Effect of Gamification of Exercise Therapy on Elderly's Anxiety Emotion

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Abstract. The anxiety of the elderly has been one of the most common psychological disorders, which will lead to increased mortality and economic loss. Exercise therapy has been shown to alleviate anxiety in the elderly. This study aims to compare the impact of simple exercise therapy and gamified exercise therapy on the elderly's anxiety. For the elderly, this research developed a prototype system which allows players to control the video game Tetris by hitting the punch bag to gamify the process of exercise. The study recruited 14 subjects with an average age of 66 years (60–75). The participants were divided into a control group with only simply punching and an experimental group with gamification intervention. This study used The State Trait Anxiety Scale and the Rating of Perceived Exertion. The game score changes in the experimental group were recorded. The results show that compared with simple exercise therapy, gamified exercise therapy has a more significant mitigation effect on the state anxiety of the elderly. The degree of exercise fatigue of both groups is consistent. It is shown that such simple gamification is not a big challenge for the cognitive ability of the elderly, and most of the participants felt satisfied with the procedure and expressed initiatives to play the game. This method might be a promising intervention for relieving the elderly's anxiety. In the future work, it is necessary to conduct long-term experiments to verify the effect of gamification of exercise therapy on the trait anxiety of the elderly.

Keywords: Gamification · Exercise therapy · The elderly

1 Introduction

Currently, the aging of population has become a severe social issue to be solved across the world. The entire society is under pressure to achieve a goal of active and healthy aging among the elderly. Elderly people are facing a variety of stress from health, family, income, interpersonal relationships, social obligations and role transition, which may increase the burden of and even cause harm to the elderly's mental health, and lead to frequent negative emotion such as depression and anxiety [1]. The data reveal that the rate of suffering anxiety disorder among aged citizens in China is as high as 22.11% [2]. In five European countries and Israel, the prevalence rate of elderly anxiety

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disorder is reaching 17.2% [3], which has been one of the most common psychological disorders. Elderly anxiety disorder increases the mortality and brings about large economic loss [4, 5].

Existing research has proved that exercise therapy can effectively reduce the level of anxiety emotion [6], and physical exercise can increase the resilience of the emotion when people are dealing with stress. According to some data analysis, the people who frequently participate in physical activities show less anxiety and depression and more extraverted than those who do not exercise [7].

Gamification is defined as using the elements of games under a non-game circumstance [8]. It can be used as a tool to improve the motivation and participation of different activities and tasks. Gamification has been widely applied in the field of military, education, treatment and healthcare [9]. A gamified application consists of the elements of games [9]. Reeves and Read once summarized ten elements of a great game: "self-representation with avatars, three-dimensional environments, narrative context, feedback, reputations & ranks & levels, marketplaces and economies, teams, parallel communication systems that can be easily reconfigured, time pressure" [10].

Gamification has widespread use in healthcare. Some research indicates that gamification and the serious game helps prevent and treat children's chronic diseases by changing children's behaviors. For instance, Kharrazi et al. [11] proposed that Theory of Planned Behavior-based serious game can enhance the treatment adherence of adolescent Type 1 Diabetes (T1D) patients; educational games effectively reduce the risk of hypoglycemia when adolescents with T1D are driving. Knöll et al. [12] discussed how the popularization of the prevention and treatment of chronic diseases benefits from the design strategy of city games, integrating gameplay with daily healthcare of adolescent diabetes patients. Hassan et al. [13] put forward a digital storytelling concept-based personalized game that helps autistic children between 9 and 14 establish a concept with money. For common diseases in the elderly, gamification and serious game are meaningful for the improvement of Parkinson's patients' mobility [14]. Ko [15] utilized a serious game with Arduino to enhance body's coordination so that the risk of cognitive decline can be decreased. Ma et al. [16] developed and tested a serious game that assists stroke patients in recovering the strength of upper limbs by exercise.

In healthcare, the combination of exercise therapy and gamification also raises some discussion and research. Over all research, many trials intended to prove the positive effects of exergame's or gamification's intervention on physiological monitoring and health care. For example, the study from Mhatre et al. [17] suggests that Nintendo Wii Fit can be an effective form of family intervention for patients with nerve damage with more convenience and less cost. Kempf and Martin [18] conducted a randomized controlled trial to test the effect of the interactive game Wii Fit Plus on the quality of life and physical activity of patients with Type 2 Diabetes Mellitus (T2DM), finding that this game obviously motivates the patients with T2DM to increase the level of physical exercise, glucose metabolism and quality of life. Lange et al. [19] designed a rehabilitation game 'JewelMine' based on Microsoft Kinect that consists of a set of static balance exercise and encourages players to increase the level of balance.

There are many studies trying to figure out the relationship between exergame's or gamification's intervention and people's psychological parameters. Meldrum et al. [20] applied the balance and walking exercise of Nintendo Wii Fit Plus to relieving anxiety and depression of patients with gait and balance damage. The study from Song et al. [21] suggests that the people with body image dissatisfaction (BID) can benefit from exergames with which the feeling of social anxiety is alleviated. Shin et al. [22] proved that the game-based virtual reality rehabilitation combined with occupation therapy has a certain effect on the improvement of upper limb functions and depression of hemiplegia patients with chronic stroke. Knox et al. [23] found that biofeedback-assisted relaxation therapy can effectively reduce the symptoms of adolescent negative emotions. In a recent study, Benzing and Schmidt [24] examined the effect of exergames for cognitive and physical demands on the executive function of children with attention deficit hyperactivity disorder (ADHD), proving that this kind of games has positive impact on executive function and ADHD.

Dori et al. [25] invited 19 older citizens who are suffering sub-syndromic depression (SSD) to participate in a 12-week trial with Wii Sports. The result demonstrates that the retention rate (86%) and compliance (84%) are high, and the symptoms of depression are markedly improved, which comes into conclusion that exergames are practical and acceptable for elderly patients with SSD and might be a new approach to the improvement of elderly depression. Chao et al. [26] investigated the influence of Wii Fit exergame combined with self-efficacy theory upon citizens physiologically and psychologically, conducted a trial and proved that the exergame is an effective method to elevate and maintain elderly's physical and mental health.

Among these exergame or gamification studies for the elderly, most of them concentrate on rehabilitation training or cognitive function. Few of them focus on the prevention of mental disorders; even fewer on the elderly anxiety emotion. Since exercise therapy has been proven to effectively reduce anxiety emotion [6], our study aims at the elderly, gamifying the process of exercise therapy, and proves the usability and effectiveness of the design via a randomized controlled trial. By comparing the normal exercise and game-based exercise, the research investigates the effect of gamification of exercise therapy on elderly's anxiety emotion. Our goal is to design an effective and attractive intervention approach to the relief of the elderly's anxiety.

2 Materials and Methods

2.1 System Design

Before the design of the gamification, the study needs to investigate the physiological and psychological characteristics of the elderly to design. The physiological features of the elderly are as follow [27]:

- Visual acuity: color vision changed; sensitivity to color and shape reduced; descending capacity to adapt lightness and darkness; sensitivity to glare increased.
- Hearing: auditory system suffering degeneration; suffering hearing loss.

- Touch sensation: aging skin; sense of touch relatively declined.
- Brain: decreasing nerve cells; blood flow getting slow; ability to memorize, analyze and judge weakened.
- Skeleton and muscle: low bone density, high bone fragility; vulnerable to bone fractures and calcifications; suffering muscle atrophy; muscle strength lost; slowed response; athletic ability and strength declined; slow movements

As the physical decline with age and maladaptive role transition arise after the retirement, the elderly's psychological characteristics are also changed, such as cognitive decline; negative emotions caused by physical functions and external environment like anxiety, depression and loneliness [28]; nostalgia; habitual psychology; the pursuit of internal value [29].

Therefore, researchers can follow some design strategies that are suitable for the aged when gamifying the exercise therapy (see Table 1).

Considering the uncertainties and other uncontrollable factors of the outdoor activity, the study determined indoor punching on punch bags as exercise. This study integrated the height-adjustable punch bags with some pressure sensors on the surface, using pressure as a signal input to control the game Tetris in the computer. When a user hits the punch bag, it triggers the movement of Tetris in the computer. The game interface is projected from the computer onto the wall in front of the user through a projector so that the elderly user can clearly watch the projected interface and play the game. The Tetris game was chosen because of its high popularity, which reduces the cost of learning new things for the elderly and is simple to operate. Considering the various characteristics of the elderly mentioned above, the interface of the Tetris was redesigned with high contrast and low-light colors, enlarged game elements, and when each Tetris brick is falling, a transparent brick is displayed at the bottom so that the elderly can be informed of the expected whereabouts.

This prototype used the Arduino UNO and pressure sensors to create the hardware part of the project and developed the software in C and Python. Arduino UNO [30] is an open-source microcontroller board developed by Arduino.cc. It is based on the microchip ATmega328P and equipped with a set of analog and digital I/O interfaces to connect with other circuits. Via the Arduino, the pressure signal can be converted into the keystroke signal of the computer. The three film pressure sensors replace the function of the left arrow, right arrow and space key of the computer. The left arrow represents the leftward movement of the Tetris; the right arrow represents the rightward movement of the Tetris; the space key represents the deformation of the Tetris. Researchers fixed the three film sensors on the three punch bags respectively. The elderly will hit these three punch bags with gloves to control the Tetris in the computer, and the game interface will be projected on the wall. The elderly can achieve the goal of exercise by the movement of the upper limbs and body.

The study used some gamification elements to motivate the elderly to exercise (see Fig. 1). In the sidebar of the redesigned game interface, there is a scorer which shows the score of the current game and the highest record. Every time a line of Tetris bricks is eliminated, the score will increase and positive feedback sound will be given.

The game has three difficulty levels, each of which is related to the falling speed of the brick, and the user can select the level according to his or her own need. The game maintains a hierarchy. When the user's playtime reaches a certain amount, the game can get into a higher level. Within different levels, the user can obtain different game titles and badges.

Table 1. The design strategy for the elderly

Characteristic	Manifestation	Strategy
Visual acuity	Color vision changed; sensitivity to color and shape reduced; descending capacity to adapt lightness and darkness; sensitivity to glare increased	High contrast color; fewer visual elements; large screen; large font size
Hearing	Auditory system suffering degeneration; suffering hearing loss	High feedback volume
Touch sensation	Aging skin; sense of touch relatively declined	Appropriate texture
Brain	Decreasing nerve cells; blood flow getting slow; ability to memorize, analyze and judge weakened	Relatively simple rules and flows; adjustable game speed; handy operations
Skeleton & muscle	Low bone density, high bone fragility; vulnerable to bone fractures and calcifications; suffering muscle atrophy; muscle strength lost; slowed response; athletic ability and strength declined; slow movements	Appropriate exercise intensity; protective measures; adjustable height
Psychology	Cognitive decline; negative emotions caused by physical functions and external environment like anxiety, depression and loneliness [28]; nostalgia; habitual psychology; the pursuit of internal value [29]	Simple rules; clear objectives; clear feedback; motivations; fewer new things

2.2 Participants

In order to verify the impact of gamification of exercise therapy on elderly's anxiety, this study recruited 14 participants of different backgrounds with an average age of 66 (ranging from 60 to 75). All participants were asked to sign a consent and fill out a subjective basic information questionnaire. The inclusion criteria are as follow: (a) clear consciousness and communication with people; (b) autonomous mobility, no physical diseases that may cause serious discomfort due to exercise, such as heart disease and cerebral infarction; (c) no large amount of food or alcohol consumption 1 hour before the experiment; (d) no large amount of exercise 1 hour before the experiment.

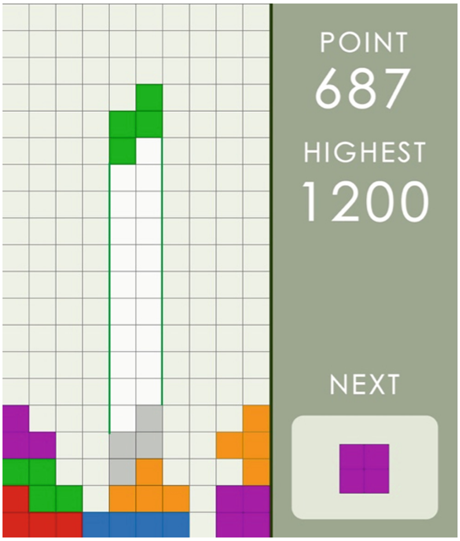

Fig. 1. Game interface

2.3 Procedure

First of all, a training session was given to all participants in order to familiarize our equipment, user interface and the correct method and strength of punching on the punch bag. After the training session, each participant was expected to reach a status of self-use of the equipment. Researchers sequenced 14 participants sequentially, and then used a pseudorandom number generator to generate the serial number. The first 6 participants were selected into the control group and the last 8 participants were selected into the experimental group. The control group only performed single punching on the punch bag, while the experimental group engaged in the game intervention during the punching. The experiment lasted for 20 minutes.

2.4 Measurements

The study mainly measures the following aspects: anxiety level, fatigue level, satisfaction and design efficacy.

- Anxiety level—Anxiety level is tested by using the State-Trait Anxiety Inventory (STAI). The STAI consists of two subscales which evaluate two different types of anxiety for a total of 40 items. The State Anxiety Scale (S-AI) primarily assesses an individual's immediate emotional experience or feelings. The Trait Anxiety Scale (T-AI) is used to assess more stable anxiety and tense personality, i.e., emotional sensations in a near period of time [31]. The higher the score is, the higher the anxiety level is. In order to verify the influence of gamification of exercise therapy on the anxiety of the elderly, the control group and the experimental group need to fill out the scale before and after the experiment.

- Fatigue level—The Rating of Perceived Exertion (RPE) [32] is used to assess the perceived amount and intensity of exercise in order to investigate the fatigue level of gamified exercise.
- Efficacy indicators—The change in scores of each task is recorded and compared by the researchers.

3 Results

3.1 STAI

After an F-test, this study used a two-sample homoscedastic T-test to evaluate whether the baselines of the two groups were consistent. The result of the T-test shows no significant difference between the baseline of the S-AI in the experimental group and the control group ($p = 0.95 > 0.05$) and the baseline of the T-AI ($p = 0.08 > 0.05$) (See Table 2). Therefore, the samples have statistical significance.

Table 2. STAI score baseline

Scale	EG (Mean ± SD)	CG (Mean ± SD)	F test (p)	Homoscedastic T-test (t)	Homoscedastic T-test (p)
S-AI	40.00 ± 9.97	40.33 ± 10.91	0.35	2.18	0.95
T-AI	45.50 ± 6.30	39.50 ± 5.01	0.14	2.18	0.08

Table 3. Paired T-test of baseline and post-intervention STAI of experimental group

Scale	S-AI		T-AI	
	Baseline	Post-intervention	Baseline	Post-intervention
Mean	40.00	27.88	45.50	37.38
Variance	99.43	55.55	39.71	81.41
Person correlation coefficient	0.52		0.29	
t Stat	3.89		2.44	
P(T <= t)	0.006		0.044	
t	2.36		2.36	

The study used a paired T-test to evaluate the difference in values between the experimental and control groups before and after the experiment. The T-test shows that the S-AI of the experimental group is significantly different before and after the experiment ($p = 0.006 < 0.01$), while the T-AI has some differences before and after the experiment but not obvious ($0.01 < p = 0.044 < 0.05$) (See Table 3). The S-AI of the control group shows some differences before and after the experiment but it is not obvious ($0.01 < p = 0.029 < 0.05$), and the T-AI does not differ before and after the experiment ($p = 0.65 > 0.05$) (See Table 4). This proves that the gamification of exercise therapy has a significant effect on reducing the state anxiety of the elderly compared with the simple exercise therapy, and has a certain effect on relieving the trait anxiety of the elderly but is not obvious.

Table 4. Paired T-test of baseline and post-intervention STAI of control group

Scale	S-AI		T-AI	
	Baseline	Post-intervention	Baseline	Post-intervention
Mean	40.33	34.00	39.50	36.67
Variance	119.07	180.80	25.10	243.07
Person correlation coefficient	0.93		0.38	
t Stat	3.03		0.48	
P(T <= t)	0.029		0.65	
t	2.57		2.57	

3.2 RPE

The study used a two-sample heteroscedastic T-test to detect differences in RPE between the experimental and control groups. The data shows no obvious difference in RPE between the two groups ($p = 0.08 > 0.05$) (See Table 5).

Table 5. RPE score

Scale	EG (Mean ± SD)	CG (Mean ± SD)	F test (p)	Heteroscedastic T-test (t)	Heteroscedastic T-test (p)
RPE	11.13 ± 2.42	13.00 ± 1.10	0.059	2.23	0.080

The mean of RPE in the experimental group is 11.13, and that in the control group is 13.00. According to Scherr et al. [33], for individuals with less exercise, the fatigue level of 11–13 is recommended. In this experiment, most of the participants in both the experimental group and the control group obtained a relatively comfortable exercise experience.

3.3 Efficacy Indicators

All participants in the experimental group were able to quickly master the skills of our equipment and game after a brief training by the researchers. Most of the game scores in the experiment rose during the procedure (See Fig. 2). In the experimental group's game, only a small number of participants required researchers to perform very little verbal intervention, and most participants did not need verbal intervention. The operation of all participants became more and more skilled in 20 minutes.

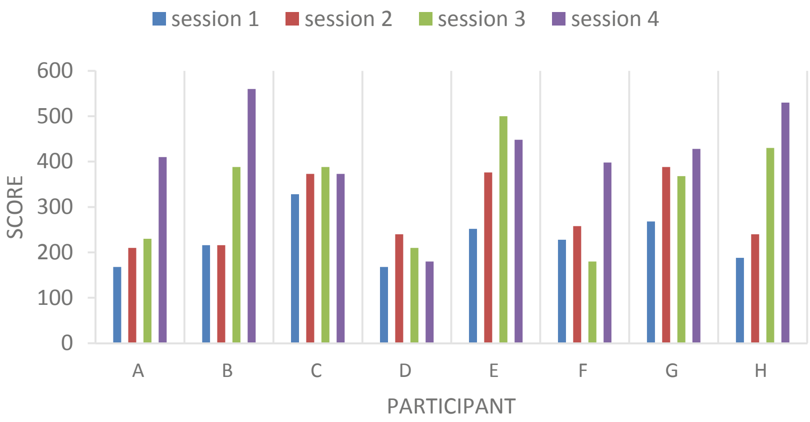

Fig. 2. Tetris score obtained in the first four sessions

3.4 Qualitative Feedback

Among the participants, the most popular exercise is walking; the second popular exercise is Tai Chi, gymnastic exercise and dance, followed by basketball, table tennis and cycling. All participants stated that they exercised for the health of the body and relief from mental fatigue. One participant said that in addition to the above reasons, she also had physical exercise to alleviate dementia.

As for the incentives for physical exercise, except that two participants said that physical exercise was carried out only when a friend invited, other participants said that they would take the initiative to carry out sports activities.

In the choice of sports locations, most of the participants prefer inside the community. The second popular is the park or plaza in the neighborhood. The third is on campus near the home. A small part of people exercise at home.

In the number of years of persistence in physical exercise, the proportion of participants who persisted for less than 5 years accounted for 21%. The proportion of participants who adhered to 5 years to 10 years accounted for 21%, and the proportion of participants who persisted for more than 10 years accounted for 58%.

In terms of anxiety, 50% of the participants said they often feel anxious. 28% said they have occasional anxiety. 22% said they never feel anxious. The main cause of their anxiety is family reasons, followed by work issues, and a fraction of the people felt anxious for economic and physical reasons. The most popular way among them to cope with anxiety is by exercising to ease negative emotions, followed by entertainment and reading. Only a small number of participants did not know how to handle the emotion when they were anxious.

In terms of contact with video games, 14% of participants said that they never have any experience, 28% said they play regularly, 16% said they play occasionally, and 42% said they played before but they do not play recently. One participant introduced himself as a result of excessive addiction to video games, once leading to periarthritis of the shoulder and cervical spondylosis. They mainly play games in casual and chess. 28% of people said that they have never downloaded a game in their electronic devices, and 28% said they had games in their electronic devices before but they don't have them. The remaining 44% said they have games in their electronic devices. At the attitude of video games for entertainment purposes, most of the elderly are open and tolerant. They believe that it is harmless to control the time of play. A small part believes that video games for entertainment purposes are harmful. For serious games, all the elderly think it is beneficial and acceptable.

At the end of the study, except for one participant who felt that the experimental process "not so meaningful", the other participants expressed "satisfactory with the procedure" and "willing to take the initiative to play the game". One of the participants was reluctant to end the game after the experiment, indicating that she could continue to play multiple sessions of games. The other two participants even asked the researchers to reopen the device and let them continue playing after the experiment.

4 Discussion and Conclusion

The results show that under a 20-minute experiment, the gamification of exercise therapy has a significant mitigation effect on the state anxiety score of the elderly compared with the simple exercise therapy, and has a certain influence on the trait anxiety value, although it is not obvious. The simple exercise therapy has a certain relief effect on the state anxiety value of the elderly, which is not obvious, and has no impact on the trait anxiety value. The reason might be that the trait anxiety value reflects the emotional feeling of the subject in the near future. Thus the short-term experiment has little effect on it. The effect of gamified exercise therapy on anxiety is not much differentiated between genders.

Through the results of the RPE measurement, it can be proved that the gamification of exercise therapy has no significant effect on the level of the elderly's fatigue and exercise intensity compared with the simple exercise therapy. And during the 20-minute experiment, both sides can obtain a more comfortable exercise experience with time. This study is at low cost of learning for the elderly since the elderly can master and use the device in a short time, which proves that in the face of simple video games, their cognitive ability is not a big challenge, and through the qualitative feedback, most of the participants felt satisfied with the procedure and expressed initiatives to play the game, and were positively optimistic about physical exercise and video games. Therefore, the use of gamification to promote exercise therapy is achievable and encouraged.

The limitations of this study include a small sample size that falls within a small experimental range, and it belongs to a short-term experiment, which can only test the influence of the gamification of exercise therapy and simple exercise therapy on the state anxiety of the elderly, but cannot reveal the impact on the long-term trait anxiety. In the future work, it is necessary to have a larger sample size and long-term trial of the experiment. In the meanwhile, it is also important to study further the changes in the anxiety of the subjects after the stop of the treatment for a period of time.

In conclusion, this study initially shows that the gamification of exercise therapy has a more significant mitigation effect on the elderly's anxiety than simple exercise therapy. This might be a more promising intervention method for the anxiety of the elderly.

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