Sense of Familiarity: Improving Older Adults' Adaptation to Exergames

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ABSTRACT

Exergames are proven to be effective in helping older adults improve their physical and mental capabilities. However, older adults' maladaptation to exergames may occur due to the complexity of game tasks and interfaces. In this work, we show that familiarity can improve older adults' adaptation to exergames. The results of our first study indicate that older adults with higher level of familiarity to exergames exhibit higher level of motivation and ability. To maximize the effectiveness of exergames, it is helpful to provide older adults exergames which they are more familiar with. To evaluate the familiarity level of exergames, we propose a novel familiarity model with five factors, namely prior experience, positive emotion, repeated time, level of processing, and retention rate. Results from our second study show that the identified five factors have significant positive correlations with familiarity and there is a high positive correlation between familiarity levels and participants' satisfaction to the exergames.

CCS CONCEPTS

• **Human-centered computing** → **HCI design and evaluation methods**; *Empirical studies in HCI*.
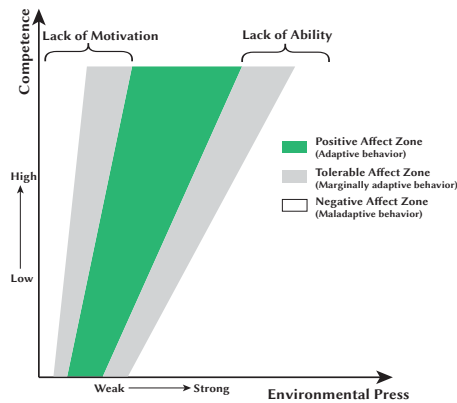
Figure 1: P-E fit model

KEYWORDS

Familiarity; P-E fit; exergame; older adults.

INTRODUCTION

Aging is accelerating around the world. One common issue faced by a large portion of older adults is the decline in their functional abilities. As technology advances, exercise games (exergames) are designed to rehabilitate older adults with entertaining graphics and tasks [8]. Previous research has shown that exergames are effective in helping older adults maintain their physical and mental abilities [9]. However, due to the perceived complexity and difficulty of new technologies, it is sometimes difficult for older adults to voluntarily take up exergames or engage in exergame playing [1]. As highlighted by Loos [7], such barriers are often caused by the unfamiliar game interface and task designs.

To improve older adults' engagement in exergames, we refer to Person-Environment (P-E) fit theory in gerontology research [6]. This theory indicates that person's Behavior (B) is reflected by the matching between Person's competence (P, personal abilities) and Environmental press (E, environmental stimuli): $B = f(P, E, P \times E)$ [6]. Figure 1 shows that adaptive behavior will be activated when personal competence can appropriately match environmental press. Older adults with high competence lack motivation in the weak-press environment and older adults with low competence lack ability to interact with strong-press environment, which lead to their maladaptation to environment.

To address the issues above, an ideal design should be able to expand the positive affect zone by increasing older adults' motivation and ability. Familiarity is the relationship between individual and something that individual has had considerable experience with [4]. It plays an important role in reducing the perceived complexity in handling the environment, and in creating a feeling of harmony and comfort. On the one hand, familiarity will evoke older adults' past memories and make them recall the approaches to interact with the stimulus to enhance their abilities [2]. On the other hand, there will be an activating effect to arouse older adults' past feelings and enhance their motivations when encountering familiar stimulus [5]. Motivated by this, we suggest that familiarity can improve P-E fit and increase older adults' engagement in exergame. To test the effectiveness of familiarity on improving older adults' engagement in exergames, we first developed *Ping Pong* exergame based on table tennis, which is one of the most common sports in Singapore[1]. A one-month study with *Ping Pong* involving 44 Singaporean older adults was conducted. The participants were divided into three groups of familiarity levels based on their prior table tennis experience. The experiment results indicate that familiarity has significant influence on participants' ability and motivation in exergames.

Above results show that exergames with high levels of familiarity are more helpful for older adults. Therefore, evaluating exergames' level of familiarity is important. A common approach to evaluate familiarity in previous research is to ask users to directly rate their overall familiarity [3], which is not
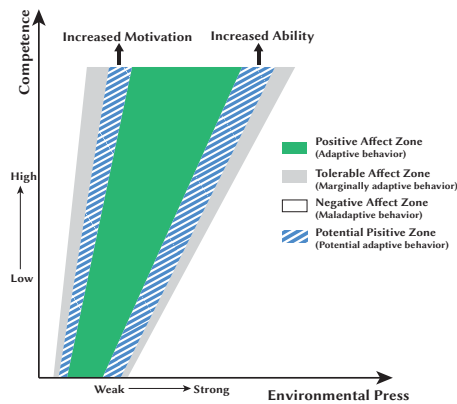
Figure 2: Expanded P-E fit model

Table 1: Participants categorization based on their prior experiences of playing table tennis.

	Never	A few times	Often
Group	A	B	C
No.	7	10	27

Table 2: Participants' game performance ANOVA results

	Mean	SD
Group A	2658	375.2
Group B	2905	225.3
Group C	3076	417.5

ANOVA: $F = 3.61, p = 0.036$

accurate enough since users may share different evaluation standards. After reviewing literature on human factors affecting familiarity, we propose a novel multi-dimensional model that explores five factors that are correlated with familiarity: prior experience, positive emotion, repeated time, level of processing, and retention rate. Our second study aims to evaluate the proposed familiarity model and users' satisfaction to exergames with different familiarity levels. Four exergames are selected in this study. 59 older adults participated in this study and reported their overall familiarity and satisfaction levels to each exergame with 7-level Likert scale questions. Meanwhile, we collect their self-assessment to the proposed five factors on each exergame. The experiment results indicate that the five factors have significant positive correlations with familiarity and that there is a significant positive correlation between familiarity and users' satisfaction towards exergames.

FAMILIARITY IN P-E FIT MODEL

To improve older adults' adaptation, prior research focuses on changing environmental press to fit older adults' competence. Familiarity can ensure the environment design is derived from older adults' personal preferences and increase the P-E fit. We extend the original P-E fit as: $B = f(P, E, P \times E | F)$, where F denotes the adaptation change with familiarity incorporated (Figure 2). On the one hand, a sense of familiarity in exergames increase older adults' functional abilities by evoking their memories. On the other hand, older adults' prior emotions will be aroused by familiarity and their motivation will increase. Thus, the positive affect zone in original P-E fit model can be expanded (Figure 2).

Study I

This study aims to test the effect of familiarity on older adults' motivation and ability when playing exergames. 44 participants aged between 58 to 90 ($M = 71.7$, $SD = 7.88$) joined this study. During the study, the participants are required to play *Ping Pong* exergame 20 minutes once a week for consecutive five weeks. Participants were divided into three groups based on their prior experiences with table tennis (Table 1). We recorded their game performance and designed a 5-level Likert scale questionnaires to collect their subjective opinions to *Ping Pong* exergame. We investigated the influence of familiarity on participants' performance, perceived difficulty and satisfaction levels in *Ping Pong*.

- Participants' performance is reflected by the average scores they received after playing the game. Since participants' age may affect their performance, we first used ANCOVA tests with familiarity group and age as the factors. The 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 and results show that there is significant performance difference among three familiarity groups (Table 2). The results support the argument that familiarity can positively impact elder participants' performance in exergames.

Table 3: Participants' overall satisfaction Kruskal-Wallis test results

	Mean	SD
Group A	3.0	0.22
Group B	3.1	0.18
Group C	3.7	0.13

Kruskal-Wallis: $H = 8.93, p = 0.012$

Table 4: Participants' perceived difficulty Kruskal-Wallis test results

	Mean	SD
Group A	4.0	0.22
Group B	3.7	0.26
Group C	4.4	0.14

Kruskal-Wallis: $H = 7.61, p = 0.022$

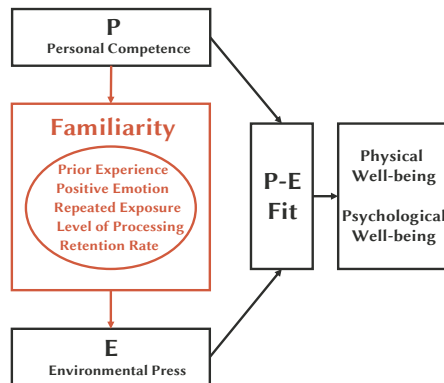**Figure 3: Extended P-E fit model with familiarity**

- Participants' perceived difficulty was collected by their self-reported understanding of the rules and skills to play *Ping Pong* exergame. ANCOVA was conducted and the results show that the interactive effect between familiarity and age on participants' perceived difficulty is not significant ($F = 0.81, p = 0.611$). Then Kruskal-Wallis test was conducted and the results show a significant difference of rated scores in different groups (Table 4). However, the mean scores of Group B is smaller than Group A, which is contrary to our hypothesis. Pairwise Mann-Whitney test analysis between Group A and B was conducted and no significant difference is found ($z = 0.745, p = 0.456$). To sum up, the group with very high level of familiarity would perceive significantly less difficulty than other groups when playing *Ping Pong* exergame.
- Participants' satisfaction to *Ping Pong* exergame was also gathered by a 5-level Likert scale question. The Kruskal-Wallis test results show that groups with higher level of familiarity rate significantly higher satisfaction scores (Table 3).

In summary, this study shows that familiarity has influence on older adults' performance, perceived difficulty and satisfaction to exergames. This suggest that familiarity can improve P-E fit by improving older adults' ability and motivation.

MODELLING FAMILIARITY

The results of study I show that older adults exhibit higher adaptation to the exergames with higher level of familiarity. Therefore, it is important to evaluate familiarity and recommend appropriate exergames to older adults. Prior research usually treats familiarity as a single-dimensional construct. A common approach to evaluate familiarity is to ask users to directly rate the perceived familiarity subjectively [3]. To better evaluate exergames' familiarity levels, we propose a novel multi-dimensional familiarity model with five factors highly correlated with familiarity: prior experience, positive emotion, repeated time, level of processing, and retention rate.

Prior experience represents a person's knowledge and experiences related to current stimulus. The source of prior experience is not necessary the stimulus itself, but the meaning of it or another stimulus related to it. *Positive emotion* refers to people's past positive emotions elicited by a similar stimulus. Highly emotionally intense events or stimulus tend to be remembered longer and with greater vividness. *Repeated time* refers to frequency of the stimulus appeared in one's memory. High frequency of repeated exposure will increase one's feeling of familiarity. *Level of processing* is the depth of processing in one's memory. Compared with shallow processing (perceptual-based), deep processing (meaning-based) leads to a consistent enhancement in familiarity. *Retention rate* refers to how much memory of the stimulus is retained, which is reflected by the time interval between last encounter and current encounter. Figure 3 shows the framework of our proposed familiarity model.
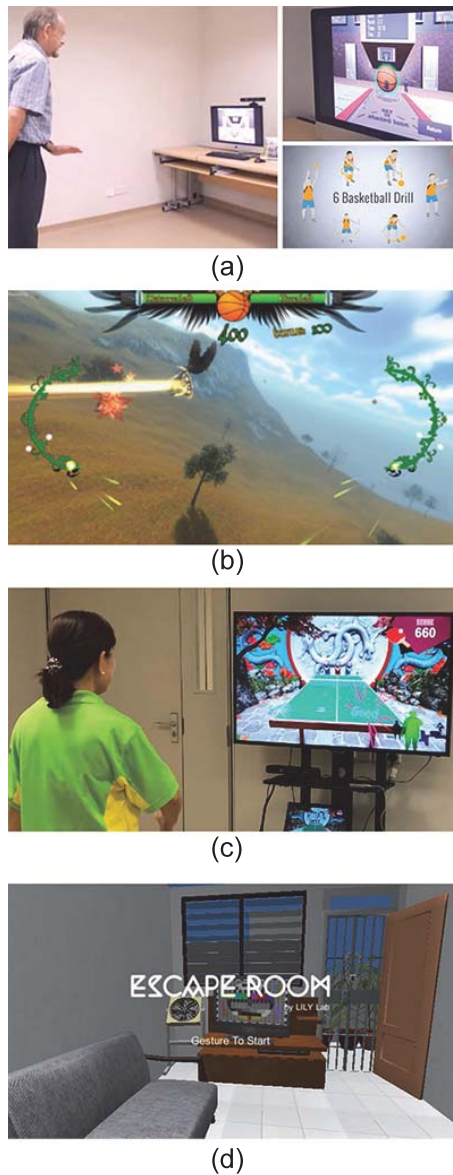
(a)

(b)

(c)

(d)

Figure 4: (a) Basketball Genius; (b) Flying Eagle; (c) Ping Pong; (d) Escape Room.

Study II

Study II aims to find the relationship between our identified five factors and familiarity. In this study, four exergames were included: *Basketball Genius*, *Flying Eagle*, *Ping Pong*, *Escape Room* (Figure 4). Older adults may share more or less familiarity towards different exergames based on their prior knowledge. 59 able-bodied Singaporean older adults (17 males) aged between 56 to 80 ($M = 67.3, SD = 6.1$) participated in this study. The participants were required to play all the four exergames and to fill a 7-level Likert scale questionnaire after each game. The questionnaires include specifically designed questions to collect participants' opinions about the five identified factors as well as their self-assessment of overall familiarity and satisfaction to the exergames. After removing the incomplete ones, we collected in total 222 valid questionnaires from all of the 59 participants (*Basketball Genius*: 54, *Flying Eagle*: 58, *Ping Pong*: 54, *Escape Room*: 56). We analyzed the collected results as below.

- Spearman's correlation coefficient test was conducted first to evaluate the correlation between the identified five factors and overall familiarity. Table 5 shows the results that the correlation coefficients between the five factors and familiarity are all significant. All the coefficients are larger than 0.5, which denotes at least moderate positive correlations. Three Factors show strong correlations with overall familiarity (coefficient > 0.6).
- The scatter plot of participants' overall familiarity and satisfaction is shown in Figure 5. The fitted value indicates the positive relationship between familiarity and users' satisfaction. We conducted the ordered logistic regression to statistically analyze this correlation. The results in Table 6 show that the correlation coefficient between familiarity and satisfaction is high (0.765), and it is statistically significant ($p < 0.01$). This result indicates that participants would exhibit higher satisfaction to the exergames with higher levels of familiarity.

The correlation values of *repeated time* and *retention rate* are relatively low. During the interviews with the participants, they often recalled their memories when they were still young and mentioned the keywords such as *childhood* and *many years ago*. It seems that some past memories, though occurred long time ago, are etched into their memory and will not fade away over time. For such experiences, *repeated time* and *retention rate* make a relatively smaller impact on their overall familiarity. The regression results shows that older adults are more satisfied with the exergames that is more familiar.

Table 5: Spearman's correlations between the proposed five factors and familiarity.

	Prior experience	Positive emotion	Repeated time	Level of processing	Retention rate
Familiarity	0.694	0.614	0.588	0.652	0.511
Sig.	<0.01	<0.01	<0.01	<0.01	<0.01
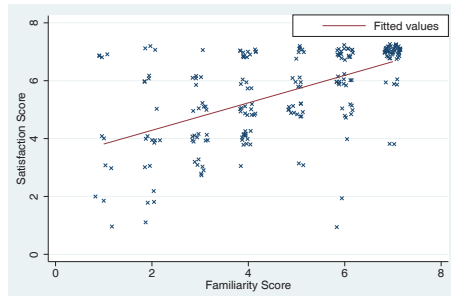
Figure 5: Scatter plot of overall familiarity and satisfaction scores.

Table 6: Ordered logistic regression result.

Observation = 222	LR $chi2(1)$ = 92.7			
Prob > $chi2$ = 0.00	Pseudo R^2 = 0.133			

	Coef.	Std. Err.	z	p
Familiarity	0.765	0.087	8.81	< 0.01

CONCLUSION

In this research, we suggest familiarity can improve older adults' adaptation to exergames. The results of study I show that familiarity can increase participants' ability and motivation in the exergame. To evaluate familiarity in exergames, we propose a multi-dimensional familiarity model with five factors. The second study highlights that all the five factors are significantly correlated to familiarity and there is a strong correlation between familiarity and user' satisfaction to exergames. Game designers can also consider the five factors when designing an exergame to increase the familiarity levels for older adults. Although the feelings of familiarity varies from person to person based on their prior experiences, we can always seek the shared experiences and stories for older adults from the same region, culture or with the same hobbies. For example, the game environment of *Escape Room* is designed as a typical Singapore housing unit and most participants reported they were familiar with that environment. Considering the similarities of a certain group of elderly, it is possible to design an exergame with familiarity that is suitable for a large group of elder users.

ACKNOWLEDGMENTS

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