous artistic styles and more sophisticated controls. However, regardless of these differences in game mechanism, design, and graphical appearances, outstanding games is the ones which earn player's full attention. Sometimes a game is so engaging that it can succeed to distract the player from the "real world". They won't notice at the time passing by or the movement of others around them. They can be too focused that even their physical body conditions can be disregarded. Such a game experience is called "immersion" [23]. But it is continued to be vague as just a game experience.

There is divergence even within the definition of the term immersion. Coomans and Timmermans defined immersion as "a feeling of being deeply engaged where people enter a make-believe world as if it is real" [24]. While Radford described immersion as the capability to step into the game through game controllers [25]. Slater et al have given an another concept from a different view, which is "a sense of presence" in a virtual environment and the experience is only applicable to virtual reality(VR) field. Moreover, he stated clearly that non-VR games could not lead to immersion [26].

However, there are dissenting voices. Schubert and Crusius [27] argued that media like books can also provide the feeling of presence as imaginative and emotional involvement is essential components to immersion. Thus, immersion should be restricted just to VR domains. This is also argued further more whether the 3D games are more immersive than 2D games. Some people might think realistic 3D or virtual reality games might be more immersive. It is not 100% accurate. This is supported by gamers who claim that although 2D games might not be visually more appealing than some photo-realistic 3D games. In the opposite, many people really love the classic 2D games and had a very strong impression on them. Imagination can fill the gap [28].

While we can conclude that immersion describes the engagement of a person with media like games, cinema and even books, a profound feeling of involvement with a special medium [29]. There are three identified distinct levels of immersion. The first one is called "engagement". The player needs to spend time learning to master the controls and overcome the influence of personal inclination. The second stage is "engrossment", the controls are becoming invisible as player throw their emotions into the game, and the highest one is called "total immersion", a sense of presenting and being a part of the virtual world and when the game is the most important. However, total immersion is hard to achieve, they can be hindered by a lot of factors like "human physical and emotional perspectives, computer and contextual designs" [30].

In this research, we don't want to limit the definition just to VR domains for three reasons: Firstly, 3D touch controls have not been used often in VR fields, and the technology itself is restricted to specific models of iPhone. Secondly, the most enjoyable or impressive 3D touch control utilized in games we've discovered so far is an apple-award winning game called "Dividr" [31], and it's simply a 2D arcade game. Thirdly, as we mentioned above, the main barrier of immersion is gamer preference.

1.5.2 Immersion, the UI elements and 3D touch controller

The player experience can be affected by distinct input controllers. Primarily, the game controller should match up with the game mechanism. However, even with the similar mechanism, it's still interesting to find 3D touch performs differently because of the various designs. For example, both use 3D touch controls for steering, Breakneck use the visual elements to indicate how hard you press the screen. While "Into the dead" chose to remove the visual elements to make the game scene a harmonious whole during the gameplay. As a personal experience, 3D touch seems to be much more handy with the visual elements in Breakneck. Although it might sacrifice the immersion of the game since the visual elements (In the game Breakneck, it's non-diegetic which refers to interfaces that are rendered outside of the game world, like most of the classic Head-up displays) would somewhat block the view of the game scene.

Put aside the specific game example above. In conclusion, it is arguable that the non-diegetic elements provide extra information for a better understanding of the game system [17]. However, there are opposite opinions that those elements would block the view and decrease the immersive experience [18]. Moreover, Past research has been shown that there is a trend for non-diegetic elements to be as minimal as possible due to the smaller screen size (such as Apple Watch) [19]. Research done by Ioanna Iacovides concluded that removing the non-diegetic elements such as the HUD displays can make the game more immersive for expert players in the first-person shooter game [20]. So here comes the issue. New 3D touch controls would definitely bring new player experience. But if it's not designed well, then it might be counterproductive, and further impact the player performance and experience. It is essential to figure out the finest way to design the 3D touch controls in games. More importantly, what can be the tradeoff between the sophisticated control and complete immersion of the game?

1.6 The research question

In this research, we intended to conduct certain experiments to study the observations and answer the questions above. Specifically, we only study the continuous use of 3D touch in this paper. Because most of the 3D touch games now in the app store are using the pressure change linearly. Also, the importance of UI elements of discrete use mostly depends on how many levels you can achieve. For example, if there are 2 or 3 levels, then the 3D touch can be so intuitive that the UI elements are not meaningful at all.

Very little research has been done to explore the relative merits of presence or absence of non-diegetic elements on players' experience in the gameplay empirically. Let alone the 3D touch related UI elements. The aim of this study is to help game developers interested in 3D touch making better choices in design.

Thus, the research question in this study is presented as follows:

1. Would the presence of UI elements related to 3D touch influence the control accuracy of 3D touch?

2. Would the presence of UI elements related to 3D touch influence the level of immersion?

Accordingly, possible hypothesis can be:

A: The presence of UI elements related to 3D touch controls will help the participants master the 3D touch control better and get a higher score.

This might because the UI elements could make a better understanding of what actions you're performing (how hard you press) and the related events that you expect to happen(the movement of the character in games).

B: The level of immersion of the game will be lower with the presence of the visual elements of 3D touch control than the version without.

This hypothesis is based on the previous research that the non-diegetic UI elements might block the game world and further decrease the level of immersion.

II. METHODS

2.1 Observations and notes

User interface design in games can offer a lot of information to users. It's different from other UI designs because it's related to the game narrative. The links between the fiction of the game and UI elements can be direct or partial or not at all. The visual elements in games would also offer indirect or direct cues for the range of 3D touch controls. We can basically categorize those UI elements into non-diegetic, diegetic ones.

For example in the game "AE moto GP", a motor racing game. The road (Diegetic UI elements) width becomes a fairly clear hint for 3D touch controls(See Fig. 4), and it also provides a speed bar(Non-diegetic UI elements) to directly indicate the range of the pressure. Also in the game like "Breakneck" or "Race the sun" (See Fig. 5), first-person racing game, the barriers(Diegetic UI elements) in the game will also indirectly let you know how hard you should press, what's more "Breakneck" as we mentioned in section 1.4 had the speed bar (Non-diegetic UI elements) too when you press on the screen. In 2D platform games like "Badland 2" (See Fig. 6), the scene height can be a clue for the range of pressure you can reach. More obviously, in the 2D arcade game like "Dividr" (See Fig. 7), the rectangles(Diegetic UI elements) in the scene could tell you how hard you can press and how hard you need to press. All of the games have diegetic visual elements and the construction determines that they could more or less give instructions to 3D touch controls.

Fig. 4. AE moto GP

Fig. 5. Race the sun

Fig. 6. Badland 2

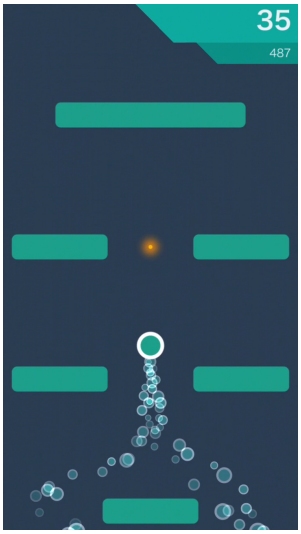

Fig. 7. Dividr

In order to understand different usages of 3D touch controls in games, an experiment has been conducted. In this section, the methodology, details of data collection and results are presented below.

2.2 The game

A game called "PlaneWar" is cloned and modified to use in the experiment, which has been the most popular game in WeChat. The game is chosen for several reasons: first of all, the gameplay is really simple, the player wouldn't need much time to understand the game concept, mechanism and construction. Which, on one hand, would be good for the experiment time control. One the other hand, the player would be forced to focus only on adapting the 3D touch controller.

Before the experiments, we did a pretest to see how beginners (people with no 3D touch experience) could react to the games. It is interesting to find that people would automatically start tapping during the game. Thus, we need more time for players to adapt the 3D touch controller. Secondly, the character will auto-shoot, which highlights the 3D touch controller. There will not be other operations to share or distract the experience of 3D touch controls. Thirdly, The gameplay is intense, and can easily attract the player's attention.

Basically, the player should use two fingers together to move the plane either right or left to eliminate the enemies as much as possible. The movement is determined by the difference of the input pressure from left and right finger. The absolute difference in left-right pressure is translated to the horizontal position of the character.Two different versions of the game are created to use in this experiment. A version with the non-diegetic UI elements which indicate how hard you can press on the screen and a version without, see Figure 8&9.

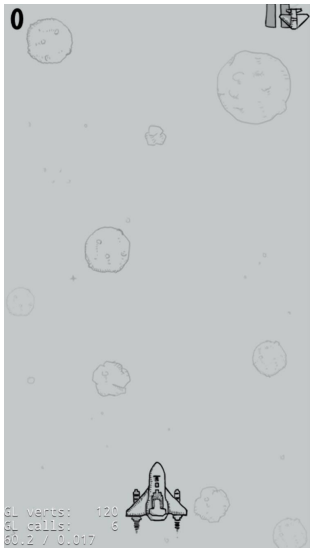

Fig. 8. Version without UI

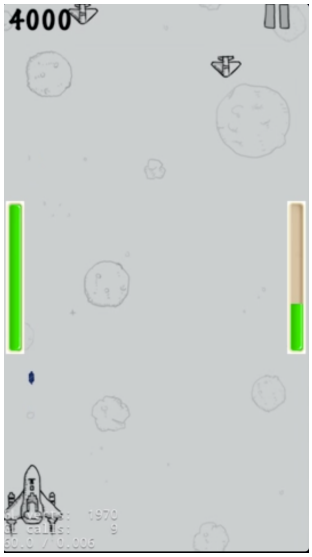

Fig. 9. Version with UI

2.3 Experiment design

In order to study the effects of existence of UI elements of the 3D touch controller on player experience. A within-subject design is used, which has the advantage of fewer participants needed compared to between-subject design. Also, the results would not influence by individual difference like personal skills. The experiment started with a demographic questionnaire collecting personal data. Questions are selected to acquire basic information like whether they are familiar with 3D touch or not (The full questionnaire is in the appendix). Then, a brief introduction to the procedure of the experiment was made. Participants could know that the research topic is about 3D touch. They would be aware that they need to test both of the two versions. And after each gameplay, they were asked to fill in the questionnaire related to the game just played. They were told to stop automatically if they failed the game or a timer (one and a half minutes) would be set for them to force them to stop. Before they officially started testing the game. A short demonstration would give them a basic knowledge of how to play the game. The whole experiment was carried in a private room which ensured silence.

2.4 The data collection

The player performance and player experience were both measured in this experiment. The game score was recorded to measure the control accuracy. This is the score that the players try to maximize when they are playing the game. This will enable to compare the overall performance. Differences in score, are an indication of the performance of the controller. And the immersion score measured by IEQ was also recorded to acquire subjective game experiences. To achieved this, Jannett etal's IEQ [32] has been selected and modified to fit this experiment. It is officially published and validated by a lot of previous studies. And it's been supported empirically by reasonable experiments. The IEQ consists of 32 questions and 9 more questions exclusively for 3D touch control experience. There are five essential factors of immersion: "cognition involvement", "emotional involvement", "real world dissociation", "challenge", and "control" [32]. They correlate with each other and develop the immersion together into a particular game experience. Further research can be done to break down the results into precise details.

III. RESULTS

This section shows the results and data analysis after collecting all the data from the experiment. This study is a with-in subject design, thus the samples are matched pairs. The paired t-test was chosen for statistical analysis. All the t-test are conducted with the JMP and IBM SPSS software. Because the game score is really a big number, thus there results keep the number as an int. The immersion value is rounded to one decimal places to make the distinction clearer. And, the t and p-value keep three decimal places.

3.1 Participants

A total of 35 participants completed the experiment. 17 of them played in sequence as follows: Game with UI elements - IEQ- Game without UI elements - IEQ. And another 18 of them played in sequence: Game without UI elements-IEQ-Game with UI elements - IEQ. The participants are randomly assigned to the two sequences. Participants are aged from 15 to 40 with 18 males and 17 females. 18 of them reported often play mobile games. 8 of them are familiar with 3D touch. While only 4 participants had experience of 3D touch games before.

3.2 Results of the A group

This section presents the results(Game score and immersion score) from the first 17 participants. Those 17 participants play the version with UI first.

A. Game score

Game scores are recorded after the participants finished the game. One with the UI elements and another one without. To test the hypothesis that the score is higher with UI than the score without UI, a paired t-test was performed. Table I shows the paired sample statistics. In the paired sample statistic graph, the mean and standard deviation for the game with UI elements is 144900(45929), and the mean and standard deviation for the without UI condition is 147300(47207). The number of participants in each condition(N) is 17.

The test revealed no statistically significant difference between the two conditions on the game score with the sig(2-tailed) value or p-value at 0.790.

Test A	Sequence	N	Mean	SD
With UI	1	17	149647	45929
Without UI	2	17	150941	47207

Table I.The mean and standard deviation results of game score

B. Immersion score

The immersion score is also recorded with the IEQ immediately after the participants played the game. The results of mean and standard deviation of the IEQ scores are shown in Table II.

The Mean values of the first 17 participants are—with UI condition(103.8) and without UI condition(106.5). The paired sample t-test results(t=1.580, p=0.131) indicate that the participants are not experienced statistically significantly higher level of immersion when under the condition without UI elements.

Test A	Sequence	N	Mean	SD
With UI	1	17	103.8	13.3
Without UI	2	17	106.5	14.5

Table II.The mean and standard deviation results of IEQ score

3.3 Results of the B group

This section presents the results(Game score and immersion score) from the B group of 18 participants. Those 18 participants played the version without UI first.

A. Game score

As can be seen in Table III, the game score under the with UI condition has the mean value of 141833, which appears much higher than the one under the without UI condition with the mean value of 104278. There is strong evidence (p=0.0006) that the existence of UI elements improves the control accuracy. With the mean difference of 37555 points.

Test B	Sequence	N	Mean	SD
With UI	2	18	141833	37420
Without UI	1	18	104278	28470

Table III: The mean and standard deviation results of game score

B. Immersion score

Also, IEQ scores were gathered after the test. The mean and standard deviation value are displayed in Table IV.

The results of the p-value at 0.051 revealed no statistically significant difference.

Test B	Sequence	N	Mean	SD
With UI	2	18	106.7	10.7
Without UI	1	18	102.2	10.8

Table IV:The mean and standard deviation results of IEQ score

3.3 Results combined all the participants

A. Game score

Finally, an additional analysis was made to combine all the samples from two groups (N=35). Table V presents the means and standard deviations of the game scores collected from both groups. Paired t-tests were conducted to figure out the significant difference between the two conditions. The statistic evidence(p=0.004) suggests that the participants made better controls when they were playing the game with the UI elements(mean=145629, SD=41334) than playing the game without UI elements(mean =126943, SD=44876).

B. Immersion score

The results of further analysis on the combination of IEQ scores from two groups are displayed in table VI. No significant difference(p=0.507) is observed in terms of under which condition they have a higher level of immersion.

Test All	N	Mean	SD
With UI	35	145629	41334
Without UI	35	126943	44876

Table V: The mean and standard deviation results of game score

Test All	N	Mean	SD
With UI	35	105.3	11.9
Without UI	35	104.3	12.7

Table VI: The mean and standard deviation results of IEQ score

3.4 Comments on the controller

Along with the IEQ, specific questions were asked about the personal experience with the 3D touch controller. 28 participants agreed that the UI elements do make a better understanding of the possible pressure they can reach. Only 7 of them reported that the UI elements would distract them when playing the game. 21 participants feel more confident of the controller with the UI elements. 20 participants disagree that the UI elements would decrease the level of immersion, while only 5 participants strongly favor the version without UI elements because then the screen looks clearer. Also, if we make a comparison with two groups. Significant differences can be observed. 12 participants out of 17 in group A reported being confident of 3D touch controller without UI, while only 5 out of 18 participants in group B claims they're confident with the controller. 4 out of 17 participants from group A disagree that without the UI would make them more focused, while 10 out of 18 participants from B group disagree the version without UI would make them more focused. Another big difference is, only 4 out of 17 participants in A group agree they feel lost without the UI, and there are 12 out of 18 participants in group B agree with this.

IV. DISCUSSION

4.1 Effects of UI elements on control accuracy

While we expect that the version with UI would bring higher control accuracy. The results of the A group shown in the previous section displayed that statistically there is not much difference. However, from the results of the B group, it can be observed that when player play the version without UI first, the control accuracy is significantly increased with the existence of UI elements. For the A group, this might be caused by the fundamental disadvantage of the with-in subject design, which is called "carryover effects" [34]. Basically, it means the participation in the with UI condition can influence the performance of the subsequence which is the without UI condition. In this study, it is fairly understandable. Because it's a simple and intuitive game, and the participants first played the version with UI will learn and adapt the pressure range from the real-time UI changes. This short-term memory will drive and guide the finger to press in the condition without UI. However, when the sequence changes, most of the participants of the B group cannot fully interpret the 3D touch controller without the UI elements. The advantage of the visual pressure display appears when they played the version with UI elements.

Therefore, the control accuracy is much higher with the existence of UI elements. Moreover, it can be observed that the participants who test the game with UI first adapt the controller faster than the participants who test the game without UI first. Thus, starting the game with UI first could make the participants learn 3D touch controls quickly and help to increase the control accuracy when removing the UI elements.

In conclusion, the overall results indicate that the UI elements are quite important for beginners to learn and adapt the 3D touch controller. The influence of the UI elements is significant that some participants who play the game with UI first even get higher scores when they played the version without UI later. They were becoming more skilled during the experiment.

4.2 Effects of the UI elements on level of immersion

While there is no difference between the two conditions in all the three statistic analysis of immersion score, removing the UI elements did not increase the level of immersion. On the contrary, from the whole view, the mean value showed that the immersion score recorded with UI is slightly higher than immersion score recorded without UI. This could be because without the UI elements the participants kept blind of the pressure range, and this reduces the dexterity of the controller because they need more time to explore the correlation of the character movement and the pressure during testing. Therefore, it sacrifices the level of immersion. Instead, UI elements help to understand the controller far better and conversely make the game more immersive to the players. It is noteworthy that the mean values of group A showed that the participants seem to have higher immersion scores without UI. The reason could be the fact that they adapted the controller first with UI, and later they might be more focused on the shooting and upcoming enemies instead of the UI elements.

Additionally, the change of UI itself could be described as homogeneous, it is not a big variation considering the influence of the carryover effects. In the A group, some participants particularly mentioned that they feel no difference between the two versions after the gameplay. The simplicity and the intuition of the game mechanism might also be the reason.

The highlight of the 3D touch controller makes it the only thing they need to concern and there is no complex game story or conversations between the game world and the character.

Although there are still five participants strongly prefer the version without UI elements. One claimed that the screen look much clearer and it can be easily observed that the controller became awkward to use when she switched to the version with UI elements. And another reason is that they often play shooter games. Thus, they thought the version without UI is much immersive than the version with UI. Also, one participant commented that the game was too familiar to him, thus, he didn't need the UI elements.

4.3 Implications for game design

Suggestions can be made for the developers and designers based on the results of this research. First of all, it is proved that the UI elements play an important role in learning and mastering the 3D touch controller for beginners, especially users who never played 3D touch games before. Thus, the UI elements can be used to make the controller more adaptive and intuitive.

Moreover, the results imply that the presence of UI elements might not sacrifice the level of immersion. Largely because how well the user masters the controller can directly influence the player experience. They might have a bad first impression and give up playing if the controller is not intuitive to master.

However, according to the comments of the A group. The UI elements could be removed when they were familiar with the controller. Or even better, UI elements can be turned on and off depend on individual demand.

Another possible solution is to use the diegetic UI elements cue. For simple 2D games, the hints for pressure range can be quite clear. For example, the structure of the game world like barriers, shape of the map, and moreover the frame of the device. For 3D games, the factors mentioned above can also be helpful.

4.4 Conclusion and future work

The study shows that the presence of the UI elements of the 3D touch controller could possibly influence the game experience and player performance. There are some limitations. The control mechanism is specifically designed for this game used in the experiment. The correlation of the controller and character movement could not be a perfect mapping. Few participants were observed to be prone to release one finger or tap during the gameplay. This could require further research of what is the most natural interaction design to use 3D touch in the game. Additionally, the study is limited to consideration of action games. These kind of games are normally easy to play and can hold the player's attention even in a very short duration. Thus, the level of immersion in different conditions could both be high but the difference is small. It could strongly depend on the game mechanism and designs.

Also, the experiment can be designed more precisely, Like collecting not only the game score but also the shooting mistake or percentage of shooting different types of enemies etc. And, a real-world task can be added before and after the game to further test the immersion.

Future work can be done to further check the other possible game genre. And what's more, the research of discrete usage of 3D touch could also be potential. Other factors like vibrations which should also be a good hint for 3D touch controller. Also, in the future research, the experiments could include more complex tasks and make the gameplay longer. Then, the difference could be more obvious.

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VI. APPENDIX

Immersion Questionnaire used in Experiment

Your Personal Experience of the Game

Please rate how far you would agree with the statements below just before you were interrupted.

1. To what extent did the game hold your attention?
   Not at all 1 2 3 4 5 Very much so
2. To what extent did you feel you were focused on the game?
   Not at all 1 2 3 4 5 Very much so
3. How much effort did you put into playing the game?
   Not at all 1 2 3 4 5 Very much so
4. Did you feel that you were trying you best?
   Not at all 1 2 3 4 5 Very much so
5. To what extent did you lose track of time?
   Not at all 1 2 3 4 5 Very much so
6. To what extent did you feel consciously aware of being in the real world whilst playing?
   Not at all 1 2 3 4 5 Very much so
7. To what extent did you forget about your everyday concerns?
   Not at all 1 2 3 4 5 Very much so
8. To what extent were you aware of yourself in your surroundings?
   Not at all 1 2 3 4 5 Very aware
9. To what extent did you notice events taking place around
   Not at all 1 2 3 4 5 Very much so
10. Did you feel the urge at any point to stop playing and see what was happening around you?
    Not at all 1 2 3 4 5 Very much so
11. To what extent did you feel that you were interacting with the game environment?
    Not at all 1 2 3 4 5 Very much so
12. To what extent did you feel as though you were separated from your real-world environment?
    Not at all 1 2 3 4 5 Very much so
13. To what extent did you feel that the game was something you were experiencing, rather than something you were just doing?
    Not at all 1 2 3 4 5 Very much so
14. To what extent was your sense of being in the game environment stronger than your sense of being in the real world?
    Not at all 1 2 3 4 5 Very much so
15. At any point did you find yourself become so involved that you were unaware you were even using controls?
    Not at all 1 2 3 4 5 Very much so
16. To what extent did you feel as though you were moving through the game according to you own will?
    Not at all 1 2 3 4 5 Very much so
17. To what extent did you find the game challenging?
    Not at all 1 2 3 4 5 Very difficult
18. Were there any times during the game in which you just wanted to give up?
    Not at all 1 2 3 4 5 A lot
19. To what extent did you feel motivated while playing?
    Not at all 1 2 3 4 5 A lot
20. To what extent did you find the game easy?
    Not at all 1 2 3 4 5 Very much so
21. To what extent did you feel like you were making progress towards the end of the game?
    Not at all 1 2 3 4 5 A lot
22. How well do you think you performed in the game?
    Very poor 1 2 3 4 5 Very well
23. To what extent did you feel emotionally attached to the game?
    Not at all 1 2 3 4 5 A lot
24. To what extent were you interested in seeing how the game's events would progress?
    Not at all 1 2 3 4 5 A lot
25. How much did you want to ''win'' the game?
    Not at all 1 2 3 4 5 Very much so
26. Were you in suspense about whether or not you would win or lose the game?
    Not at all 1 2 3 4 5 A lot
27. At any point did you find yourself become so involved that you wanted to speak to the game directly?
    Not at all 1 2 3 4 5 Very much so
28. To what extent did you enjoy the graphics and the imagery?
    Not at all 1 2 3 4 5 A lot
29. How much would you say you enjoyed playing the game?
    Not at all 1 2 3 4 5 A lot
30. When interrupted, were you disappointed that the game was over?
    Not at all 1 2 3 4 5 Very much so
31. Would you like to play the game again?
    Definite not 1 2 3 4 5 Definite yes
32. How immersed did you feel?
    1 2 3 4 5 6 7 8 9 10

Extra Questionnaire used in Experiment for 3D touch controller (The rating use a Likert scaling as SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree.)

With UI

33. I feel distraction with the visual elements.
34. I feel more confident of the control with the UI elements
35. I feel the visual elements really decreased the level of immersion
36. I don't feel like I need the UI indicator of 3D touch control
37. I feel that the visual elements helpful to raise the control accuracy

Without UI

38. I feel confident of 3D touch without the UI elements
39. I feel more focused with the controls without the visual elements

40. I feel that without visual elements helpful to raise the control accuracy
41. I feel lost sometimes with the controls without the visual elements