The Effect of Familiarity on Older Adults' Engagement in Exergames

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Abstract. With entertaining game graphics and tasks, exergames can provide benefits for older adults to effectively exercise their physical and mental capabilities. However, it is sometimes difficult for exergames to engage older adults due to maladaptation. In this work, we suggest that the feeling of familiarity can positively influence older adult's adaptation to exergames. Based on this intuition, to help exercise older adult's upper limbs, we design a Ping Pong Exergame (PPE) infused with table tennis activities, which has been shown to be one of the most popular (thus familiar) sports among Singaporean older adults. A five-week study involving 44 Singaporean older adults shows that the participants who have higher levels of familiarity to table tennis exhibit higher motivation and ability in playing PPE, which indicate that familiarity can improve older adults' adaptation to exergames.

Keywords: Familiarity · Exergame · Person-Environment fit

1 Introduction

The pace of aging is accelerating all over the world in the coming decades [26]. Older adults may encounter various health related issues as they age, such as the reduction in their motor and cognitive abilities. Rehabilitation exercise has been designed to help older adults recover from their deteriorated capabilities effectively and efficiently. Older adults are advised to frequently take those rehabilitation exercises designed based on their specific conditions. However, the adherence rate to rehabilitation exercises is often low, due to the fact that most rehabilitation exercises contain repetitive physical movements which tend to be boring for older adults [24]. As technology advances, gamified rehabilitation exercises, or exergames, has been shown to be more attractive to older adults with entertaining game graphics and interactive tasks [23]. Moreover, exergames with

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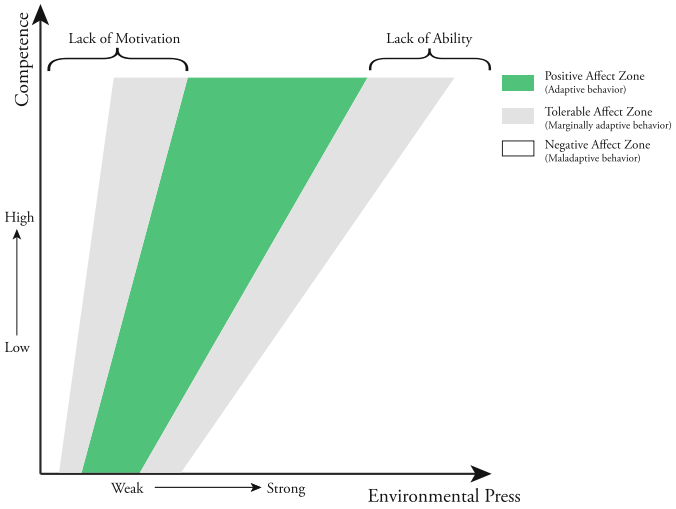

Fig. 1. P-E fit model.

motion detection devices, such as Microsoft Kinect, make it easy for older adults to interact with exergames using natural body movements. Hence, exergames have been widely studied to help older adults recover their physical and mental capabilities [6,7,29].

However, it is not easy to motivate older adults to voluntarily play exergames unless the games are attractive enough [1]. One of the key reasons that make exergames unappealing is the lack of engagement and enjoyment [18]. Moreover, some of the new technologies and devices may be over complex and difficult for older adults to use [18]. All these reasons lead to older adult's maladaptation to exergames. To understand why maladaptation occurs, we refer to the Person-Environment (P-E) fit theory originated from the gerontology research [16]. According to this theory, a person's Behavior (B) reflects how well the Person's competence (P, personal abilities) matches the Environmental press (E, environmental stimuli and barriers): $B = f(P, E, P \times E)$ [16]. As shown in Fig. 1, optimal adaptation will occur only when older adults' personal competence can appropriately fit the surrounding environment. Good adaptation will result in a feeling of comfort and enhance engagement and enjoyment [16]. However, maladaptation can occur in the following two cases: older adults with high competence in low press environments (low motivation) and older adults with low competence in high press environments (low ability).

As maladaptation occurs when personal competence does not match environmental press, we suggest that maladaptation can be mitigated by familiarity, which characterizes the relationship between a person and something (such as the environment) that the person has had considerable experience with [15]. Previous research shows that familiarity has an activating effect to arouse older adults' past feelings and emotions [14]. In familiar environment, old adults may

feel more comfortable and be more willing to improve their social and functional capabilities. Moreover, familiarity can evoke the older adults' past implicit and explicit memories [15], from which to recall the approaches to interact with the familiar environment [2].

To test whether familiarity has a positive effect in improving older adult's adaptation to exergames, we designed a Ping Pong Exergame (PPE) infused with table tennis activities for exercising older adults' upper limbs. The game offers older adults an enjoyable interactive environment for physical exercise and cognitive training. Table tennis is one of the most common sports in Singapore.[1] For older adults who often play table tennis, PPE offers familiar game environments and tasks. A five-week study with PPE involving 44 able-bodied Singaporean older adults was conducted. The participants were divided into three groups based on different levels of familiarity to table tennis. The experimental results indicate that familiarity has significant positive influence on older adults' ability and motivation during exergame playing.

The rest of this paper is organized as follows. Section 2 reviews the related works on P-E fit theory and familiarity design. Section 3 presents the framework of P-E fit theory with familiarity incorporated. We show the methodology and results of our study in Sect. 4. In the end, we make a discussion and conclude this paper.

2 Related Work

Comparing with traditional rehabilitation exercises, exergames can provide attractive graphical virtual environments designed in various ways to encourage users to become more engaged, immersed, and motivated [28]. In this section, we first review the P-E fit theory and then the existing research on familiarity.

2.1 P-E Fit Theory

Lewin first proposed the heuristic formula $B = f(P, E)$ in the initial P-E fit model, which is used to characterize the behavioural effect caused by the matching between the state of a person P and his/her surrounding environment E [19]. Lawton then added another interactive term $P \times E$ into the original formula: $B = f(P, E, P \times E)$, to account for the behaviors influenced by the interaction between an individual's competence and the environmental press [16]. This theory was used to analyze older adults' physical and psychological well-being [17]. As older adults age, they need to cope with both the external environment change and the internal capability decline. Iwarsson et al. [11,13] applied the P-E fit theory to developed a tool for evaluating interaction design of the surrounding environment for older adults. They stated that in order to help older adults age well, it is important to understand the relationship between the person and the

[1] https://www.channelnewsasia.com/news/singapore/table-tennis-gains-popularity-in-singapore-8127732.

environment [12]. However, research on new technology design for older adults seldom consider P-E fit. Our research aims to improve P-E fit between older adults and exergames.

2.2 Familiarity

Familiarity is thought to be an unconscious, automatic process that demands minimal attention [27]. Prior research on memory indicates that aging leads to a decrease in recollection, but does not influence familiarity [22]. Being familiar with a system means we are ready to operate it in an appropriate way based on our prior experiences [8]. On the one hand, familiarity plays an important role in any products use; if a user can implicitly recognize a thing, then he or she is more likely to understand its purpose and how to use it [21]. Son et al. [25] stated that familiarity can enhance older adults' functional ability (physical, psychological, and emotional abilities). Boger et al. [4] also found that familiarity can enhance faucet usability for older adults. On the other hand, familiarity can bring about emotional meaning and increase safety, usability, and attractiveness of the environment. Brittain et al. [5] found that familiar surroundings can provide the older adults with the confidence to get outdoors. Barry [3] also encouraged the incorporation of familiarity into the home design to bring positive changes for older adults.

In addition, familiarity has also been applied in new technology design for older adults. Leonardi et al. [18] designed WIMP (Window, Icons, Menus and Pointing) interfaces with familiar interaction modalities to enhance user experience for older adults. Hollinworth and Hwang [10] designed an e-mail application for older adults with familiar visual objects and operations. All the senior participants found the familiar interface easy to understand and they can quickly master how to use it. Prior research showed the effectiveness of familiarity in helping older adults to understand and interact with new technology, which encourages us to employ familiarity in exergame design to improve older adults' adaptation.

3 Modeling Familiarity in P-E Fit Theory

As shown in Fig. 1, Lewin defined three zones, i.e., positive affect zone, tolerable affect zone and negative affect zone, where adaptive, marginally adaptive and maladaptive behaviors can be produced, respectively. Familiarity characterizes a positive relationship between a person and the past experienced environment, which can improve the fit between older adults and the environment. Figure 2 illustrates how familiarity can impact Lewin's P-E fit model. We argue that familiarity can potentially enlarge the positive affect zone by improving both ability and motivation, referred to as zone A and zone M respectively. On the one hand, a sense of familiarity can evoke a person's implicit and explicit memories, so as to enhance their functional abilities [25]. On the other hand, familiarity can

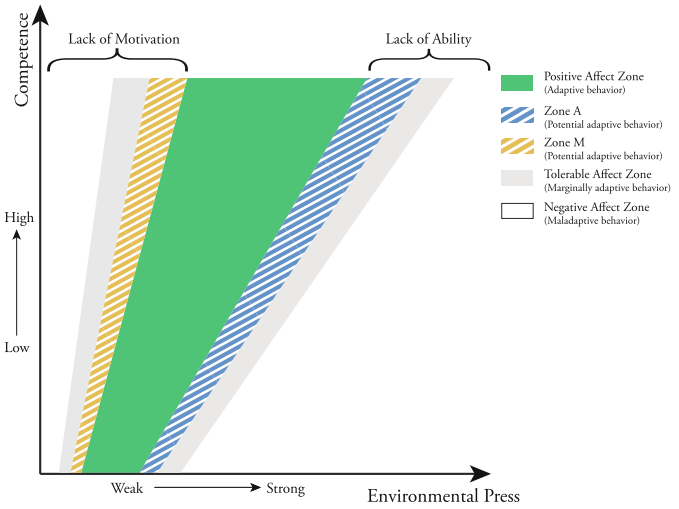

Fig. 2. Improved P-E fit model.

arouse a person's past positive emotions, so as to enhance their motivation [9,14]. Based on the original P-E fit formula, we extend it as:

$$B = f(P, E, P \times E \,|\, F), \tag{1}$$

where F represents familiarity that can induce positive adaptation changes.

4 The Study

To investigate whether familiarity can improve the P-E fit between older adults and exergames, we conducted a field study involving 44 Singaporean older adults. After the experiment, each participant received compensation in the form of shopping vouchers worth 20 Singapore dollars. IRB approval was obtained ahead of the experiment.

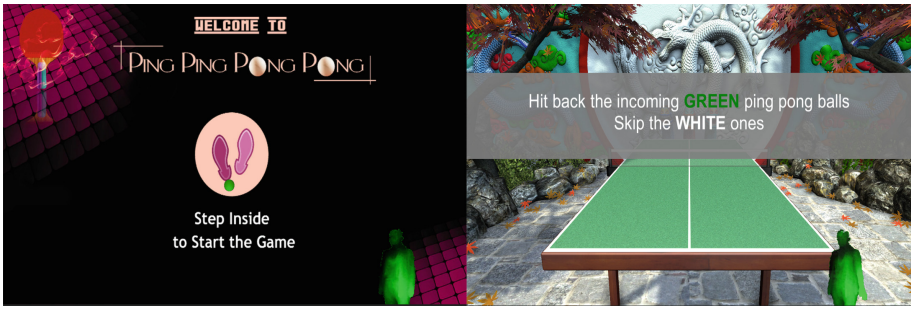

Fig. 3. Ping Pong Exergame.

4.1 The Ping Pong Exergame

In this experiment, we use a Ping Pong Exergame (PPE) designed by the Joint NTU-UBC Research Centre of Excellence in Active Living for the Elderly (LILY). PPE is an upper limb exercise game in the theme of table tennis (Fig. 3). Some fundamental cognitive tasks such as selective attention have also been infused into PPE for cognitive training. To play PPE, a participant simply stands in front of a Microsoft Kinect and naturally wave his/her chosen arm as if holding a table tennis bat. He/she needs to identify and hits the Ping Pong ball with designated color and ignore others (to practise selective attention). In this way, PPE offers both physical and cognitive training to older adults. Table tennis is one of the most common sports for older adults in Singapore. For older adult who frequently play table tennis, the interface and interaction mode of PPE tend to be familiar for them.

4.2 Participants

44 able-bodied Singaporean senior citizens (10 males and 34 females) volunteered to participate in this study. The study was conducted at a community center in Singapore. Participants were aged between 58 to 90 ($M = 71.7, SD = 7.88$). They were divided into three groups (never play, played a few time, often play) according to their prior experiences to table tennis, which are summarized in Table 1. Considering the fact that a person's age can have a significant impact on his/her game performance, we conducted ANOVA and pairwise T-test to investigate whether there are significant age differences among the three groups. From the statistical results (as shown in Table 2), it can be observed that all the computed $p > 0.05$, which indicates that there is no significant age difference

Table 1. Participants categorization based on their prior experiences to table tennis.

	Never play	Played a few times	Often play
Group	A	B	C
No.	7	10	27
Mean age	75	74	70
SD	3.28	2.23	1.26

Table 2. Pairwise T test and ANOVA results for group age difference.

Pairwise T test	t	p
Group A&B	0.16	0.877
Group A&C	1.53	0.135
Group B&C	1.62	0.114
ANOVA: $F = 2.01, p = 0.15$		

among different groups. Based on this results, we can exclude the effect of age to some extent on players' performance in different groups.

4.3 Experiment Design

A five-week longitudinal study is conducted to collect participants' long-term performance change and their adherence rate to PPE. A questionnaire with five-level Likert scale was designed to collect participants' subjective opinions. The questionnaire includes rated scores for enjoyment, satisfaction and perceived difficulty while playing PPE. Meanwhile, participants' game performance was automatically tracked by the game system. These results allow us to compare the motivation and ability of the participants in different groups, so as to find the impact of familiarity on users' P-E fit. The following four hypotheses were tested in this study:

H1: *Familiarity positively impacts older adults' performance in exergames.*
H2: *Familiarity reduces older adults' perceived difficulty of exergames.*
H3: *Familiarity improves older adults' enjoyment while playing exergames.*
H4: *Familiarity improves older adults' satisfaction for exergames.*

Hypothesis 1 and Hypothesis 2 are related to participants' ability while Hypothesis 3 and Hypothesis 4 concerns their motivation while playing PPE.

4.4 Procedure

Participants are required to play PPE once a week in the community center for five consecutive weeks (Fig. 4). Upon the first arrival at the experiment venue, all participants filled in a consent form and a short demographic survey before the experiment start. Each participant was allocated a QR code to track their long-term performance. During the experiment, participants were required to play PPE for about 20 min each time. Throughout the whole experiment, one researcher accompanied each elderly participant in case they encounter any problem during the experiment. After completing all five game sessions, the participants filled the questionnaire to collect their opinions about PPE. Although we

Fig. 4. Participants are playing PPE.

divided the participants into three groups based on their prior experiences of table tennis, they were not aware of the grouping during the whole experiment.

4.5 Results

38 out of 44 participants completed all the five sessions of the experiment. The other six participants each completed four sessions due to their unavailability in one of the five weeks. All participants joined the first and last game sessions.

H1: Does familiarity improve participants' performance? Participants' performance can be reflected by the in-game scores they received after each game session. We recorded their game scores for all the game sessions and calculated the average scores as their final game performance. We first conducted ANCOVA test to check the interactive effect between familiarity and age on participants' performance. The ANCOVA results show that the interactive effect between familiarity and age on participants' performance is not significant ($F = 1.33$, $p = 0.321$). Then, one-way ANOVA was conducted to compare the performance between different familiarity groups. Table 3 shows the ANOVA results. The results indicate that there is significant performance difference among three groups. In addition, the group with higher levels of familiarity received higher scores. These results support Hypothesis 1 that familiarity can positively impact older adults' performance in exergames.

Table 3. Game performance ANOVA results.

	Mean score	SD
Group A	2658	375.2
Group B	2905	225.3
Group C	3076	417.5
ANOVA: $F = 3.61, p = 0.036$		

H2: Does familiarity decrease participants' perceived difficulty? To evaluate the participants' perceived difficulty, we collected their self-rated understanding of the game rules through a five-level Likert scale in the questionnaire. Higher scores represent that the participants perceive less difficulty and they are more confident to complete the game tasks. As Hypothesis 2 is also related to the participants' ability to play the exergame, we first conducted ANCOVA to see the interactive effect between familiarity and age. The ANCOVA result indicates that this interactive effect is not significant ($F = 0.81, p = 0.611$) and the influence of age on participants' rated scores is not significant ($F = 0.93, p = 0.578$). Then, Kruskal-Wallis test was conducted to compare rated scores among different familiarity groups and the results are shown in Table 4. The results indicate a significant difference of rated scores in different familiarity groups. However, the mean score of Group B is smaller than Group A, which is in contrary to the hypothesis. To test whether the difference between Group B and Group A is

significant, we then conducted a pairwise analysis through Mann-Whitney test. The Mann-Whitney test result indicates that there is no significant difference between the two groups ($z = 0.745, p = 0.456$). In summary, the data provides partial support for Hypothesis 2. In particular, the group with the highest level of familiarity to table tennis would perceive significantly less difficulty when playing PPE than other groups.

Table 4. Perceived difficulty Kruskal-Wallis test results.

	Mean score	SD
Group A	4.0	0.22
Group B	3.7	0.26
Group C	4.4	0.14
Kruskal-Wallis: $H = 7.61, p = 0.022$		

H3: Does familiarity improve participants' enjoyment? Participants' enjoyment was also collected through a five-level Likert scale in the questionnaire. We conducted Kruskal Wallis test to compare the rated enjoyment among different familiarity groups. Table 5 shows the Kruskal Wallis test results, which indicate that the influence of familiarity on participants' enjoyment is not significant ($p > 0.05$). Hypothesis 3 is not supported from this results. However, the mean values of the rated enjoyment increase with higher levels of familiarity, which indicates some effect of familiarity on improving participants' enjoyment during the exergame.

Table 5. Enjoyment Kruskal-Wallis test results.

	Mean score	SD
Group A	3.57	0.37
Group B	3.60	0.27
Group C	4.19	0.16
Kruskal-Wallis: $H = 4.91, p = 0.086$		

H4: Does familiarity improve participants' satisfaction? In the questionnaire, we asked participants to rate their overall satisfaction to PPE with a five-level Likert scale. The Kruskal-Wallis test results of rated satisfaction in different groups are shown in Table 6. The results indicate that familiarity has significant influence on participants' overall satisfaction to PPE. From the mean scores we can find that groups with a higher level of familiarity rated higher satisfaction scores. Therefore, Hypothesis 4 is strongly supported by our data.

Table 6. Overall satisfaction Kruskal-Wallis test results.

	Mean score	SD
Group A	3	0.22
Group B	3.1	0.18
Group C	3.7	0.13
Kruskal-Wallis: $H = 8.93, p = 0.012$		

4.6 Discussion

In this section we discuss the experimental results and summarize the contribution of our work. We explored the effect of familiarity on the P-E fit between older adults and exergames. Hypothesis 1 and Hypothesis 2 concerns older adults' ability during the exergame play. The results indicate that participants' prior experience to table tennis significantly influence their game performance and their perceived game difficulty. During the study, we found some participants who are familiar with table tennis showed professional posture and mastered the rhythm of hitting quickly. They quickly understand the rules of PPE and received high scores after the game sessions. In terms of perceived difficulty, we found only Group C rated higher scores for their understanding the game rules. This suggests that the participants who often play table tennis are really confident to play PPE. Although participants in Group B did not rate higher score for their understanding of game rules than those in Group A, the in-game performance of Group B is actually significantly higher than Group A. Therefore, although the participants only play table tennis a few times in their daily life and they are not confident enough of their table tennis skills, they still perform better than participants with no experience of table tennis at all.

Hypothesis 3 and Hypothesis 4 focus on participants' motivation while playing PPE. However, Hypothesis 3 is not supported by the statistical results, which means that participants' enjoyment is not significantly improved with familiarity. Yet some effect of familiarity can be found because the mean enjoyment scores is growing with increased level of familiarity. Moreover, participants' enjoyment is influenced by many factors. For example, five weeks of the same exergame playing may decrease their enjoyment. Hypothesis 4 is supported by the collected data. Higher satisfaction represents higher motivation of the participants to play PPE, which can improve the P-E fit between older adults and the exergames. In addition, we found no significant difference of rated scores for enjoyment and satisfaction between Group A and Group B. However, a significant increase of those scores is observed in Group C. This indicates that the influence of familiarity on improving older adults' motivation is more effective when the exergames are highly familiar for them.

5 Conclusion

In this work, we suggest that older adults' feeling of familiarity can improve their adaptation to exergames. We incorporate familiarity into the initial P-E fit model and show that familiarity can improve P-E fit by enhancing older adults' motivation and ability. A study involving 44 Singaporean older adults was conducted to evaluate the impact of familiarity. The experimental results show that familiarity can positively influence participants' ability and motivation in the exergame. Thus, we suggest that familiarity design can increase older adults' engagement in exergames. Although the feeling of familiarity is related to people's past experiences and varies from person to person, we can always find some shared experiences and stories for the older adults from the same region, culture or with the same hobbies.

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