Flow Experience in AR Application: Perceived Reality and Perceived Naturalness

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Abstract. As the emergence of augmented reality (AR), game industry has promptly adopted AR to their products for better user experiences. Due to fact that the AR could deliver more realistic experience to users, AR based applications received a lot of attentions from various industries. Recent researches revealed that AR game can enhances users' flow experience more than ordinary game applications leading to better educational performance. This study pays attention to the phenomenon that AR based application can lead users' flow more than simple online applications and explored antecedent factors users' flow experiences.

By utilizing text mining method and structured interview with AR Application users, this study discovered two influential factors on users flow experience; perceived reality and perceived naturalness. We also found that perceived naturalness is a more influential factor than perceived reality on users' flow in AR context. In addition, this research discovered privacy concerns as a main cause of decreasing flow.

Keywords: Augmented reality · Perceived reality · Perceived naturalness · Privacy concern · Flow experience · Experiment · Text mining

1 Introduction

Since augmented reality (AR) was developed in 1990s, it has been commercialized in various fields such as medical, broadcasting, architecture and game industry. Because AR provides more realistic experience to user by mixing real world and virtual information compared to ordinary online environment, game industry enthusiastically adopted AR on their applications. According to SuperData's research, there are 55.8 million users in virtual and augmented reality game [31]. Investment in virtual and augmented reality game would be 3 billion dollar in 2017 and 4 billion dollar by 2018 [31].

Recently, education field also start to aware the value of AR application for educational purpose. In education perspectives, learners' state of flow is one of most important factors increasing learning outcomes. According to research of Noh et al. AR applications enhance users' interest, enjoyment, flow compared with simple applications in game context [21]. Even though there is growing popularity of AR applications for various field, there is little research empirically investigating AR app's utilities in terms of users' flow experiences. This study, as a preliminary study, explored factors affecting users flow experience in AR applications. Flow, which is mental state,

D.D. Schmorrow and C.M. Fidopiastis (Eds.): AC 2017, Part II, LNAI 10285, pp. 185–198, 2017.
DOI: 10.1007/978-3-319-58625-0_13

concentration on what people are doing with feeling of full involvement and enjoyment about their activity, is one of main factors accelerating learners' proficiency in learning process [32]. This study focused on characteristics of AR application enhancing users' flow state. The main characteristics of AR application differentiate with ordinary application is users' enhanced reality perception through combining real spatial information with informational layer. Two factors, reality and naturalness, are discussed as important influencers increasing users flow using AR applications. This study also tried to discover other factors which have a potential to influence on flow experience and then discovered privacy concerns. The results of this study could provide useful insights to AR application developers by suggesting factors which they must consider.

In Sect. 2, we explain theoretical background with literature review. We also suggest a research model and hypotheses in Sect. 3. Methodology, result and conclusion are discussed in the flowing sections.

2 Literature Review

2.1 Augmented Reality

Augmented reality (AR), as a one form of virtual reality (VR) technology, allows application can mix real world and virtual information. In 1960s, a device called head mounted display (HDM) was first invented could overlap virtual information and real environment [28]. However, no specific term was used for a technology which combines real world and the virtual information until 1990s. Tom Caudell of the Boeing Company first used a term "augmented reality" to refer the technology combining real spatial world with information [3]. The first functional AR system 'Virtual Fixtures' was developed to train surgeons in early 1990s at the U.S. Air Force's Armstrong Labs [22]. And Azuma suggested the definition of AR as a system with specific characteristics [2]; AR combines real and virtual and AR Is interactive in real time. From early 1990s, AR has been widely used in military, motor and aerospace industries. In 2000s, AR technology began to be used in various industries such as game, mining, and tourism [11, 16, 30]. Especially, game industry is a first mover in adopting AR technology on their services. AR provides higher presence to game players and flow is one of main predictor of game service satisfaction [9].

2.2 Augmented Reality in Learning

A few studies in education field have been conducted to find out an impact of using AR contents in learning process. Ibanez et al. (2014) and Bressler et al. (2013) found out that students' flow on the class increased when they use augmented reality applications [34, 35]. Mostly, studies on AR contents in education suggested that students' level of understanding on complicated concepts can be increased by realistic experience with AR contents through virtual objects in 3D environment [4, 15, 24, 25]. Learning based

on AR contents is also effective in enhancing students' interest on the class compared to traditional textbook based learning [21].

Past studies on AR in education area assented to positive effect of AR contents in learning process for increasing flow. However, there is no research uncovers what factors affecting to flow state in AR based learning so that further research is needed.

2.3 Purpose of This Study

Realistic experience in AR applications allows better employee training, service, and way of working, with these reasons, organizations consider implementation of AR applications [46]. To achieve expected results of AR applications, organizations need to know characteristics of AR applications leading users' flow. Based on situated learning theory and flow theory, this study explores main characteristics of AR applications fostering users flow. Findings of this study can provide important insights for AR industries when they develop AR applications.

3 Theoretical Background

3.1 Flow Theory

According to Csíkszentmihályi, when people concentrated on what they are doing, they could feel full involvement and enjoyment about their activity [7]. To fulfill flow state, there should be a balance between challenge of activity and people's skill [8]. Flow theory has been widely adopted in various contexts such as sport, gaming and education [5, 14, 18]. In business context, flow state corresponds to optimal state in work [38]. Flow state stimulates employees' motivation of achievement in their work [36] so that they can show high performance in their complicated knowledge works [37]. Flow state of employees at work also affects to increase their intension of using information technology [44] resulting in enhancement of employees' performance [45] Recently organizations implement AR applications in employee training for workers to provide real workplace experience [39]. Based on flow theory, it is better for employees archive flow state to maximize training outcome.

3.2 Situated Learning Theory

Situated learning theory derived from Constructivism [1] assuming that there is a positive relationship between human experience and learning. The theory insists that there is difference between school learning environment and real world so that knowledge acquired in school cannot be properly applied in real world situations [6]. To solve this problem, researchers suggested that it is important for teachers to make learning environment similar to the real world [17]. In business context, organizations implement learning by experience training due to increase training results by reducing

gaps between learning environment and work place [47]. From this situational context, AR applications are widely used in the training to provide more realistic experience for employees [40]. Based on situated learning theory, this study figured out perceived reality and naturalness are the most important factors increasing users' realistic experiences through AR applications. Sensory realism is a prerequisite in making realistic environment with virtual 3D environment [41]. Perceived reality is related to visual reality in real world representation [23] and perceived naturalness is related to feeling correspondence between environment and manipulation so that it contribute to experiencing presence in AR environment [20].

3.3 Perceived Reality

Perceived reality was first suggested in television media studies. Hawkins suggested the term "perceived reality" to explain how people judge the reality of television media in the first time [13]. A common definition of perceived reality is the degree of correspondence between the media texts and the real-world [18]. Malliet introduced concept of perceived reality to the video game context [19]. Malliet asserted that users' perceived reality of game be critical to increase players' concentration in the game [19]. Shafer et al. used the extended definition of perceived reality examining perceived reality of various media such as animations, dramas and video games [23]. They focused on "perceptual fidelity" which is visual reality. Based on their research results, we can conclude that visual reality is also very important in AR application since most of AR applications provide visual information through combination of real space with visual information.

3.4 Perceived Naturalness

Natural mapping is suggested as a related factor of perceived naturalness. Natural mapping means "a system's ability to map its controls to correspond to changes within a mediated environment, doing so in a manner that is natural and predictable (p. 104) [27]." Natural mapping help their players to make accurate and quick decision on game situation so that player could align the real-world and virtual world behavior closer [29]. Skalski explained that natural mapping increases the degree of perceived naturalness [26], which means the degree of congruent feeling between the virtual world and their manipulation in the game through controller [20]. However, perceived naturalness was never explored in AR application context.

4 Research Model and Hypotheses

When students use AR application in study, AR technology adds virtual objects on the real environment. They can observe and experience phenomena with AR application. This allows them to develop better conceptual understanding about what they learn,

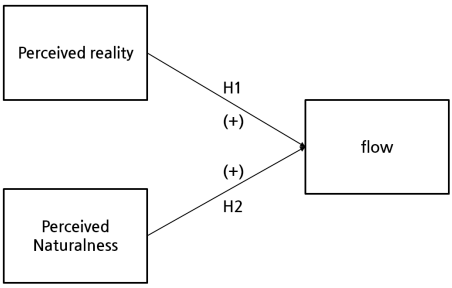

Fig. 1. Conceptual research model of this study

leading to have interest about it. By adopting AR application, students easily concentrate on the class and feel enjoyment [25].

Previous research proved that the similarity between the representation of world in game and real world has a positive relationship with players' flow experience [29]. Likewise, if virtual objects in AR environment are similar to the real objects, students could have more realistic experience like applying their real world skill [33]. Therefore, interest on the class would be increased. Interest on the study subject makes students concentrate on the class so that they could have a higher probability of experiencing flow state. Therefore we posit this hypothesis 1 (Figure 1).

H1: Perceived reality in AR application and flow has a positive relationship.

Students could manipulate virtual objects in real environment with educational AR application. They experience phenomena by navigating AR environment, feel enjoyment and interest about the class [21]. If the objects in AR game were controlled in a lifelike manner, students don't have to care about game control and could fully concentrate on the game [10]. Higher perceived naturalness contributes to the students' concentration so that it performs a key role in achieving flow experience with AR game. Therefore, we suggest following hypothesis.

H2: Perceived naturalness in AR application and flow has a positive relationship.

5 Research Methodology

5.1 Study 1: Text Mining

To select smart phone AR applications to fit our study purpose which provide differences in perceived reality and perceived naturalness, this study applied text mining method. We selected 2 AR smart phone astronomy applications that have same operation system and functions. To find out differences in perceived reality and perceived naturalness of 2 applications, we collected the review of last 18 months (June 1, 2015–December 31, 2016) from Google play store. Application A received 258

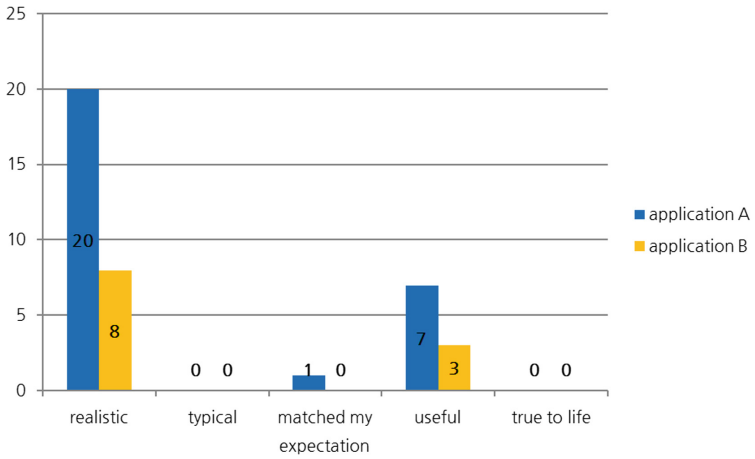

Fig. 2. The frequency of keyword/key phrase in perceived reality

reviews from players and Application B received 220 reviews from players during the time (Fig. 2). Because reviews contain free expression of customer opinion, it is useful to know true reactions of customers on products or services [42]. We deployed text mining technique called word frequency analysis on the reviews. Customer review text mining is often used in a customer satisfaction research, and word frequency analysis is widely used to find out how many reviews give positive/negative opinions on products or services [43] (Table 1).

Table 1. Frequency of top 10 word in the reviews

A	Frequency	B	Frequency
Constellation	46	Constellation	34
Best	40	Best	25
Location	14	Planet	18
Thank	11	Amazing	16
Extraction	10	Study	13
Camera	10	Name of B	10
Science	8	This	8
Cool	8	Accurate	8
Subscription	8	Universe	7
Screen	8	Location	7

To conduct key term extraction, we collected keywords and key phrases from measures of perceived reality [23] and perceived naturalness [20]. We counted the frequency of keywords and key phrases with R 3.3.2 ver. The analysis result shows that

application A has higher frequency of perceived reality keywords and application. (Figure 3) B has higher frequency of perceived naturalness keywords (Fig. 4). Based on this result, we conclude that app A has higher perceived reality and app B has higher perceived naturalness.

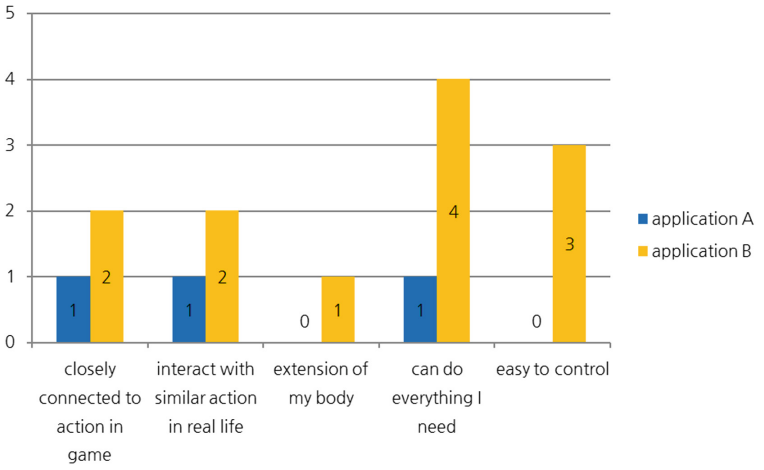

Fig. 3. The frequency of keywords/key phrases in perceived naturalness

Fig. 4. Representation of same constellation in 2 applications

5.2 Study 2: An Experiment

Users evaluated that A was better than B in perceived reality. Likewise, users evaluated that B was better that in perceived naturalness. To find out the impact of perceived reality and perceived naturalness on flow state, we conducted an experiment and carried out structured in-depth interviews.

Subject
The participants for this study were 10 Koreans who have never experienced AR application. 2 interviewees were male, and 8 interviewees were female. All of 10 interviewees spent more than 2 h on the smartphone manipulation per day and 8 interviewees were regular smartphone game application users spent more than 1 h per day.

Procedure
Study participants were asked to use each of two selected applications A and B. By using two AR applications each, participants need to answer 10 questions during 30 min for each of applications. Table 2 shows 10 questions used in this study. After each 30 min experience for two applications, participants answered 50 min longs in-depth interview.

Table 2. 10 questions to answer in 30 min

1.	Please find out satellites of the Jupiter(write down at least 4 satellites)
2.	The moon is _____ km in diameter.
3.	What is the name of galaxy surrounded by the Corvus, Centaurus, and Libra?
4.	Please write down 3 signs of zodiac which can be seen in the northerly sky.
5.	Please write down 2 planets which can be seen in the westerly sky.
6.	What are the nickname of Cetus alpha and its origin?
7.	What are the names of stars located on Orion's belt?
8.	What is the name of galaxy located on the head of Andromeda?
9.	Please find out satellites of the Saturn (write down 3 satellites).
10.	Please write down 3 constellations which can be seen in the southerly sky.

The Interview Question
We developed interview questions based on perceived reality measure of Shafer et al. [36] and perceived naturalness measure of McGloin et al. [20], and flow measure of Jackson et al. [14]. The measurement questions are modified to fit AR application environment and they went through a pilot study to ensure reliability of measurements. The interview questions are as follows;

(1) Perceived reality

- Please choose one application whose feature of night sky was more realistic and explain your own reason to make a choice.

(2) Perceived naturalness

- Please choose one application that actions you performed with smartphone were closely connected to the actions happening in the AR environment and explain your own reasons to make a choice.
- Please choose one application that can be control naturally and explain your own reasons to make a choice.

(3) Flow experience

- While you find out the answers for the questions with 2 applications, were the challenge and your ability at an equally high level? Please describe your thought and feeling.
- While you find out the answers for the questions with 2 applications, which application was easy to concentrate on? Please describe why and how that application was helpful for you.
- Did realistic feature of night sky help you to concentrate on the challenge?
- Did natural control help you to be concentrate on the challenge?

(4) Additional factors which could affect to flow state

- If there were additional factors that enhance you to fully concentrate on the task, please describe which factor is it and why.
- If there were additional factors that disturb you to fully concentrate on the task, please describe which factor is it and why.

6 Result

6.1 Perceived Reality and Flow Experience

Among interviewees, 6 interviewees explained that application A was better than application B in perceived reality. 2 interviewees were male, and 4 interviewees were female. They suggested that "A's virtual environment is similar to the real environment (2 times).", "the color of night sky was realistic (2 times)."

Among 10 interviewees, 7 interviewees stated that higher perceived reality affected to the higher flow experience. They suggested that "As the night sky of the application seemed more real, it helps me to feel more curiosity and interest on it (2 times).", "More realistic graphic helps me to concentrate (4 times).", "Realistic graphic is attractive to me (1 time)."

Interviewee 10: Compare to application B, It feels like I was watching the star at the countryside (when I use application A). So I could deeply concentrate on it.
Interviewee 7: I could see the stars with application A that I cannot see on the earth. So I could concentrate on it more.

6.2 Perceived Naturalness and Flow Experience

Among 10 interviewees, 6 interviewees explained that application B was better than application A in perceived naturalness. 2 interviewees were male and 4 interviewees were female. "Application B reflects my control more effectively (2 times).", "Application B moves faster than application A (1 time)." Among 10 interviewees, 9 interviewees explained that higher perceived naturalness affected to the higher flow experience. They suggested 'When it has a lot of lag, I feel so frustrated (1 times).' 'Easy control helps me to freely explore the galaxy with application.'(3 times), and 'definitely yes (1 times).'

Interviewee 2: When it has a lot of lag, I feel so frustrated. So I chose application B, which has no lag in control and could concentrate on it more.
Interviewee 3&4: Easier control helps me to freely explore the galaxy with applications. I feel very comfortable and concentrated on.
Interviewee 5: When easier control is available, it was feel like I am really watching stars. I feel more immersion with application B.

6.3 Perceived Reality vs Perceived Naturalness

6 Interviewees stated that application B was more immersive than application A. 2 interviewees said that application A was more immersive that B. 1 interviewees stated there was no difference between 2 applications (Fig. 4).

6 interviewees choosing application B explained that impact of perceived naturalness on the flow experience was stronger than impact of perceived reality on flow state. Interviewees stated; "When I have trouble in controlling the applications, I couldn't care about graphic at all (2 times)." and "The graphic is good enough. I think easy control or naturalness is more important in playing (1 time)." (Fig. 5).

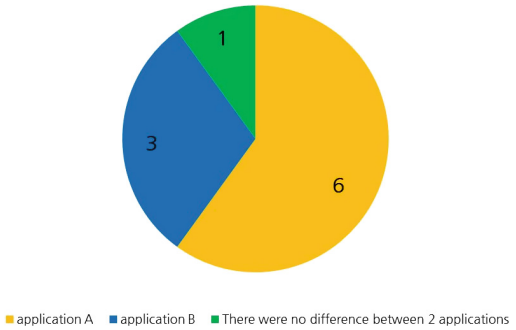

Fig. 5. Answer about the question "which application was easy to concentrate on?"

Interviewee 1: I am totally satisfied with graphic. There is no need to upgrade it. However, naturalness needs to be upgraded. I have much experience in manipulating smart phone, so I didn't have any difficulty in manipulation. But I think that people who don't have much experience in manipulating smart phone would feel uncomfortable due to insufficient naturalness.
Interviewee 6: I was hard to control the application. I could not care about anything except manipulation. So, I think that easy control is a very important factor. I think if I used bigger device, it would be easy to control applications.

6.4 Additional Factor Affecting to Flow Experience

2 of Interviewees stated that they feel privacy concerns due to Global Positioning System (GPS). They feel uncomfortable when they turn on GPS function in smart phone. Interviewee 1 and 3 stated about their privacy concerns.

Interviewee 1: I could concentrate on using applications with GPS function. However, if I have a chance to use the game with risky device, I don't want to play game.
Interviewee 3: I care about my privacy a lot. If there is a big privacy invasion risk caused by using GPS function, it will make me hard to concentrate on. I hope games have strong security measure to protect it.

7 Discussion and Implication

In this exploratory research, we suggested a model of flow in the context of AR application. After carrying out a text mining and an experiment with 10 participants, we discovered that perceived reality and perceived naturalness have positive relationships with users' flow state. This means that users achieve higher flow state when they use the application with higher perceived reality and perceived naturalness. Therefore, it is important to enhance perceived reality and perceived naturalness when companies develop new AR applications.

We also found out that perceived naturalness have stronger impact on flow experience compared to perceived reality. Study participant stated that they think perceived naturalness was more important than perceived reality. AR application provides information with actual spatial image through camera so users may feel high level of perceived reality in application usage. Due to this reason, users may focus on easy manipulation and naturalness more than reality itself.

Participants point out that when they have privacy concerns related to AR applications, they would experience lower flow experience and their intention to play AR application would decrease. Recently, many AR applications provide realistic experience based on GPS or camera functions in the smart device. Adopting GPS or camera can enhance players' realistic experiences so that players could achieve higher flow state. However when those AR applications don't have enough information security measures to protect users' privacy, users could be disrupted to reach flow even with two major characters; perceived reality and naturalness, are ensured in an application.

8 Conclusion

This research adds new dimensions on literature body in an AR application by focusing on users flow. Especially, this study examined users' perceived reality and perceived naturalness which have not been explored in prior research. Based on our study results, this research confirmed that positive impact of perceived reality and perceived naturalness on users flow state in an application context.

However, the study results indicate that perceived naturalness has more influence on users flow state compared with perceived reality. Our research findings are differentiated from prior studies in a way that the role of reality on flow is weaker in AR environment. Beside of two main factors, this research discovered a negative impact of privacy concerns on users' flow experience.

This research has a practical contribution to the industries by suggesting useful insights for application developers. Study results suggest that it be important to provide privacy protection measure in AR applications for flow experience. In addition to the privacy protection measure, it is important for developers to enhance perceived reality and perceived naturalness. By enhancing realistic AR environment with higher perceived reality and naturalness, users' flow experience could be maximized.

This exploratory research has several limitations. First, only few factors were tested to develop the model of AR application flow. Likewise, study participant were 10 people which is hard to generalize our results. To overcome these limitations, we plan to conduct future studies discover more predicting factors of AR application flow experience. By executing survey with large study participants, we expect to find out a powerful explanatory model to users flow state in AR environment.

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