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以介面投入時間評估不同遊戲平台之遊戲表現

林大偉

摘要

本研究關心遊戲玩家面對同一款遊戲在不同遊戲平台採用不同遊戲介面的遊戲表現。32 位受測者根據觸控螢幕、鍵盤和手把 3 種遊戲介面的年度累計投入時間（簡稱介面投入時間）來進行分群，共同參與由被視爲自變數的 4 種遊戲介面搭配被視爲實驗任務的 6 款平台遊戲的實驗任務，其遊戲得分被視爲依變數。結果顯示：(a) 整體來看，介面投入時間的多寡顯著影響遊戲表現；(b) 單一介面投入時間越多，則受測者使用該介面之遊戲表現越好；(c) 單一介面投入時間越多，受測者不一定越容易適應其他三種遊戲介面，但鍵盤除外；(d) 重度遊戲者也往往熟悉各式遊戲介面而具備跨遊戲平台的特質。據此，本研究建議，介面投入時間可以被視爲遊戲表現的重要受測者分群基礎。

⊙ 關鍵字：介面投入時間、玩家經驗、遊戲介面、遊戲表現
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An Analysis of Gaming Performance on Different Game Platforms Utilizing Interface Engaging Time

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Abstract

This study focuses on the gaming performances of gamers playing the same game using differing gaming interfaces. 32 subjects were grouped according to their annual accumulated time spent (*interface engaging time* for short) on three-game interfaces: touch-screen, keyboard, and gamepad. The subjects participated in research involving four types of game interfaces viewed as independent variables. Results show: (a) Interface engaging time has a significant influence on gaming performance. (b) The longer the engaging time on a certain interface, the better the gaming performance on said interface. (c) Except for the keyboard, a longer engaging time does not necessarily lead to easier adaptation to other interfaces. (d) Heavy gamers are familiar with all gaming interfaces and have the potential to play across interfaces. In view of the above, this study suggests that interface engaging time can be considered as a prominent method of subject categorization for research on gaming performance.

⊙ Keywords: gamer experience, gaming interface, gaming performance, interface engaging time

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Introduction

From the 1970s, people have witnessed an astonishing eight game generations over a short period of 50 years (Beck & Wade, 2004). With the ongoing evolution of electronic games, computer game developers should strive to increase the believability of game characters and game environment to increase gamer engagement (Bianchi-Berthouze, Kim, & Patel, 2007). To achieve this goal, creating more suitable game interfaces should be taken under consideration. However, the researches of interaction between games and gamers have been undergoing relatively slow development in the realm of Human-Computer Interaction (HCI). It was not until recent years as technology advanced and created increasingly complicated game controllers, that the importance of game controllers was gradually seen (Brown, Kehoe, Kirakowski, & Pitt, 2015; Gilleade & Allanson, 2003). However, most researches focus either on the casual gamer's subjective experience (Birk & Mandrk, 2013; Gerling, Klauser, & Niesenhaus, 2011; Mueller & Bianchi-Berthouze, 2015) or objective information (Mueller & Bianchi-Berthouze, 2015; Nacke, 2010; Purkayastha, Eckenstein, Byrne, & O'Malley, 2010) on different game interfaces. In contrast, research focusing on gamer characteristics and exploring the adaptability of gamers of differing levels on different game interfaces are few and far between (Bernhaupt, 2015).

The astounding retail number of iPads (including the iPhone, hereto referred to as "the iPad platform") has motivated many classic games that were popular on console and PC platforms to try to port to the iPad platform; however, the main obstacle these classic games face is the colossal challenge of rewriting the code, and the appropriateness of interface transformation. Crenshaw, Orzech, Wong, and Holloway (2011a) and Crenshaw, Holloway, Orzech, and Wong (2011b) believes the main concerns of interface transformation to be as follows: (1) How to simplify the complex controls used on the PC or console platform to fit the iPad platform; and (2) How to integrate the original controls onto a new interface that uses the same source for output and input (e.g., fingers will cover where the target needs to be moved to). The first matter of concern is often addressed by redesigning the Graphic

User Interface (GUI), whereas the second issue remains a daunting dilemma. The reason behind this dilemma is because veteran players who are accustomed to a specific input interface will often be disappointed when using a slippery touch screen that just doesn't feel right. According above, a lack of research exploring whether or not gaming performance is affected when older generation gamers accustomed to complex controls play classic platform games transferred to new platforms with simplified game interfaces designed for new generation gamers, which is the main issue of concern in this study.

Background

Gaming Interface Revolution and Gamer Adaptability

Control systems are a crucial part of a majority of games (Johnson & Wiles, 2003). At the same time, with the ongoing development of electronic games, gamers are pursuing smoother gameplay, and increasing sophisticated visual effects. Therefore, most game developers are oriented towards providing better performing CPUs and graphic cards (Claypool, 2009). Due to these circumstances, besides designing game interfaces for games with specific needs (e.g., force feedback steering wheels), most game interface designs hinge on standard game controllers with similar control methods (e.g., joysticks and buttons for arcade machines, the D-pad and buttons on console controllers, and keyboards and mouses for PCs.) (Brown et al., 2015). The concept of standardized controllers is beneficial to both game designers and gamers, because a unified game interface will greatly lower problems of adaptability which may occur when alternating between game platforms.

Most game designers were willing to predominately follow the ground rules set by these game platforms (Rabin, 2010), until the emergence of the Wii, Kinect, and the iPad. These devices broke the long established understanding between game designers and game platforms. The Wii was the first to renounce the pursuit for game speed and image quality, and announce the concept of body movement (Bianchi-Berthouze et al., 2007). Kinect announced the disappearance of an input interface, but gamers must still play within a certain area (Nacke, 2010). The iPad (and iPhone) combines input and output interfaces. They are ubiquitous, and show potential for unprecedented affordance (Melhuish & Falloon, 2010). Especially, the advantage of formless input interfaces such as the Kinect and iPad is that gamers will not need to put on or carry any input interface. However, the price they will have to pay is the need to adapt to the changes brought on by an entirely different gaming interface. In light of the current trend of this particular interface, this study aims to understand the problems new and veteran players face when playing games ported to a new interface, along with their causes.

Evaluating Game Performance through Game Interface

Past researches on electronic games mostly approached user experience from aspects such as game content, graphics, interactivity, and game plot. Rarely is user experience explored from the perspective of a specific input modality (Bodén, Jegers, Lidstrom, Wiberg, & Wiberg, 2007). Now with an increasing number of multiple platform games, game designers face two new challenges worthy of attention: integrating the different interaction paradigms of console gamers and PC gamers while maintaining the core mechanics, and understanding the suitability of game interfaces from gamer experience and gaming performance (Gerling et al., 2011). In general, the method of studying gamer experience can be divided into two stages: (1) Post-playing evaluation (e.g., Interviews or questionnaires). (2) In-playing evaluation (e.g., Quantitative analysis of behavior, or physiological measurement) (Mueller & Bianchi-Berthouze, 2015). Among these methods, questionnaires are the most commonly used. Questionnaires often utilize existing game-related theories, including flow (Novak, Hoffman, & Yung, 2000), immersion (Brown & Cairns, 2004), affective ludology (Nacke & Lindley, 2009), and heuristic evaluation (Pinelle, Wong, & Stach, 2008). Brockmyer et al. (2009) even designed a questionnaire specifically for surveying gamer experience known as the GEnQ (Game Engagement Questionnaire)(Fox & Brockmyer, 2013). However, questionnaire surveys are considered an explicit measure of investigation. No matter if the questionnaire is issued during or after participants play the game, the results of the survey will often be drastically influenced by objective cognitive differences, which will in turn seriously impact the results of this research. In comparison, gaming performance generated from subjective data can effectively rule out interfering variables such as cognitive difference, even through there will be differences in the players' skills. Therefore, this study will utilize the implicit measure of analyzing gaming performance as its method of research.

Gaming performance is another important factor in evaluating game interface (Gerling et al., 2011). Most game input devices lean towards being pointed devices. In cases where experimental conditions can be adequately controlled by the researcher, a common research strategy would be to use Fitts' Law along with the ISO 9241-9 experimental paradigm to evaluate different non-keyboard input devices (MacKenzie & Teather, 2012; Zaranek, Ramoul, Yu, Yao, & Teather, 2014). The main dependent variable being observed would be the throughput calculated from the index of difficulty and movement time (Pinelle et al., 2008). In practice, Fitts' Law has long since been used in the field of HCI (Fitt, 1954; Soukoreff & MacKenzie, 2004), and is an iconic method utilizing experimental tasks combining target width and movement distance, and is often used to observe the usability of input devices. For example, Klochek and MacKenzie (2006) used five indicators gained through extending the throughput, and found that the acceleration rate of mouse outperform that of gamepad in First Person Shooter (FPS) games. Research done by Natapov and MacKenzie (2010b) use the throughput to prove how the prototype of a trackball gamepad outperformed the standard gamepad.

However, Fitt's Law is not applicable to all studies on game interface evaluation. A popular alternative for recording gaming performance is done by utilizing the by-products of gamer-game interaction, and quantitative data that can be recording during the course of the game. For example, studies done by Natapov and MacKenzie (2010a) view target hits as gaming performance in FPS games, and have found the performance of keyboard-mouse combinations to be better than standard gamepads. Natapov and MacKenzie (2010a) also observed game performance in another FPS game using completion time, in this study, the keyboard-mouse combination again surpassed standard gamepads. A study of Zaman, Natapov, and Teather (2010) used both completion time and character death to evaluate the gaming performance in Action-adventure games (A-AVG), and found that physical buttons on the NDS outperformed virtual buttons on the iPhone. Bodén et al. (2007) observed the scores of mobile games, and discovered how gamers using buttons would score higher than gamers using the stylus. The research results mentioned above seem to imply two trends: (1) Complex controllers are superior to simple controllers, and (2) Physical interface is better than virtual interface. But is this really the case? A study by Gerling et al. (2011) showcases comparative experiences: 45 subjects felt challenged when facing a new game platform, and are more comfortable playing on familiar game platforms. Therefore, gaming experience should be considered as another variable when evaluating game interface.

Basis of Gamer Grouping

To understand how gamers adapt to different gaming interfaces, gamers are primarily grouped based on their levels. In game-related studies, gamer experience is usually employed as the basis of subject grouping (Hoysniemi, 2006; Lopes & Bidarra, 2001); for example: expert, good, so-so, and beginner. This method is used to observe the opinions and performance of different level gamers within the same circumstances (Sun, Lin, & Ho, 2003). But this method often provides results overly reliant on the subjective perception of subjects. For example, beginners do not necessarily perform so-so. Another grouping method leaning towards quantification is to group subjects based on gaming seniority. This method is based on the accumulated time the subject started to gaming (Wu, Wang, & Tsai, 2010). But it has difficulty accurately assessing game spent time, and frequency is another independent variable that should be accounted for. Therefore, these two methods of grouping are either overly general or too subjective to be viewed as reliable, thus unable to clearly illustrate the distinguishing characteristics of the grouped subjects.

For this reason, a grouping basis that could further illustrate the characteristics of the grouped subjects was considered. One approach was to refine the method of grouping subjects based on spent time. For example: Asking subjects about their time distribution of everyday activities that included gaming (Anand, 2007), and the amount of time they spent on gaming during the weekdays and the weekend (Skoric, Teo, & Neo, 2009). Another approach is to evaluate subject characteristics through game grading, which is often employed to explore subject exposure to violent games. The usual procedure is to ask subjects to choose three most commonly played games, and then grade the games by their violence rating (Ferguson, Colwell, Mlacic, Milas, & Miklousic, 2011; Jackson, von Eye, Fitzgerald, Witt, & Zhao, 2011). However, Gauntlett (2005) considers this method to pose certain difficulties and flaws. On one hand, *most commonly played* is based solely on the subjects' judgment; there are no means for comparison with other subjects. On the other hand, the limitation on the number of games will make it difficult to expose the diversity of games the subjects have played.

In light of this situation, Ventura, Shute, and Kim (2012) defined gamers' style of video gameplay based on spent time and number of played games. As shown in Table 1, there are three categories: (1) habitual players: based on how many hours the subject plays games per week, (2) selective players: based on the accumulative time the gamer spent playing his or her favorite game, and (3) diverse players: based on the number of different games played in a year. Data about spent time inferred from *habitual players* and data regarding number of played games known from *diverse players* can be respectively used to illustrate the depth and breadth of gaming experience. However, it cannot showcase the time spent on a certain game. While *selective players* can make up for this shortcoming, it is limited to demonstrating the total time gamers have spent on their favorite game. On the other hand, in related studies focusing on game interface, the subjects' gaming experience will often be perceived as supplementary information for analyzing research results. There will only be vague descriptions of how many (Zaman & Mackenzie, 2013) or how often (Nacke & Lindley, 2009) subjects play on specific gaming platforms, and the subjects' level (Zaman, et al., 2010). Only a small number of studies view gaming experience as the basis for subject grouping to further understand the difference between gamers (Natapov & Mackenzie, 2010a, 2010b). Therefore, according to the three methods of subject grouping proposed by

Ventura et al. (2012), the difference between experience on various game interfaces can be illustrated as the concept of *habitual players*, then the total time gamers have spent on a specific interface can be seen as *interface engaging time* (which is discussed in the Subject and Grouping subsection), and may be used to further understand how game interface adaptability is influenced by the gamers' experience on different platforms.

Table 1
Three Styles of Video Gameplay According to Cumulative Hours of Play and Number of Games Played

Style of video gamepla	Cluster base	Low	Moderate	High
Habitual players	Average hours per week	0~1 hr.	2~6 hrs.	Above 7 hrs.
Selective players	Total hours on favorite games	1~10 hrs.	11~50 hrs.	51 hrs.
Diverse players	Number of games per year	0~3 games	4~6 games	Above 7 hrs.

Note. The data were from Ventura et al. (2012), arranged by this study.

Methods

This quasi-experimental research measured the gaming performances of gamers playing the same game using four-gaming interfaces: touch-screen, joystick, keyboard, and gamepad. The gaming performances were compared by gamer experience based on their annual accumulated time spent on three-game interfaces: touch-screen, keyboard, and gamepad.

Independent Variable, Dependent Variable, and Hypothesis

This study draws on the *style of video gameplay* proposed by Ventura et al. (2012), which cross multiplies the subjects' average time spent on gaming per week with the percentage of number of games played on different game platforms to determine *interface engaging time* (see the Subject and Grouping subsection for details). After organization, subjects were then groups into three types: keyboard, gamepad, and touch-screen, also viewed as gaming experience. According to the varying degrees of experience, subjects in the gamepad group were divided according to their engagement levels as *no-engaging* and *low-engaging*. In the keyboard group and touch-screen group, there are two additional levels *moderate-engaging* and *high-engaging*. The four gaming interfaces observed in this study are: touch-screen, joystick, gamepad and keyboard. The four interfaces are viewed as the four levels of the independent variable, as can be seen in Figure 1.

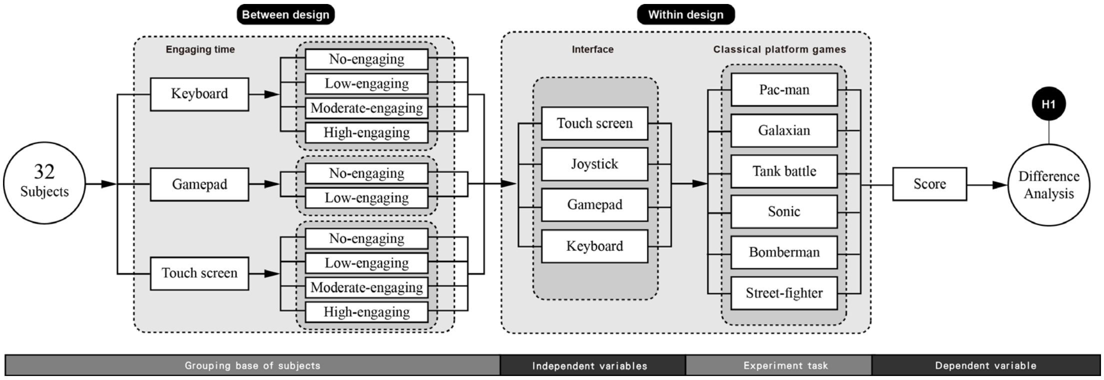

Figure 1. The independent variable, dependent variable, and hypotheses of this study.

To observe the subjects' gaming performance on the four interfaces, six classic games from the platform game period were utilized: Pac-man, Galaxian, Tank Battle, Sonic, Bomberman and Street-fighter. However, the scoring and control methods of the six games are entirely different, resulting in a lack of an objective basis for comparison between games. Therefore, the six games can only be viewed as experimental tasks, and not variables. To effectively observe the subjects' gaming performance, each subject must begin from the easiest level of every game, and play until *resources* such as health power, lives, and the time limit have run out, thus ending the game. The *Score* was viewed as the dependent variable. According to the above statement, the *interface engaging time* subjects spend on specific game interfaces on different game platforms are seen as the main basis for subject grouping. This between-subject design is used to observe whether or not there is significant difference between the gaming performance of subjects in different groups. Moreover, subjects from each group must undergo a series of experiments employing all four interfaces and six games, which can be labeled as a within-subject design. To avoid the sequence effect, the orders of the 24 tasks are presented using the Latin square to avoid repetition. To avoid order effects, the 24 tests were split into two categories: interface (4 types) and game (6 titles). The tests were then organized in a Latin Square Design before being distributed to participants.

Participants were given 10-minute breaks or “intervals” when switching between the 4 interfaces to prevent fatigue. Each subject is also given a 30 second adaptation time in the beginning of each task before the task is re-started, and officially recorded. The research methods mentioned above are centered around the three topics of research explored in the literature mentioned above: gamer adaptability, game performance, and gamer grouping. This study focuses on gamer adaptability to gaming interfaces. Gamers will be classified based on interface engagement time, and gamer performance will be observed through gaming performance in lieu of a subjective questionnaire survey. The purpose of the study is to analyze how gamers of different skill levels adapt to different gaming interfaces. This study proposes one hypothesis:

H1: Interface engaging time significantly affects the scores obtained from the same game on different interfaces.

Subject and Grouping

This study employs 32 subjects between the ages 20 to 22. To understand the subjects’ gaming experience, this study draws on the grouping basis proposed by Ventura et al. (2012) to explore the total time spent on a specific game interface per year, which is the interface engaging time, similar to selective players in Ventura et al. (2012). Accordingly, the subjects were asked to answer three questions related to game interface before the experiment: (1) The average hours spent on gaming each week, (2) The number of games played each year, (3) The number of game platforms corresponding to the games played every year. The answers to the three questions were then cross-multiplied. The results are as shown in Table 2. In total, there are five game platforms, PC, Xbox, the Wii, the iPad, and the iPhone. From the perspective of game interfaces, the results can be further divided as three groups: keyboard, gamepad, and touch-screen.

Table 2

Summary of All 32 Subjects' Annual Interface Engaging Time Based on Cumulative Hours, Games and Platforms

Platforms	PC	Xbox	Wii	iPad	iPhone
Cumulative subjects	22	2	6	6	23
Annual cumulative hours	3681.17 (33.31%)	101.38 (0.92%)	643.96 (5.83%)	466.30 (4.22%)	6156.74 (55.72%)
Grouping base	Keyboard (33.31%)	Gamepad (6.75%)		Touch-screen (59.94%)	

According to Table 2, from both the perspective of *Cumulative subjects* and *Annual cumulative hours*, the 32 subjects were engaged in the touch-screen the longest (6623.04 hrs.), followed by the keyboard (3681.17 hrs.). Subjects spent the least time playing on the gamepad (745.35 hrs.). With the data obtained in Table 2, Cluster Analysis was done on the touch-screen, keyboard and gamepad. Subject grouping was based on the coefficient of variation after integration, and observing icicle diagrams. The results are as shown in Table 3. It is worth pointing out that in all three gaming interface groups, there are subjects who have never played on the specific interface before, which are viewed as the *no-engaging* subgroup. The subjects in the touch-screen and keyboard group have a longer accumulated interface engaging time, and can thus be clearly divided into four subgroups. The situation with the gamepad is more particular; the group has a shorter accumulated interface engaging time due to a smaller number of subjects who have played on the interface. The cumulative number of subjects is also relatively less, thus it is only divided into two subgroups.

Table 3

Grouping Base of he Subjects' Annual Interface Engaging Time on Three Gaming Interfaces and Corresponding Number of All 32 Subjects

Grouping base	Non-engaging	Low-engaging	Moderate-engaging	High-engaging
Touch-screen	6 (0 hr.)	11 (17.33~93.6 hrs.)	11 (104~364 hrs.)	4 (650~1872 hrs.)
Keyboard	10 (0 hr.)	11 (17.33~78 hrs.)	7 (104~260 hrs.)	4 (416~650 hrs.)
Diverse players	25 (0 hr.)	7 (3.71~280 hrs)	-	-

Stimulation

After comparing the game performance of the 32 subjects on the four game interfaces, six games that have been released during the arcade period were chosen as research stimuli. The six games are: Pac-man, Galaxian, Tank Battle, Sonic, Bomberman, and Street Fighter. Release information and features of the games are as seen in Table 4. The six games have completely different scoring and control methods, and lacks an objective basis for comparison, thus the games are viewed as only experimental tasks, and not as variables. The six games were selected with three principles in mind: platform games, uniformity of hardware, and uniformity of controlled conditions. First, because the research objective of this study is in relation to the possible issues with controls that may occur when platform games are adapted to the iPad, games must first meet the criteria of being a platform game. Secondly, considering the hardware limitations of playing six games on the iPad, relatively simple and easily observable platform games were primarily chosen. Finally, for the consistency of the controlled conditions, the app Blutrol was used to connect the various game interfaces to the iPad, and used to minimize lag during the process of gameplay.

Table 4

Summary of Six Games' Release Information and Prominent Features

Game	First release	Genre	Default platform	Default interface	Scoring Approach	Gameplay goals
Pac-man	1980	Maze	Arcade	Joystick	eaten dots	Gamers control Pac-man to eat all the dots in a maze without being caught by the ghosts.
Galaxian	1979	Shooter	Arcade	Joystick	destroyed aliens	Gamers control the ship to move left and right, and fire bullets at alien invaders attacking from above.
Tank Battle	1980	Shooter, Maze	Arcade	Joystick	destroyed enemies	Gamers control the tank and shoot ammunition to eliminate all enemy controlled tanks and to protect the home base.
Sonic	1991	Racing, Sports	Console	Gamepad	collected rings	Gamers control Sonic to reach the goal in minimal time, collect rings along the way, and fight the Boss at the goal.

Bomberman	1983	Action, Maze	Console	Gamepad	destroyed enemies	Gamers control Bomberman to place bombs that explode in four directions in mazes to blow up obstacles or to eliminate the enemy.
Street-fighter	1987	Fighting	Arcade	Joystick	beat rivals	Two characters engage in a two out of three battle with a time limit, and try to lower the opponent's HP to zero.

Note. The data were from Wolf (2008), arranged by this study.

Equipment

As shown in Figure 6, four types of equipment were used in this study: (a) The 4th generation Apple iPad 32GB with Retina Display and Wi-Fi, 2048x1536 pixel screen resolution, and iOS7.1. 2 operating system. The black model was chosen to reduce light reflection. The purpose is to allow subjects to concentrate on the screen without being distracted. (b) The wireless joystick iCade Core from ON Audio. (c) The wireless gamepad PS3 Dual Shock 3 from Sony. (d) A wireless keyboard from Apple. All four types of equipment are wireless, and connect through Bluetooth. The app Blutrol was installed in the iPad to ensure all four experiment equipment will be able to connect to the interfaces required to play the six games. What's worth mentioning is, the wireless PS3 gamepad offers two choices for direction control: analog sticks and a D-pad. The analog sticks on both the left and right side were purposely turned off to keep the subjects focused on the D-pad, and lower chances of data contamination caused by confusion between the PS3 gamepad and the

Figure 2. Experiment equipment: (a) touch-screen, (b) wireless joystick, (c) wireless gamepad (d) wireless keyboard.

Environment

This study was conducted in a darkroom devoid of light; the only source of light came from the screen. The purpose is also to allow subjects to concentrate on the screen without being distracted. For the sake of understanding the gaming experience of subjects using direction controls on different gaming interfaces, the environment of this study should logically emulate the four gaming interfaces perceived as independent variable on the arcade machine, console platform, PC platform and iPad platform. However, this study is limited by two current situations: (1) The same game may not simultaneously be available for the four game platforms. Even if they do exist, the versions of the games may be different. This might lead to independent variable not controlled under the same experimental conditions, and produce many uncontrollable confounded variables. (2) The hardware of different game platforms may be designed depending on various requirements, especially the CPU and graphics card, therefore creating a huge gap between computing capacity and display performance. There is also the chance of producing confounded variables that are difficult to control. Therefore, in order to effectively control variables, and ensure the experimental conditions are constructed under the same basis, this study utilizes the iPad as the main experimental equipment. The three gaming interfaces shown in Figure 2, wireless joystick, wireless gamepad, and wireless keyboard, were connected to the iPad through Bluetooth, as shown in Figure 3.

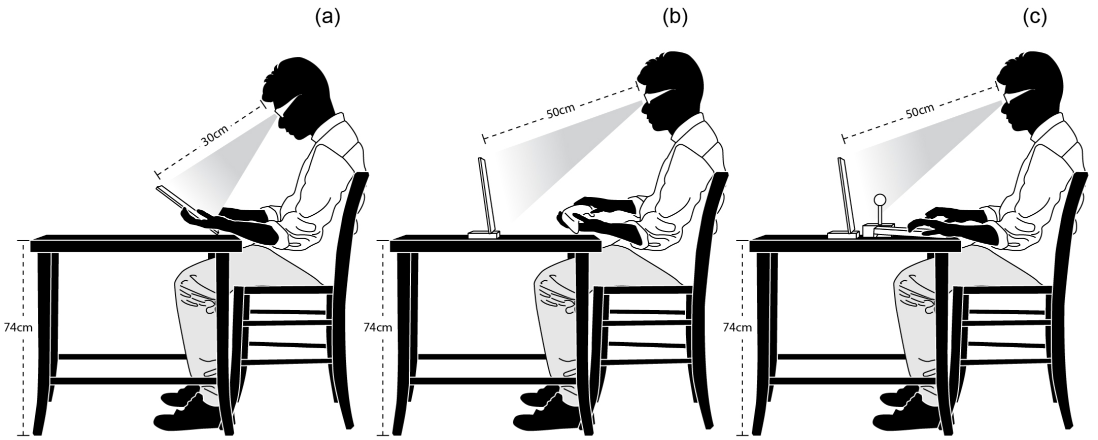

Figure 3. The three experiment environments constructed by connecting the joystick, gamepad, and keyboard to the iPad platform.

To faithfully illustrate the habitual usage of the four gaming interfaces, and to maintain the principle of consistent experimental conditions, subjects were asked to view the iPad as an output device. The iPad was placed on a table using an iPad stand in all three conditions (as shown in Figure 3b and Figure 3c) except for the touch-screen condition, during which subjects were allowed to hold the iPad. At the same time, the observation distance between the subjects' eyes and the screen were strictly regulated, but not forcefully fixated, as to ensure the subjects' pleasant mood and freedom during the gaming process. As can be seen in Figure 3a, the subjects were merely asked to place both hands holding the iPad evenly on the table, and view the screen from a distance of 30cm. Using Figure 3b and Figure 3c as further examples, all subjects were able to maintain a viewing distance of 50cm when the iPad was secured on the table. Viewing angle of game screen varied depending on the type of games. The angle was controlled at 30^{o} if the game was to be played on a vertical display, and 35^{o} if the game was to be played on a horizontal display.

Data Analysis

The gaming performance of subjects is presented through *Score*. Because the games chosen in this study all possess different scoring models and standards, the difference analysis between games are unable to be conducted based on the raw scores. Assessment could only be made on the difference between the scores obtained by subjects playing the same game on different interfaces.

Results

Differing Gaming Performance Caused by Difference of Interface

From the perspective of difference between game interfaces affecting gaming performance, The gaming performances of all 32 subjects (without grouping) on the four different interfaces were analyzed using the Analysis of Variance (ANOVA) as shown in Figure 4. Significant difference can be seen between four out of the six games: Pac-man (F (3, 93) = 4.764, p = 0.004), Tank Battle (F (3, 93) = 4.134, p = 0.008), Sonic (F (3, 93) = 2.893, p = 0.039), and Bomberman (F (3, 93) = 11.911, p = 0.000). The results display how different gaming interfaces do in fact significantly affect the subjects' gaming performance, which partially supports the hypothesis purposed in this study. Further Least Significant Difference (LSD) post-hoc analysis showed numerous interesting situations: (1) Gaming performance on Pac-man was significantly worse on the joystick than the other three interfaces, as shown in Figure 4a. (2) Gaming performance on Tank Battle was significantly better on the keyboard than the three other interfaces, as shown in Figure 4c. (3) Gaming performance on Sonic was significantly worse on the touch-screen than on the joystick and keyboard, while gaming performance on the gamepad was significantly better than both touch-screen and joystick, as shown in Figure 4d. (4) Gaming performance on Bomberman was significantly worse on the touch-screen than the three other interfaces, as shown in Figure 4e.

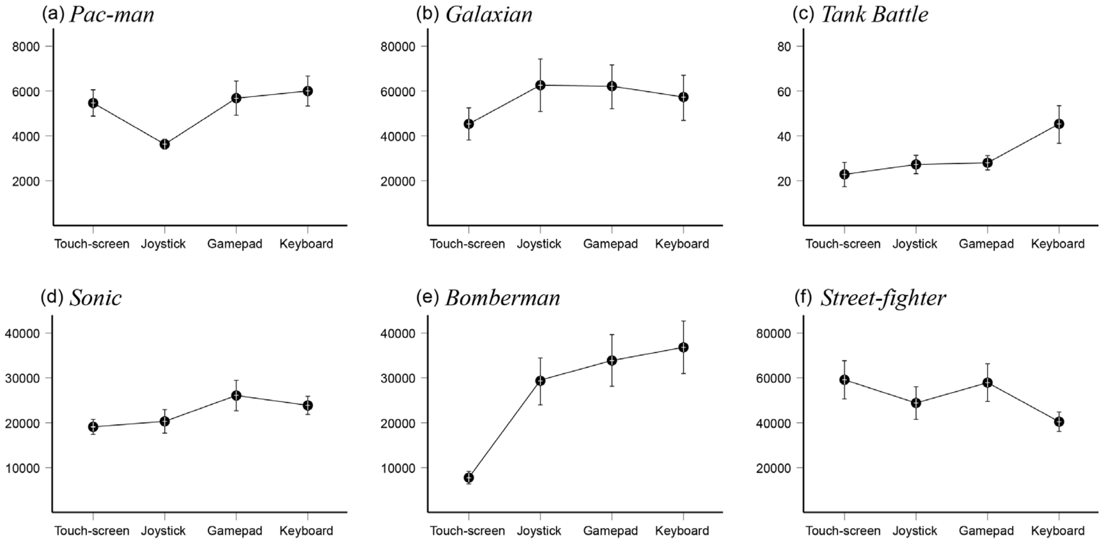

Figure 4. Gaming performance of subjects' in six games using four gaming interfaces (Error bars show ± 1 *SE*).

In summary, situation (2) and (3) are in line with expectations. The keyboard is better suited for Tank Battle, a slow-paced and strategic game. Sonic, a fast and complicated game, proves harder to control on touch-screens, and is best played on the gamepad, which was designed specifically for these types of games. However, situation (1) and (4) were surprising. It would be logical to expect that the joystick is best suited for Pac-man since both were developed during the arcade era, however, it proved to yield the worst gaming performances. On the other hand, from the perspective of reaction needs, the touch-screen should be better suited for Bomberman, which is slow-paced and strategic, but results proved otherwise. The reason for this may be because Bomberman has a relatively complex control system (to place bombs that explode in four directions in mazes to blow up), which could be difficult to control through a touch-screen without the game being fully adapted to the touch-screen.

Subject Difference Shown through Interface Engaging Time

From the perspective of subject difference affecting gaming performance, *interface engaging* time in Table 3 is used as the basis for grouping. The subjects' mean of scores on the four gaming interfaces were analyzed using ANOVA in order to observe whether or not there existed significant difference between subjects in differing groups. The results are as shown in Figure 5. Firstly, the four touch-screen engaging time groups are indicated using white dots, there is significant difference can be found between the gaming performances of four games: Pac-man (F (3, 124) = 4.642, p = 0.004), Tank Battle (F (3, 124) = 5.644, p = 0.001), Bomberman (F (3, 124) = 6.796, p = 0.000), and Street-fighter (F (3, 124) = 3.296, p = 0.023), as can be seen in Figure 5a, Figure 5c, Figure 5e, and Figure 5f. This indicates that the amount of time the subjects are engaged in the touch-screen markedly affects gaming performance. Secondly, the four keyboard engaging time groups are indicated using gray dots, there is significant difference between the gaming performances of five games: Pac-man (F (3, 124) = 11.120, p = 0.000), Galaxian (F (3, 124) = 4.499, p = 0.005), Tank Battle (F (3, 124) = 7.652, p = 0.000), Sonic (F (3, 124) = 10.900, p = 0.000), and Bomberman (F (3,

124) = 9.654, p = 0.000), as displayed in Figure 5a ~ Figure 5e. This illustrates that engaging time on the keyboard notably influences gaming performance. Lastly, the two gamepad engaging time groups are indicated using black dots, only show significant difference in gaming performance of three games: Galaxian (t (126) = 2.319, p = 0.023), Tank Battle (t (126) = 2.882, p = 0.005), and Street-fighter (t (126) = 2.573, p = 0.011), as shown in Figure 5b, Figure 5c, and Figure 5f. This reveals that subject engagement time on the gamepad significantly influence gaming performance.

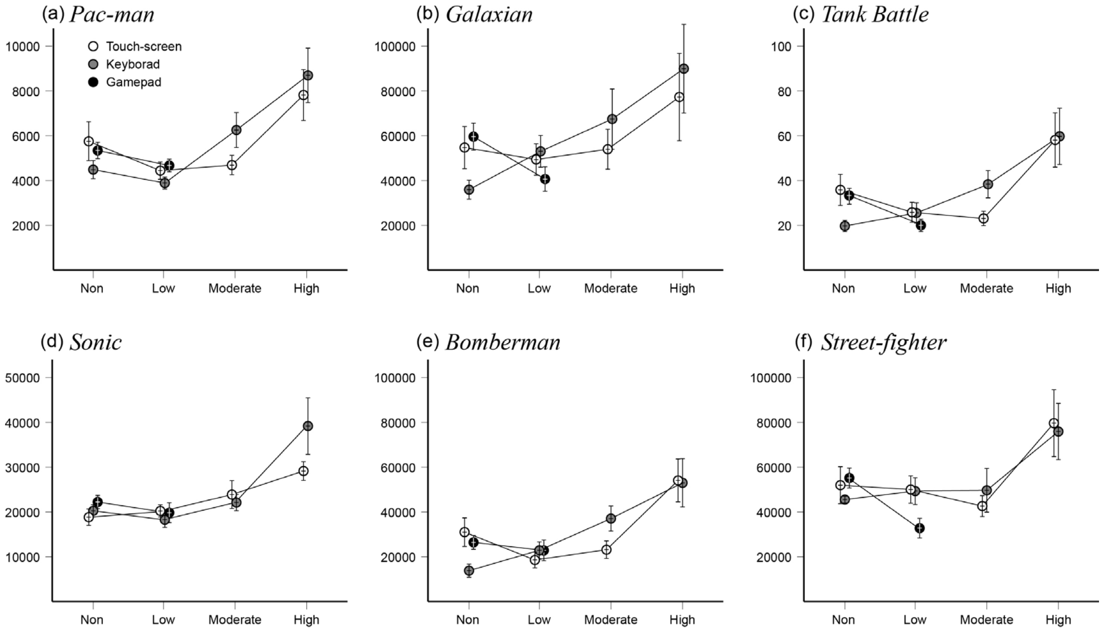

Figure 5. Gaming performance of subject groups based on touch-screen, keyboard, and gamepad interface engaging time (Error bars show ± 1 *SE*).

What's interesting is, it can be seen through Scheffe's post hoc analysis that *high-engaging* subjects who were grouped based on touch-screen engaging time had significantly better gaming performance than *low-engaging* and *moderate-engaging* subjects in three games: Pac-man, Tank Battle, and Bomberman. This result shows that the more the subject is engaged in the touch-screen the better the gaming performance. However, it is baffling to observe how *no-engaging* subjects have better gaming performances than *low/moderate-engaging* subjects. A similar situation is recognized amidst conditions utilizing keyboard engaging time and gamepad engaging time as subject grouping basis. Although no significant difference between the two groups exists, the two display shocking similarities. The results above show when observing the data obtained from the four game interfaces, there is significant difference between the gaming performance of subjects grouped based on interface engaging time, which partially supports H1 purposed by this study. However, do differences exist between the gaming performance of different subjects when playing on familiar (longer engaging time) or unfamiliar (shorter engaging time) game interfaces? To answer this question, the gaming performance on four game interfaces of subjects grouped based on interface engaging time on three interfaces must be observed separately.

The Gaming Performances Differing by Interface Engaging Time

The following uses the performance of subjects of varying levels on four different interfaces to observe gaming performance from the perspective of the three types of interface engaging time. Firstly, the gaming performances of subjects grouped based on touch-screen engaging time were analyzed using ANOVA. There were four groups in all, and gaming performances on four different interfaces were obtained. The results are as shown in Figure 6. No significance difference between performances in all six games was found between the *moderate-engaging* and *high-engaging* subjects, which prove how the two groups are highly adaptive to the four gaming interfaces. On the other hand, there is significant difference between the performance of *no-engaging* subjects in two games: Tank Battle (F (3, 15) = 3.496, p = 0.042) and Bomberman (F (3, 15) = 3.785, p = 0.033), as shown in Figure 6c and Figure 6e. As for low-engaging subjects, significant difference was found between the gaming performances of two games: Sonic (F (3, 30) = 4.442, p = 0.011), and Bomberman (F (3, 30) = 4.316, p = 0.012), as shown in Figure 6d and Figure 6e. Compared with the *moderate/high-engaging* subjects, the *no/low-engaging* subjects show relatively inconsistent adaptation abilities. By using Fisher's LSD post-hoc test, it can be seen that *no-engaging* subjects perform better when playing Tank Battle and Bomberman on keyboards than on touch-screens. *Low-engaging* subjects have better gaming performance when playing

Sonic using gamepads and keyboards instead of touch-screens. Gaming performance in Bomberman was best when playing on the keyboards. The above results suggest how *no-engaging* and *low-engaging* subjects in the touch-screen engaging group might specialize in game interfaces other than the touch-screen. Meanwhile, the keyboard stands out from all other game interfaces.

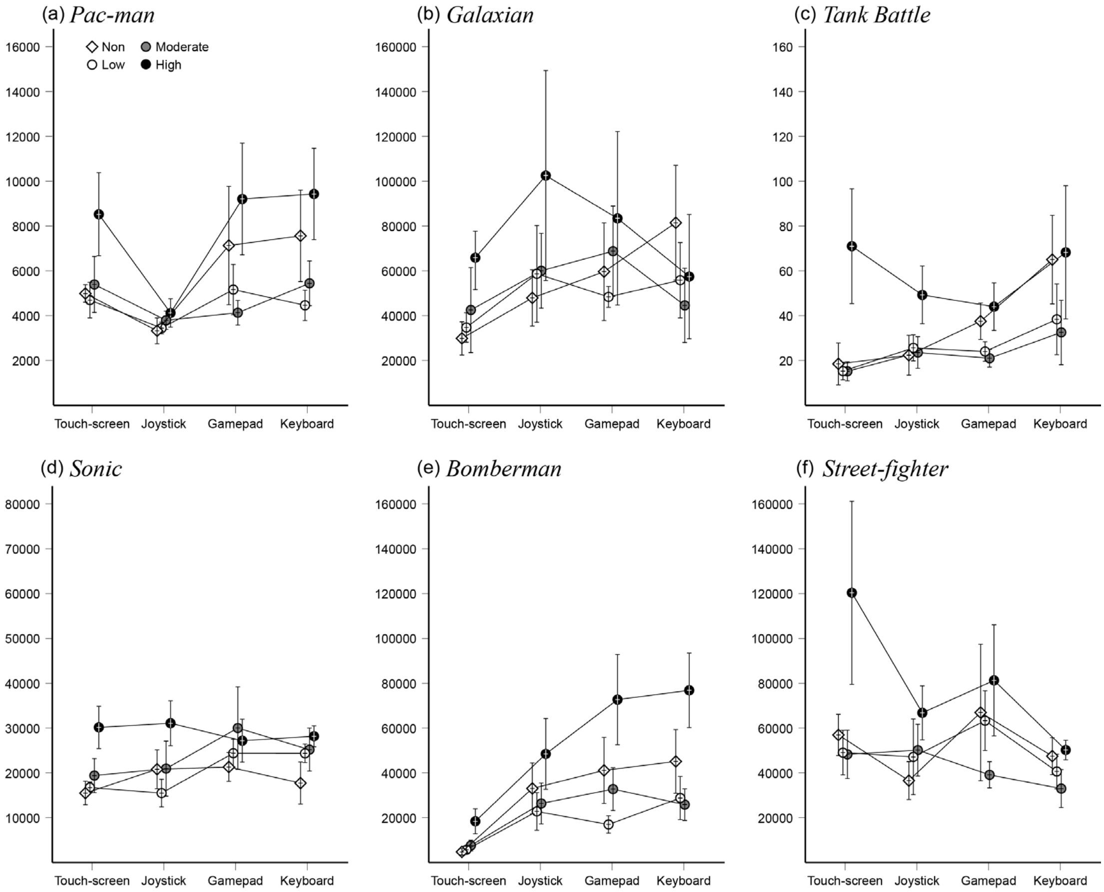

Figure 6. Gaming performances of subjects grouped by touch-screen engaging time on different interfaces (Error bars show ± 1 *SE*).

Secondly, the gaming performances of the four groups of subjects grouped based on keyboard engaging time was analyzed using ANOVA. Results are as shown in Figure 7. There is no significant difference between the gaming performances of *no-engaging* and *high-engaging* subjects. This indicates that gaming performances on different interfaces in these two groups have a certain degree of stability. On average, *high-engaging* subjects have better gaming performance, suggesting that *high-engaging* subjects might be adept at controlling all four types of game interface. In addition, significant difference can be seen between the gaming performance of *moderate-engaging* subjects in the games Pac-man (F (3, 18) = 3.338, p = 0.043) and Bomberman (F (3, 18) = 8.126, p = 0.001), as shown in Figure 7a and Figure 7e. There is also significant difference between the *low-engaging* subjects' gaming performance in Bomberman (F (3, 30) = 3.609, p = 0.025), as shown in Figure 7e. By using the LSD post-hoc test, it can be seen that *moderate-engaging* subjects have better gaming performance when playing Pac-man using keyboards as opposed to touch-screens and joysticks. When playing Bomberman, both keyboard and gamepad outperforms the touch-screen. And *low-engaging* subjects perform better in Bomberman when using gamepads and keyboards instead of touchscreens. The above results indicate that keyboards might be more suitable for complicated maze-based games.

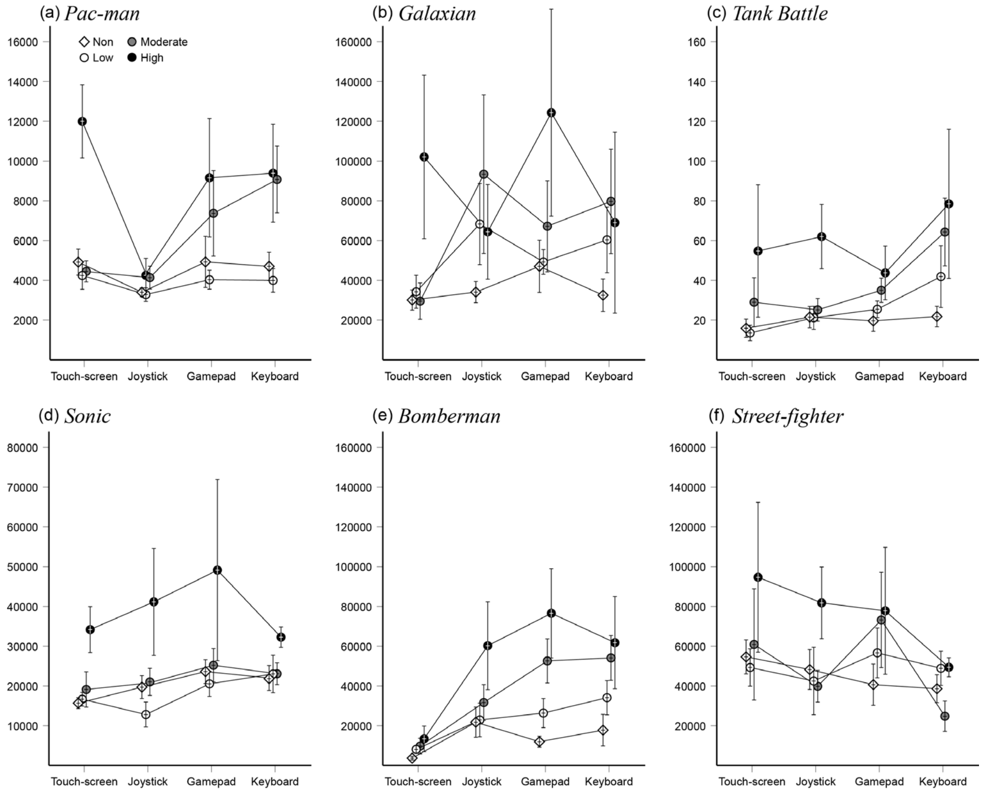

Figure 7. Gaming performance of subjects grouped based on keyboard engaging time on different interface (Error bars show ± 1 *SE*).

Finally, the gaming performances of the two groups of subjects grouped based on gamepad engaging time were analyzed using ANOVA. The results are as shown in Figure 8. There is significant difference between the gaming performances of *no-engaging* subjects in three games: Pac-man (F (3, 72) = 3.962, p = 0.011), Tank Battle (F (3, 72) = 3.401, p = 0.022), and Bomberman (F (3, 72) = 8.594, p = 0.000), as shown in Figure 8a, Figure 8c, and Figure 8e. There is also significant difference between the gaming performances of *low-engaging* subjects in the game Bomberman (F (3, 18) = 4.594, p = 0.015). By using the LSD post-hoc test, it can be seen that out of the three game interfaces, *no-engaging* subjects have the worst gaming performance when playing Pac-man using joysticks. They also performed better in Tank Battle when using keyboards as opposed to joysticks and gamepads. Both *no-engaging* and *low-engaging* subjects performed worst when playing Bomberman using touch-screens.

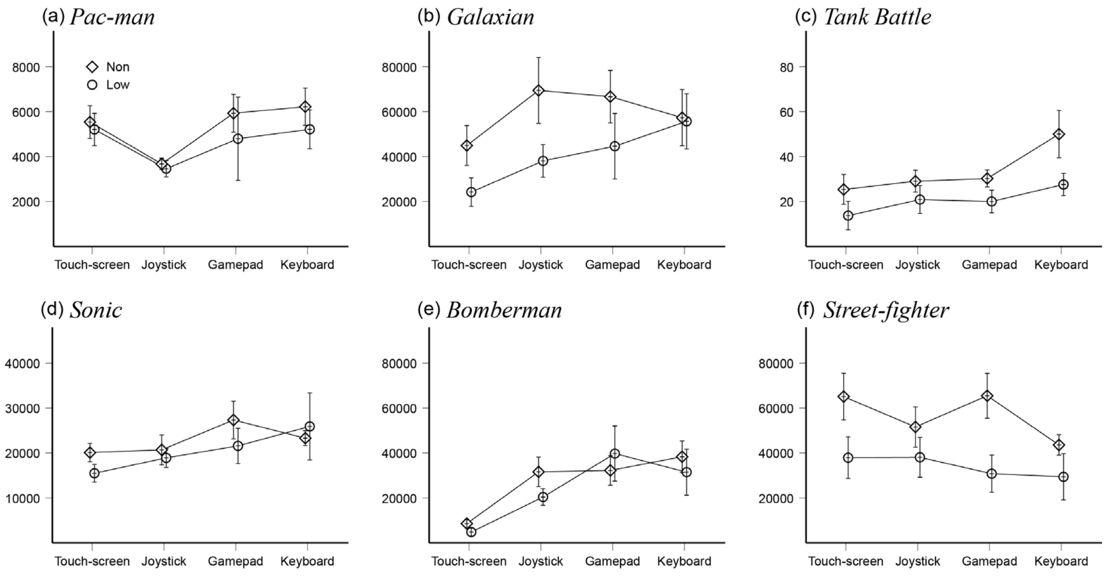

Figure 8. Gaming performances of subjects grouped based on gamepad engaging time on different interfaces (Error bars show ± 1 *SE*).

Discussion

Interface Adaptability Affected by Interface Engaging Time

After subsequent observation of subjects grouped by the three types of interface engaging time in 4.3, three phenomena are worth noting: (1) *No-engaging* and *low-engaging* subjects in the touch-screen engaging time group are unskilled at using the touch-screen when playing some of the games. (2) *Low-engaging* and *moderate-engaging* subjects in the keyboard engaging time group were still adept at using the keyboard to play some of the games. (3) *No-engaging* and *low-engaging* subjects in the gamepad engaging time group are also inept at using the gamepad to play some of the games. In other words, besides the keyboard, subject who spend less time engaging with touch-screens and gamepads are noticeably unskilled at using the two interfaces. These three phenomena do not completely correspond to the observation made in Gerling et al. (2011): feeling challenged when facing a new game platform, and comfortable with a familiar platform. Presumably, there are two reasons for these phenomena: (1) The subjects might have more than one familiar interface, (2) Gamers from different generations differ greatly when it comes to interface familiarity, similar to the phenomenon discussed in Differing Gaming Performance Caused by Difference of Interface subsection. Therefore, the subject's gaming performance cannot be observed from a unidimensional perspective.

Using gamepad engaging time as an example, in terms of gamepad engaging time, the seven *low-engaging* subjects are engaged in the gamepad for a range of 3.71 to 208 hours annually. However, the 25 *no-engaging* subjects might be more engaged in other game interfaces, thus accumulating experience and skill through the process of being engaged in alternative gaming interfaces. Therefore, it is possible for *no-engaging* subjects to deliver better gaming performance than *low-engaging* subjects. This reasoning may also be used to explain the condition of the subjects grouped based on the other two interfaces. Accordingly, as shown in Figure 5, if the gaming performances of *no-engaging* subjects of both touch-screen and keyboard are excluded, it can be seen that the locus consisting of the touch-screen engaging time (indicated by white dots) and keyboard engaging time (indicated by gray dots) of the six games moves upward towards the upper right corner. This indicates that interface engaging time contributes significantly to gaming performance, and thus supports H1. However, the reason *no-engaging* causes the trajectory to be reversed may be because the subjects have spent a considerable amount of time on other game interfaces. But this remains to be further analyzed and explained.

Further analysis was performed on the engaging time of subjects who were grouped based on single interface engaging time regarding the two other gaming interfaces. The results are as shown in Figure 9. Firstly, in both groups touch-screen and keyboard engaging time, subjects relatively lack engaging time on the gamepad, as shown in Figure 9a and Figure 9b. This observation can be used to explain why when grouped based on gamepad engaging time, *no-engaging* subjects have significantly better gaming performances than *low-engaging* subjects, as can be seen from the black dots in Figure 5. As a matter of fact, most *no-engaging* subjects on the gamepad invest their time in the other two interfaces, as shown in Figure 9c. A similar situation can be seen from the gaming performances of subjects grouped based on touch-screen and keyboard engaging time. *No-engaging* subjects again invest a certain amount of time on other gaming interfaces, as shown in Figure 9a and Figure 9b. Secondly, for the touch-screen and keyboard groups, as the engaging time on a certain interface increases, so will the engaging time on another gaming interface. In other words, subjects spending more time on the keyboard will equally spend more time on the touch-screen. This also provides an explanation as to why three types of *high-engaging* (or *heavy* for short) gamers have a better average gaming performance across interfaces. The reason does not lie simply in game engaging time, but also the time being exposed to a wide range of gaming interfaces. Namely, these *heavy* gamers often possess the ability to play across the game platforms. What's interesting is, this trait is especially visible in subjects grouped based on keyboard engaging time.

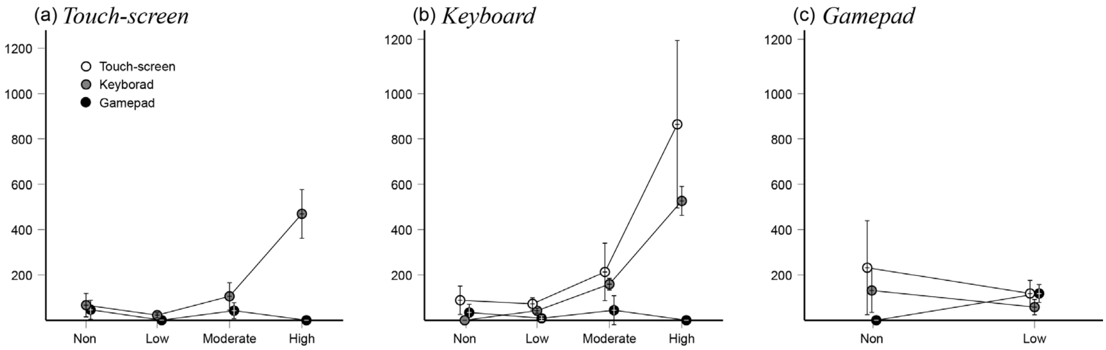

Figure 9. The amount of time subjects grouped based on mean of engaging time of three interfaces are engaged in other interfaces (Error bars show ± 1 *SE*).

Interface Adaptability Affected by Generation Difference

The younger gamers' unfamiliarity with the classic games of previous generations (ages 20 to 22) highlighted is though the comparatively worse gaming performance when using joysticks and gamepads. Discussing the joystick first, from the overall observation of the 32 subjects' game performance on different game interfaces made in Differing Gaming Performance Caused by Difference of Interface subsection, it was found that the joystick, which should be the most suitable for controlling Pac-man to roam around the maze, resulted in the worst gaming performance. However, it was further revealed in The Gaming Performances Differing by Interface Engaging Time subsection that all subjects, regardless of being grouped based on touch-screen, keyboard, or gamepad, demonstrated the worst gaming performance playing Pac-man using the joystick. The relatively low standard deviation showcases stability among the subjects. Post hoc interviews conducted with the 32 subjects aged between 20 to 22 found that for the younger generation, the fast-emerging new game interfaces lead them to be unfamiliar with the previously popular game interface. Some subjects even had no experience with the joystick, and as a result, displayed relatively poor gaming performance when using the joystick to play games with complex controls like Pac-man.

As for the poor performance on the gamepad, indications could be seen from the 32 subjects' engaging time on gamepads illustrated in Table 2 and 3. Only seven people were grouped as *low-engaging*, and 25 people were grouped as *no-engaging*. This exhibits how console games are not commonly played by the 32 subjects, and results in unfamiliarity with the gamepad. However, looking at overall performance, subjects did not perform too poorly on the games originally compatible with gamepads, Sonic and Bomberman; most subjects performed better than when playing on the touch-screen or with the joystick. When playing Bomberman, subjects performed better using the keyboard than the gamepad. The reason behind this observation may be inferred from the keyboard engaging time in Table 2: the total keyboard engaging time of the 32 subjects (3681.17 hrs.) is second to only the touch-screen (6623.04 hrs.). From the post hoc interviews, it was found that subjects who spend more time playing PC games think: Keyboards have the advantage of having more keys, making it able to control more functions, and suiTable for games with complicated controls like Bomberman. Furthermore, besides gaming, keyboards are also used for clerical work and social networking, which enhances familiarity, and makes it easier for keyboards to replace gamepads as the preferred controller. The same phenomenon can be seen in Differing Gaming Performance Caused by Difference of Interface subsection and The Gaming Performances Differing by Interface Engaging Time subsection, from how subjects perform significantly better when playing Pac-man, Tank Battle, and Bomberman using keyboards.

Finally, curiously, according to Table 2, the 32 subjects' accumulated the most time on the touch-screen, meaning the generation of gamers aged between 20 to 22 engage in touch-screens the most. However, in some games, the subjects do not perform better on the touch-screen. On the contrary, subjects will perform worse than using other interfaces, especially when playing Bomberman. The possible reasoning behind the relatively poor performance on touch-screens might not be only be generation difference, but also partially caused by game features, which will be discussed in Interface Adaptation Affected by Game Features subsection.

The above discussion and analysis in relation to joysticks, gamepads, and keyboards is in accordance with observations made in Gerling et al. (2011): being more comfortable playing on familiar game platforms. However, the findings in this study might further add to the discussion on how familiarity brought on by time is not the only reason gamers perform better on platforms they are used to. The difference between game generations might serve as a hidden factor worthy of attention and discussion.

Interface Adaptation Affected by Game Features

As Brown et al. (2015) suggested the concept of a standardized controller (Rabin, 2010), when a game is designed, the most suitable game interface is usually related to the default game platform and game interface. For example, games developed in the era of arcades usually use joysticks as the main game interface, and games developed during the era of consoles use gamepads. However, the game features derived from the rules of the game might lead later developed game interfaces to become more suitable for the game, and therefore replace the original interface. A few interesting examples of this phenomenon can be found in this study: (1) Compared with joysticks, keyboards are more suitable for playing Pac-man. (2) Keyboards outperform joysticks when playing Tank Battle. (3) Bomberman is easier to control using a keyboards instead of a gamepads. It can be seen from Table 3 that Pac-man, Tank Battle, and Bomberman are all maze-based games. The subjects need to rapidly control the characters to move in four directions to either avoid or defeat the enemy. Using Bomberman as an example, gamers must place strategically bombs that will explode in four directions in the maze. Therefore, the keyboard, with its large number of keys and corresponding complex functions, makes it easier to play maze-based games. The phenomenon is similar to observations made in Isokoski and Martin (2007) and Natapov and MacKenzie (2010a): The keyboard-mouse combination outperforms the gamepad.

Furthermore, better performance in Sonic when using the gamepad is in accordance with the game features listed in Table 4. The reason might be due to how Sonic gameplay values speed, high scores are earned by collecting the most rings and defeating the Boss at the goals in the shortest amount of time. In this situation, the core movement of the game is the acceleration key controlled by the right hand, and directions are only slightly adjusted.

The design of gamepads is able to suit these needs. In comparasion, Pac-man, Tank Battle, and Bomberman put more emphasis on agilely roaming through the mazes, with the core movement being controlling direction. Therefore, keyboards are best game interfaces for these three games.

Conclusion

According to the results of this study, after multidimensional cross-comparison and discussion, interface engaging time does significantly affect the subjects' gaming performance in a number of games, thus partially supporting H1. Moreover, both generation difference and game features affect the subjects' gaming performance to a certain extent, in traceable patterns, but can only be sustained within the scope of this study. Furthermore, interface engaging time affect subjects' performance due to how mastery of an interface comes alongside accumulated engaging time, an observation that can be commonly proved. The results of this study can be easily extended to related research on game interface. Thus it is suggested that interface engaging time be viewed as an important basis for gamer grouping.

To sum up the above, when focused on how gaming performance is affected by interface engaging time, this study shows: (a) Interface engaging time significantly affects gaming performance. (b) The more time spent on a specific interface, the better the subject's gaming performance using that interface. (c) Apart from the keyboard, increased engagement time on a specific interface will not enhance gaming performance on other interfaces. (d) Subjects that are *high-engaging* in all interfaces are usually also familiar with other interfaces. In addition, although game difficulty is often closely linked with subject characteristics, it is challenging to control, especially in released games, and therefore has not been adopted in this study. Future game interface related studies are recommended to view game difficulty as an independent variable to further observe its influence on game performance.

Last but not least, due to the recent surge of cloud gaming brought on by the prevalence of mobile devices and cloud technology (Cai, Leung, & Chen, 2013; Cai, Chen, & Leung, 2014; Chuah, Yuen, & Cheung, 2014; Huang, Hsu, Chang, & Chen, 2013; Jurgelionis et al., 2010; Wang & Dey, 2010), gamers can play through games previously unfinished using the same account on different platforms. Therefore, how gamers of differing gaming skills adapt to the same game on different platforms will become an increasingly complex problem in need of a solution. The author hopes that the results presented in this study can serve as a base for future studies on relevant gaming practices.

Acknowledgments

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