Flow theory in the interactive design of educational games

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Abstract

This article presents a design for a VR-based game in fire safety training for the elderly, utilizing flow theory. Due to the difficulties faced by the elderly in physical learning, training for fire safety has become an important societal issue. Flow theory explains the optimal experience in which users can immerse themselves to benefit education and learning environments. Designing a VR game with a flow experience depends on the principles outlined in flow theory, which include a sense of control, goals, and challenge levels. This study focuses on the design of a VR game for training elderly individuals in fire safety skills, using the three elements of VR game interaction design: UI design, manipulation, and aesthetics. By adopting flow theory, this study aims to enhance engagement and reduce memory burden during training. The results demonstrate that VR game design using flow theory is effective in facilitating positive outcomes in fire safety skills training. Furthermore, flow theory can be employed as a method for evaluating the user experience of VR game designs. Overall, this study contributes to the improvement of VR game design.

Keywords: Flow Theory, Interactive Design, Serious Game, Virtual Reality

1. Introduction

Gaming is not only one of the oldest forms of learning but also the primary reason why people engage in playing games (Csikszentmihaly 1990). Over the past decade, games have been extensively utilized in the field of education, including medical treatment and military training. This shift has brought games beyond just entertainment, focusing on imparting knowledge, skills, and professional training in the form of serious gaming. Games have proven to be effective in various domains, such as enhancing students' performance, medical and military training, as well as emergency safety skills training. Numerous studies have evidenced the ability of games to facilitate knowledge acquisition and skill improvement. Moreover, the combination of virtual reality technology (VR) and gaming has given rise to VR gaming, which possesses the qualities of immersion, interactivity, harmony, and the ability to educate and entertain simultaneously (Zhu 2018, 164). This innovative approach provides a "real" virtual environment for fire safety training, promotes situational learning, and continues to emerge as a significant area of research in education and training.

User experience is an essential factor in evaluating a good educational game. It encompasses a multidimensional and complex process, involving the purely subjective feelings that users develop when using the product. These feelings can include emotions, beliefs, preferences, cognitions, physical and psychological responses, behaviors, and achievements. While most interactive design

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for games focus on user experience in traditional media, there is limited research on the interactive design of VR games based on user experience. By prioritizing interactive design that focuses on user experience, users can feel fully immersed and happy while using VR games. This approach also strengthens users' emotional needs and allows for the achievement of the optimal state of experience in a game, often referred to as a "flow" experience.

The proportion of the elderly population in China has been gradually increasing due to urbanization. However, the elderly face disadvantages in various dangerous situations, both in terms of cognitive psychology and their ability to take action. According to relevant data, fire is one of the most frequent and harmful disasters, and the elderly often become victims due to a lack of fire safety knowledge and the ability to escape. While there have been studies focusing on children's fire safety issues and the design of VR games for their training, there is limited research on games for training elderly individuals in fire safety. Traditional educational games have been found to have poor learning effects, while VR games have been shown to increase engagement and enthusiasm for learning. Studies have also demonstrated that the acquisition of flow experience improves engagement and enthusiasm among individuals. Therefore, this study aims to design a VR game specifically for the elderly age group to explore the most effective way to interact with the game to achieve a flow experience. This will help the elderly effectively acquire fire safety knowledge and skills, ultimately improving their ability to rescue themselves in the event of a fire.

2. Research background

Virtual reality technology is applied to game design, creating a "virtual scene" that immerses players in the game and allows them to interact with machines naturally and harmoniously. This combination of virtual reality and gaming offers advantages that traditional games do not have (Zhang 2014, 88). One example is Google Inc.'s Project Expedition, which uses virtual reality to help students explore the surface of Mars and ancient Mayan civilization sites. Virtual reality is often used for safety training, such as training mine rescue teams, fire emergency rescue capabilities, and marine lifesaving training (Qiu, Ren and Yi 2018, 68). However, safety training for non-professionals using virtual reality technology is relatively rare.

Smith and Ericson (2009, 87) explain that virtual reality technology is used to simulate real fire scenes and help students learn about fire safety. Game interface design is used to encourage students to explore the virtual world. In 2016, a fire escape training game system was developed based on the "experience learning circle" and used gaming pedagogy to guide the design of virtual reality games, effectively enriching the field of education and training (Hu, Chen and Chen 2016, 934). In 2018, a study applied the combination of BIM (Building Information Modeling) and virtual reality to fire escape training in building construction sites. In 2019, a virtual reality-based behavioral skills training (VR-BST) model was proposed to train children's fire skills using a skill training approach from pedagogy. The study demonstrated that the VR-BST model can effectively help children acquire skills through numerous tests (Çakiroğlu and Gökoğlu 2019, 56). In comparison, this study aims to explore the best method of virtual reality game interaction by using the theory of flow as the theoretical basis of virtual reality game interaction design, to create flow experiences through interaction design.

2.1 The Concept of Flow

Flow is a state of immense pleasure in which an individual becomes completely engrossed in an activity, losing all self-awareness while maintaining a profound sense of control. This concept was introduced by Csikszentmihalyi in the 1960s. He discovered that people perform at their best, both physically and mentally, when they enter this state of flow. Time becomes irrelevant to them, as does their perception of their surroundings, resulting in an unparalleled experience (Chou and Ting 2003, 663). This optimal experience can be attained in various aspects of everyday life, such as sports, dancing, artistic creation, surgery, or playing games. Artists can achieve flow while creating their artworks, athletes can enter flow during their exercise, children can experience flow when playing games, and even adults can immerse themselves in flow while watching TV.

Flow plays an essential role in enhancing the positive experience of games. When players engage in a game, they experience a high level of participation and immersion that allows them to focus solely on the game, often losing track of time. This state of mind is what we refer to as a flow experience. In this study, we apply the flow theory to guide game design, aiming to explore the impact of various factors on virtual reality (VR) games. Specifically, we seek to determine whether the player factor and the design factor of a VR game contribute positively to the flow experience. It is worth noting that very few studies have utilized flow theory to guide the interaction design of VR games. Therefore, it is crucial to investigate whether VR games can deliver a rewarding user experience through interactive design, particularly in the field of education and training, which can facilitate knowledge and skill acquisition. Csikszentimihalyi argues that the individual's perception of their skill level is matched by the challenge presented in an external activity is crucial for achieving a flow experience. This implies that the individual can only experience flow when there is an equilibrium between their skill and the challenge they face (Zhai 2014, 198).

Csikszentmihalayi divides the dimensions of flow theory into nine elements: clear goals, timely feedback, the balance of challenges and skills, integration of behavior and consciousness, elimination of interference in consciousness, freedom of control, the disappearance of self-consciousness, time-conscious anomalies, and its own purposeful experience. Some researchers have also proposed that factors such as remote presentation (Lee, Aiken, and Hung 2012, 673), curiosity (Wan and Chiou 2006, 317) (Scoresby and Shelton 2011, 227), exploratory behavior (Voiskounsky, Mitina, and Avetisova 2004, 259), playability, higher capacity state (Chang 2013, 311), stress, and tension are also dimensions that influence the flow experience. Novak and Hoffman divide the nine characteristics of the flow experience into three types of experience factors: conditional, experiential, and outcome factors. Chen and Wigand divide them into three stages event, experience, and effect (Novak and Hoffman 1997, 1), as shown in Table 1.

Table 1. The characteristics of flow experience.

Csikszentmihalyi	**Novak and Hoffman**	**Chen and Wigand**
1. clear goals	1. conditional	1.event
2. timely feedback	2. experiential	2.experience
3. balance of challenges and skills	3. outcome	3.effect
4. integration of behaviour and consciousness		

5. elimination of interference in consciousness
6. freedom of control
7. disappearance of self-consciousness
8. time-conscious anomalies
9. purposeful experience

2.2 The model of flow theory

Most studies utilize flow theory as the theoretical foundation for investigating the optimal game experience. Flow theory is equally important for both gamers and designers as it allows for the examination of gamers' involvement and immersion in the game. Additionally, researchers have developed various models for evaluating game experiences (Berta et al. 2013, 164). The achievement of a flow state by users is considered a crucial objective in the design of VR game systems (Chen 2007, 31). In his work, Chen (2007) explores the concept of flow within a game environment and emphasizes the significance of maintaining a balance between the challenges presented by the game and the player's skills to achieve flow (Renard 2013, 93). The equilibrium between challenges and skills serves as a fundamental requirement for attaining the flow state (Cowley, Charles, Black, and Hickey 2008, 1). A mismatch between the challenge and the skill level inhibits the flow state. Jin (2012) and Renard (2013) have demonstrated that a balanced combination of high challenges and advanced technology triggers a heightened flow experience. Interestingly, Wang and Chen discovered that more challenging games, rather than ones attempting to match challenges with skills, can result in stronger heart flow experiences for players. This study will utilize the nine dimensions of flow theory as the theoretical foundation for designing VR games in the field of education and training for the elderly in fire safety.

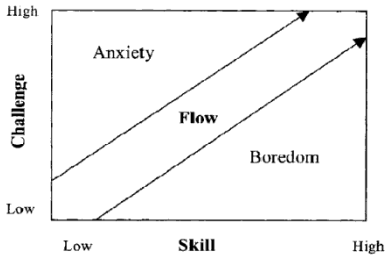


Figure 1. Flow Theory, Csikszentmihalyi

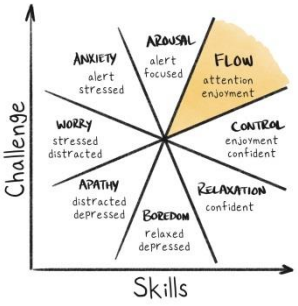


Figure 2. The Eight Channel Model.

There are several different models of Flow theory. Figure 1 shows a two channel model when the challenge constantly grows, the individual's skills must improve with it for flow to occur. Figure 2 dipicts a eight different stated of varying challenge and skills levels. If the challenge is too high, users become anxious about their performance and the outcome (Debold 2002). If the challenge is too low relative to their skill level, users get bored. When both the challenge and skill level are low, they feel apathy. Only when a user's skill level and the level of challenge are both high, will they begin to experience the deep involvement and enjoyment of a flow state. Anxiety and

boredom are common feelings that users experience regularly. Finding flow can be difficult to achieve but makes it all the more rewarding. Csikszentmihályi describes flow states as "flashes of intense living" against the dull background of our everyday lives. It is important to consider this when designing a game. In this study, we examine how flow theory can be applied to game design to enhance the user's experience. The fire safety training game has been specifically designed for elderly residents living in apartments. In the following sections, the research methods used and the outcomes are being discussed.

3. Research Methods

3.1 Interview

Interviews were used to introduce the concept of flow by Csikszentimihalyi. Interviews provide a direct, straightforward, and effective method for measuring the user's experience. This study employed semi-structured interviews, which involved making specific preparations before initiating the interview and adjusting the questions based on the user's condition during the interview process to attain the best possible outcomes.

3.2 Questionnaire

Questionnaires are one of the most commonly used research methods to evaluate the flow experience. The main questions are as follows:

a. Have you experienced flow while playing VR games?
b. How often do you experience a flow state during the game process?
c. In which scenarios do you typically experience flow?
d. Do you like to play the game again?

3.3 Experience Sampling Method

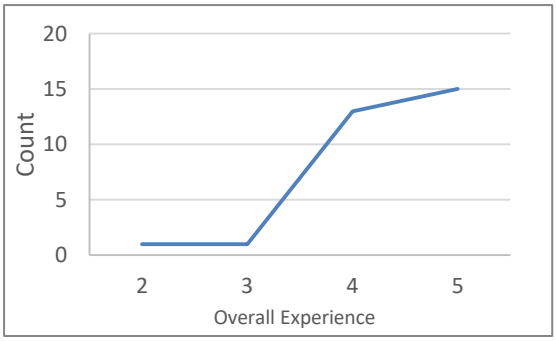
The Psychological Experience Sampling Method (ESM) provides a new perspective for studying flow. One advantage of ESM is its ability to assess an individual's daily life environment and collect information on their cognitive, emotional, and motivational states at various times (Reed and Csikszentmihalyi 2014). This method allows for the collection of real-time activities and experiences, ensuring accurate and objective results (Zhai 2014, 198). The objective of the Experience Sampling Method is to obtain self-reports for a representative sample of moments in people’s lives. Additionally, ESM enables sustainable research, enabling a better understanding of changes in subjects' flow status. To implement this method, a questionnaire should be designed in advance, including an electronic instrument capable of emitting sound and receiving questions from the main test at specified times. This method was only used during the gaming for this study. Participants should complete the questionnaire immediately and transmit it back to the main test.

3.4 Participants

Thirty participants were recruited for this study. The age of the participants were between sixty to seventy years old ($M = 63.43$, $SD = 2.96$). The selection criteria include the individual's health state, mobility, previous knowledge of fire safety, and gaming experience. The participants were required to complete the questionnaires before the game playing.

4. Results and discussion

Based on the results from the questionnaires, it has been shown that the flow experience utilized in the game design has yielded positive outcomes. Figure 3 shows that most of the users had high experience of flow. For flow experience, we asked the users to evaluate their flow experience. Most of them rated high scores (twenty-four users) while only six users rated low scores (Figure 4).To further analyze the data, we conducted tests to determine if there are any significant differences between age and the flow experience. For this study, we adopted the eight channel model, which consists of flow, worry, anxiety, arousal, relaxation, apathy, boredom, and control. A five-point Likert Scale was employed, with one point representing the lowest score and five points representing the highest score.



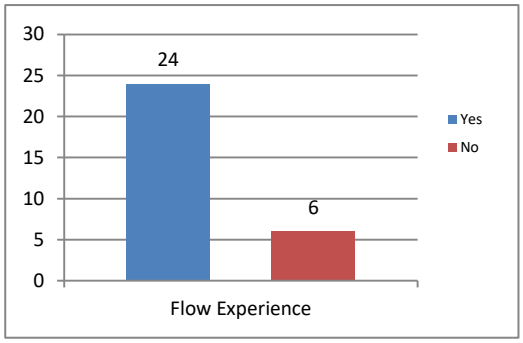


Figure 3. Overall experience of flow experience **Figure 4. Scores for the flow experience**

Table 2 presents the results of the flow experience after playing the game. The data indicates that there is no significant difference between age and the flow experience, with the exception of the apathy state. ANOVA test resulted in *p* being more than 0.05 in seven psychological states, while the results from the apathy state was $p = 0.01$ (< 0.05). This could be attributed to the fact that the players were older citizens who might not have been interested in gaming. However, this disparity does not affect their overall flow experience. Importantly, the findings suggest that the elderly population can also benefit from playing games, as they exhibit similar flow experiences to other age groups.

Table 2. Results of the ANOVA test for flow experience

Eight Channel Model		Sum of Squares	df	Mean Square	F	Sig.
Challenge	Between Groups	5.067	9	0.563	0.621	0.766
	Within Groups	18.133	20	0.907		
	Total	23.200	29			
Boredom	Between Groups	3.833	9	0.426	0.749	0.662
	Within Groups	11.367	20	0.568		
	Total	15.200	29			

Control	Between Groups	4.000	9	0.444	0.560	0.813
	Within Groups	15.867	20	0.793		
	Total	19.867	29			
Apathy	Between Groups	13.000	9	1.444	5.451	0.001
	Within Groups	5.300	20	0.265		
	Total	18.300	29			
Worry	Between Groups	4.733	9	0.526	0.585	0.794
	Within Groups	17.967	20	0.898		
	Total	22.700	29			
Anxiety	Between Groups	7.367	9	0.819	0.984	0.482
	Within Groups	16.633	20	0.832		
	Total	24.000	29			
Arousal	Between Groups	11.333	9	1.259	1.268	0.313
	Within Groups	19.867	20	0.993		
	Total	31.200	29			
Relaxation	Between Groups	11.20	9	1.244	1.098	0.407
	Within Groups	22.66	20	1.133		
	Total	33.86	29			

Most of the participants had no prior gaming experience. To determine whether there was a significant difference between gaming skills and the flow experience, we analyzed data collected from the game. The results showed that the flow, control, and relaxation states increased when the skills were high. Conversely, the flow, control, and relaxation states decreased when the skills were low. These findings indicate that higher skills lead to increased attention and enjoyment.

The results from The Psychological Experience Sampling Method (ESM) was also shown positive. We adopted interview to collect data from the users. The results from the interview also suggest positive outcomes from the experiment. Most of the participants reported experiencing a state of flow during the gaming process. For instance, they mentioned feeling enjoyment and confidence once they became familiar with the playing skills. Additionally, as the game levels progressed, they encountered increased challenges, signifying a greater level of difficulty in completing the game tasks. However, there is some limitations for this method. As this method is initially used for a research procedure for studing what people feel during their daily lives. The activity entails requesting individuals to provide regular self-reports at random intervals throughout a typical week during their waking hours. Collecting sets of these self-reports from a selected sample of individuals results in an archive of daily experiences. This type of the method

might not very suitable for this study, in particular in a gaming experience.

Overall, the results from the experiment suggest that flow theory can play a crucial role in designing games for the elderly. By considering the flow experience, designers can create various games that are better suited to the needs and preferences of this demographic.

5. Conclusion

This study proposes the design of a VR game for the elderly using flow theory. Flow is considered an optimal state of experience in game design that can enhance the user's engagement in learning. The study utilizes interviews, questionnaires, and ESM methods to evaluate the user's experience while playing the proposed game. It adopted ANOVA to analysis data. The results indicate that the game incorporating flow theory can provide a better user experience and ultimately lead to improved learning outcomes. In further studies, additional technology can be applied to enhance the learning experience, such as augmented reality (AR) game design.

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