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How to create flow experience in exergames? Perspective of flow theory

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ABSTRACT

Exergames are popular computer applications. However, exergaming literature has insufficiently explained the formulation of user-experienced flow and what user needs may facilitate such a formulation, indicating a gap. To fill the gap, this study adopts the flow theory to construct a framework and examines how enjoyment and challenge impact the creation of flow, and how users' need for achievement and need for exercise may facilitate it. We recruited 583 participants who were asked to play exergames and complete a survey. The analytical results indicate that exercise enjoyment is positively linked to flow, while the need for exercise strengthens such a link. Moreover, challenge is positively linked to flow, and the need for achievement strengthens that link. This study is the first using the flow theory to explain the process by which exergamers experience flow.

1. Introduction

Exergames are computer applications that combine gaming with exercise to enable users to exercise in the comfort of their own home without the need for a dedicated sports venue or expensive sports equipment. Exergames are growing in popularity worldwide. For example, a popular game (Your Shape: Fitness Evolved 2012) has sold over 1.16 million units globally (VGChartz, 2017), suggesting the importance of research into exergames.

Recent research has emphasized the physical and psychological health-related effects of exergames. Physical effects include improved fitness (Huang et al., 2017c), attitudes to other forms of exercise (Nguyen et al., 2016) and dynamic balance (Cone et al., 2015), as well as cardiac rehabilitation (Ruivo, 2014). Psychological effects include elevated mood states (Huang et al., 2017d), positive mood (Jin, 2010b), increasing exercise intentions by using avatar-based exergames (Jin, 2010a), excitement (Song et al., 2013), the reduction of social physique anxiety (Song et al., 2014), and self-efficiency and enjoyment during virtual-reality exercise (Zeng et al., 2017). Such literature indicates a growing interest in how exergames can influence both the physical and psychological health of gamers. In addition to physical and psychological benefits, exergames likely attract users to concentrate on playing, thus

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creating flow experience. Flow experience could encourage further use (Liao and Teng, 2017), indicating the importance of flow experience. However, no study has yet explored how exergamer needs (e.g., the need for exercise and the need for achievement) can be moderators of flow and its antecedents (i.e., exercise enjoyment, gaming challenge), indicating a knowledge gap. Research filling this gap should offer novel insights to guide exergame providers' efforts to enhance gaming experiences.

Exergames are a combination of exercise and games. The gaming element typically provides users with challenge and enjoyment (Lyons, 2015). Gaming challenges motivate users to concentrate on overcoming them and such concentration and intrinsic enjoyment are central to the definition of flow and the key mechanism of the flow theory (Csíkszentmihályi, 1997; Liao and Teng, 2017), motivating us to adopt the flow theory.

Moreover, the exercise element in exergames can create effects that are similar to doing conventional exercise (i.e., improve physical fitness) (Nguyen et al., 2016). Hence, exergames can fulfill users' need for exercise, justifying the inclusion of need for exercise as a moderator. Moreover, overcoming gaming challenges provides positive feedback when playing exergames, which can also meet users' achievement needs, justifying the inclusion of need for achievement as the other moderator.

Therefore, the purpose of this study is to examine how challenge and exercise enjoyment are related to flow, and how user needs (i.e., for exercise and achievement) moderate such relationships. Overall, this study contributes to exergaming literature by clarifying how user needs strengthen the process of flow creation. Specifically, this study contributes to exergaming literature in several aspects. First, Lyons (2015) explored the impacts of feedback, challenge, and rewards on user enjoyment while playing exergames. Our study is in line with Lyons (2015) in examining challenge and enjoyment when playing exergames, but is novel in clarifying how the two moderators (i.e., the need for exercise and the need for achievement) can strengthen the impacts of challenge and enjoyment on the formation of flow. Such a clarification deepens our understanding of challenge and enjoyment during exergame play.

Second, Barnes and Pressey (2016) examined users' propensity to experience flow in virtual worlds. In line with theirs, our study also examined the flow experience in virtual worlds, but is new in examining flow in exergames, the virtual worlds that require users to use greater body movement. Our study may lead future scholars to examine whether enhanced need for achievement could explain the findings of Barnes and Pressey (2016).

Third, Limperos and Schmierbach (2016) investigated the links among the experience of playing exergames, enjoyment and intention to play. Specifically, they found that gamer achievement directly and indirectly influenced autonomy, competence, presence, enjoyment, and intention to play. Furthermore, enjoyment and presence mediated the relation between gamer performance and intention to play. In line with theirs, the present study also investigated in-game experience and its influence on enjoyment, but is new in clarifying how the need for exercise moderates the link between enjoyment and flow, as well as how the need for achievement moderates the link between challenge and flow. The clarification demonstrates the role of user needs in determining the relations between enjoyment and user responses.

2. Literature review and hypotheses

2.1. Flow and exercise enjoyment

Flow is defined as an enjoyable experience created through total concentration in conducting a task (Csíkszentmihályi, 1997). Flow can help create user loyalty (e.g., in game contexts) (Hsiao and Tang, 2016; Liao and Teng, 2017). Flow has antecedents including immersion and presence (Novak et al., 2000), particularly when individuals fully engage in a pleasurable and challenging activity (Csíkszentmihályi, 1997). Flow provides pleasure, a sense of playfulness, and novelty (Hoffman and Novak, 2009), suggesting that individuals experience happiness and tend to repeat the same task due to the positive feedback they receive (Csíkszentmihályi, 1997). For this reason, mental states may influence individuals' behavior and attitude to re-engaging in the same tasks, warranting research on the formation of flow in exergames.

Flow theory posits that flow experience occurs when individuals engage attentively and immerse themselves in specific activities (Csíkszentmihályi, 1997) and when individuals' skills are well matched to the challenge (Hoffman and Novak, 2009). If their skills do not match the challenge, they may experience boredom, frustration or apathy, rather than flow (Csíkszentmihályi, 1997). In gaming contexts, frustration may motivate gamers to seek help through task team participation to overcome challenges (Huang et al., 2017b), which is known as necessary for creating flow (Liao and Teng, 2017). Overall, research is still needed to understand how to create sustainable flow experiences (Barnes and Pressey, 2016).

Flow theory has been widely applied in the context of the real world and the virtual worlds, including in social commerce (Liu et al., 2016), online gaming (Liao and Teng, 2017; Teng, 2017a,b), and e-selling (Parvinen et al., 2015). Such literature indicates that flow theory is useful for exploring individuals' attitudes, behavior, and experience in various contexts.

In exergaming contexts, game play can create positive psychological outcomes. One potential reason is that playing exergames resembles doing conventional exercise. During and after exercise, pleasure and satisfaction provide individuals with enjoyment (Motl et al., 2001). Hence, such exercise enjoyment should instill a positive mood in users of exergames (Song et al., 2014), and enhances engagement and interest (Sun, 2013). Strong interest should motivate users to concentrate on playing exergames. Concentration is a core element of flow (Liao and Teng, 2017) and, thus, exercise enjoyment should be positively related to flow.

H1. Exercise enjoyment is positively related to flow experienced by exergame users.

2.2. Need for exercise

Need for exercise refers to individuals' perception that they should engage in exercise to maintain or improve their health (Elliot and McGregor, 2001). Because exercise can improve health, those who pursue health are motivated to do exercise. This motivation may differ among individuals. Specifically, doing exercise can help enhance positive moods for those who suffer from health problems (Gaitan-Sierra and Hyland, 2014). Moreover, motivation to do exercise may be subject to a gender difference. For men engaging in exercise, challenge, competition, social recognition, strength, and endurance reached higher levels than among women (Kilpatrick et al., 2005). Among women engaging in exercise, weight management was given as a reason more than among men (Kilpatrick et al., 2005). That is, individuals can pursue doing exercise owing to varied motivations.

One of the motivations for playing exergames should be that it helps to improve physical health (Bronner et al., 2015). Unintentionally, playing exergames could also enhance users' attitudes toward other forms of exercise (Nguyen et al., 2016). Therefore, a higher need for exercise can boost the motivation of individuals who enjoy exercise to play exergames. Concentration is central to the definition of flow (Csíkszentmihályi, 1997). Therefore, a high need for exercise may strengthen the relation between exercise enjoyment and flow.

Conversely, individuals who have a lower need for exercise have less motivation to exercise. Without such motivation, they are less likely to engage in exercise. The similarity between doing conventional exercise and playing exergames (Noah et al., 2011) thus should hinder such less motivated (to do exercise) individuals from playing exergames. Hence, exercise enjoyment in this case is unlikely to heighten such individuals' concentration, restraining them from experiencing flow. Hence, we hypothesize the following:

H2. Need for exercise strengthens the relation between exercise enjoyment and flow experienced by exergame users.

2.3. Challenge and the need for achievement

Challenges are the obstacles and competitions embedded in certain activities (Rollings and Adams 2003). Overcoming challenges requires enhanced abilities. Challenges are vital components of exergames (Lyons, 2015), and are calibrated from easy to extremely difficult, to match the varied ability levels of gamers. Perceived challenge induces individuals to concentrate on gaming (Koo, 2009), which is core to the definition of flow (Hoffman and Novak, 2009). Hence, we hypothesize the positive link between challenge and flow. Flow theory (Csíkszentmihályi, 1997) can further be used to support this hypothesis, i.e., challenge positively contributes to flow. Such a theory has been applied to online games (Liao and Teng, 2017), but not in exergaming contexts.

H3. Perceived challenge is positively related to flow experienced by exergame users.

Need for achievement refers to an individual's need to overcome challenges when engaging in difficult tasks; this may inspire them to participate in competition (Phillips and Gully, 1997), fostering a sense of achievement. Therefore, individuals with a higher need for achievement are more highly motivated in a competition, and therefore concentrate on overcoming challenges in exergames. According to the flow theory (Csíkszentmihályi, 1997), such concentration is key to creating flow experiences. Therefore, we hypothesize that the need for achievement may strengthen the relation between challenge and flow.

However, individuals who have a weak need for achievement have a weak motivation to encounter challenges and thus their concentration is reduced in playing exergames. Such a reduced level of concentration hinders the formation of the flow experience (Liao and Teng, 2017). That is, a weak need for achievement hinders the link between challenge and flow. Hence, we hypothesize the following:

H4. Need for achievement strengthens the relation between perceived challenge and flow.

Fig. 1 illustrates the research framework. Liao and Teng (2017) found that skill and perceived challenge can independently contribute to flow, justifying our inclusion of perceived challenge. Furthermore, the present framework incorporates two novel moderators (i.e., need for exercise and need for achievement) that explain the relationship among exercise enjoyment, perceived challenge, and flow.

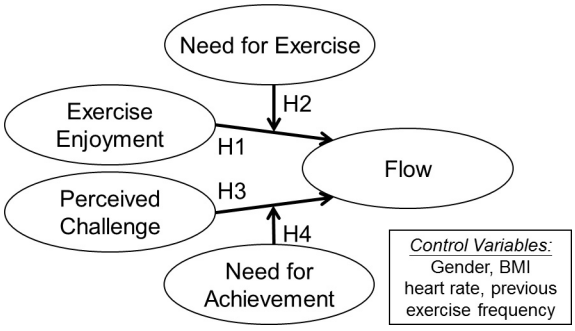

Fig. 1. Research framework.

3. Material and methods

3.1. Sample and data collection process

This study recruited participants from February to April 2016. In total, 741 university students in Northern Taiwan applied to participate. This study excluded those who had physical and psychological illness, including heart disease, high blood pressure, arrhythmia, heart failure, angina, spinal cord injuries, spinal arthritis, genetic arrhythmia, intracranial pressure, unstable blood pressure, cervical musculoskeletal system injury, glaucoma, high myopia, anemia, dizziness, asthma, or mental illnesses. These exclusion criteria ruled out the confounding effects of such diseases. The setting of exclusion criteria is a common element in recent exergaming studies (Nguyen et al., 2016).

The ethical aspects of this study were approved by an IRB (104-5543C). The sources of recruitment included bulletin boards and social networking websites, and potential participants joined this study through online registration. Before enrolling the participants, this study checked the exclusion criteria. Eligible participants were briefed on the main purpose of this study and asked to sign a written consent form.

In total, 741 participants applied, but 119 were not eligible, while 22 applied but later became unavailable. Moreover, this study discarded 17 responses that gave the same scores for all items on any page of the study questionnaire. In sum, among the 741 participants, there gave 583 valid responses (78.7%) for further analysis.

For hardware, this study chose the Microsoft Xbox 360 as its design captures the subtle motions and speed fluctuations of the gamer. For software, this study chose Your Shape: Fitness Evolved 2012, a popular exergame.

All participants played the exergame for 30 consecutive minutes. Before playing, participants were randomly assigned one program out of 10 that correspond to 10 forms of conventional exercise. After playing, the heart rate of each participant was assessed as a control variable, which enhanced the analytical rigor.

After playing, participants were asked to fill in the questionnaires, which carried items on the study constructs including exercise enjoyment, need for exercise, challenge, need for achievement, and flow. According to Hansen et al. (2001), 30 min is the amount of time needed to work out all the body muscles, and hence experience the benefits on health, both physically and psychologically. Therefore, the present study adopted the suggestion of Hansen et al. (2001). This study also collected personal information on gender, previous exercise frequency, and height and weight to calculate the body mass index (BMI).

3.2. Measurement

The items measuring perceived challenge and flow came from Novak et al. (2000). Participants were briefed on the concept of flow prior to rating items measuring flow, as done by Novak et al. (2000). Those items measuring exercise enjoyment were adapted from Motl et al. (2001) and those measuring need for exercise and need for achievement were adapted from Elliot and McGregor (2001). All of the above were measured using three items, conforming to the suggestion of the methodological literature (Iacobucci, 2010). All scores were averaged to represent the level of the construct. Moreover, high scores represented high levels in the constructs.

The participants were asked to provide information on their height and weight, and their BMI was calculated by dividing their weight (in kilograms) by their squared height (in meters). The heart rates of the participants were measured by research assistants. The BMI and heart rate (as well as gender and previous exercise frequency) were measured and used as control variables, as they may have contributed to whether participants experienced flow.

3.3. Psychometric properties

This study conducted a confirmatory factor analysis (CFA) to directly assess psychometric properties, i.e., reliability, validity, and measurement model fit. Regarding reliability, items measuring each construct had a Cronbach's α value of ≥ 0.80. Moreover, the lower bounds of the 95% confidence intervals for such Cronbach's α values were ≥ 0.77, indicating confident reliability (Iacobucci and Duhachek, 2003). Furthermore, items measuring each construct had a composite reliability (CR) value of ≥ 0.87 and an average variance extracted (AVE) value of ≥ 0.68, demonstrating acceptable reliability.

Indicator loadings were ≥ 0.73, suggesting sufficient convergent validity (Hair et al., 1998). Moreover, the maximum of the squared correlations (0.22) was still smaller than the minimum AVE (0.68), indicating adequate discriminant validity (Fornell and Larcker, 1981). Table 1 summarizes the results of CFA and the study items.

The data fit the measurement model acceptably (i.e., CFI = 0.93, NNFI = 0.91, IFI = 0.93). Such performance should be considered acceptable, as suggested in the methodological literature (Bagozzi, 2010).

Table 2 lists the correlations among the study constructs. All the correlations ranged from 0.03 to 0.47, indicating moderate correlations. These indicate the low likelihood of the issue of common method variance (CMV). This study further conducted a test on CMV based on the suggestion of Podsakoff et al. (2003). The model containing CMV had a significantly larger χ^2 value (i.e., $\Delta df = 149–122 = 27$; $\Delta\chi^2 = 883.73–670.42 = 213.31 > \chi^2$ (df = 27, $\alpha = 0.05$) = 40.11) than the original measurement model. Such a comparison indicates that the model containing CMV was statistically inferior to the original measurement model in fitting the data. That is, CMV should play a minimum role herein.

Table 1
Summary of confirmatory factor analysis.

Construct-Item	M	SD	λ	α	C.I. of α	CR	AVE
Exercise Enjoyment				0.91	[0.89, 0.92]	0.94	0.85
I enjoy playing the exergame	4.19	0.86	0.96				
I find playing the exergame pleasurable	4.15	0.89	0.97				
My body feels good after playing the exergame	4.11	0.86	0.83				
Need for Exercise				0.81	[0.78, 0.84]	0.87	0.68
It is important for me to do more exercise	4.48	0.76	0.75				
I am concerned about whether I have engaged in sufficient exercise	4.14	0.88	0.83				
I want to exercise as much as possible	4.04	0.90	0.89				
Perceived Challenge				0.82	[0.80, 0.85]	0.87	0.70
Playing the exergame challenges me to perform to the best of my ability	3.39	0.94	0.77				
Playing the exergame provides a good test of my skills	3.88	0.93	0.97				
I find that playing the exergame stretches my capabilities to the limit	3.47	1.08	0.75				
Need for Achievement				0.80	[0.77, 0.83]	0.87	0.69
I do not want to perform worse than my peers	4.01	0.95	0.74				
To me, it is very important to perform better than my peers	3.47	1.00	0.99				
My goal is to achieve better performance than my peers	3.28	1.05	0.73				
Flow				0.86	[0.84, 0.88]	0.92	0.80
When playing the exergame, I experience flow	3.10	1.29	0.82				
When playing the exergame, I frequently experience flow	2.49	1.16	0.99				
When playing the exergame, I always experience flow	2.02	1.08	0.86				

Note. λ denotes indicator loading; *α* denotes Cronbach's *α* value; *C.I.* denotes 95% confidence interval; *CR* denotes composite reliability; *AVE* denotes average variance extracted.

Table 2
Correlations among the study constructs.

	1	2	3	4
1. Exercise Enjoyment	–			
2. Need for Exercise	0.47*	–		
3. Perceived Challenge	0.40*	0.26*	–	
4. Need for Achievement	0.20*	0.37*	0.15*	–
5. Flow	0.18*	0.03	0.21*	0.08

Note. * denotes $p < .05$.

4. Results

4.1. Sample profile

This study recruited 583 participants. Table 3 summarizes the profile of the participants. Among them, more than half (62.1%) were female and most were aged between 19 and 24 years (97.4%).

4.2. Hypotheses testing

This study adopted hierarchical regressions for testing the hypotheses. Hierarchical regressions are known for their ability to evaluate contributions of certain antecedents in explaining the variance of the dependent variable. In this study, the dependent variable was flow. The independent variables were exercise enjoyment and perceived challenge. The moderators were need for

Table 3
Summary of the participant profile.

Variable	Category	Number	Percentage
Gender	Female	362	62.1
	Male	221	37.9
Age	19–21 years old	285	48.9
	22–24 years old	283	48.5
	25–29 years old	14	2.4
	Missing	1	0.2

Table 4
Sources of flow among exergamers.

	M1	M2	M3
Gender	0.06	0.07	0.06
Age	0.02	0.02	0.02
BMI	0.03	0.03	0.03
Heart rate	0.02	−0.02	−0.01
Exercise Enjoyment		0.18*	0.16*
Perceived Challenge		0.14*	0.17*
Need for Exercise		−0.10	−0.05
Need for Achievement		0.06	0.07
Exercise Enjoyment × Need for Exercise			0.11*
Perceived Challenge × Need for Achievement			0.09*
ΔR^2	0.01	0.06*	0.02*
R^2	0.01	0.07*	0.09*

Note. All numbers are standardized regression coefficients.
* Denotes $p < .05$.

exercise and need for achievement. To be consistent with the study hypotheses, the regressions included the interaction between exercise enjoyment and the need for exercise. Moreover, the regression included the interaction between perceived challenge and the need for achievement. To enhance analytical rigor, this study further included control variables, i.e., gender, age, BMI, and heart rate. The hypotheses contain specific valence, i.e., positive. To be consistent with the hypotheses, one-tailed testing was used. The significance level was set at 0.05.

The first regression model (M1) included gender, age, BMI and heart rate as the regressors. The second regression model (M2) further included exercise enjoyment, perceived challenge, the need for exercise, and the need for achievement. The third regression model (M3) additionally included two interactions, i.e., (1) the interaction between exercise enjoyment and the need for exercise and (2) the interaction between perceived challenge and the need for achievement. Such interactions were entered into the regression as they were consistent with the hypotheses. Therefore, not all possible interactions were included.

Table 4 lists the analytical results. All hypotheses were supported. Specifically, exercise enjoyment was positively related to flow ($\beta = 0.16$, $p < .05$), supporting H1. Need for exercise strengthened the relation between exercise enjoyment and flow ($\beta = 0.17$, $p < .05$), supporting H2. Perceived challenge was positively related to flow ($\beta = 0.11$, $p < .05$) supporting H3. Need for achievement strengthened the relation between perceived challenge and flow ($\beta = 0.09$, $p < .05$), supporting H4. Fig. 2 illustrates the analytical results.

The regressions had variance inflation factors < 1.64, indicating that the multicollinearity should be at a minimum herein (Stevens, 1996). The regressions explained 9% of the variance of flow. i.e., $R^2 = 9\%$. The R^2 value significantly rose from M1, M2, to M3 ($p < .05$). Such significant increases demonstrate the degree to which need for achievement, exercise enjoyment, need for exercise, and challenge can substantially explain the variance of flow. The magnitude of R^2 herein is consistent with the recent literature on this issue, i.e., 8% in Nisar and Whitehead (2016), and 12% in Bachen et al. (2016). Such a value is equivalent to an effect size of 10% and should be evaluated as between small and moderate (Cohen, 1992).

5. Discussion

5.1. Main findings and contributions

This study found that both exercise enjoyment and perceived challenge were positively related to flow. Moreover, the need for exercise strengthened the positive impact of exercise enjoyment on flow, and the need for achievement strengthened the positive impact of perceived challenge on flow. This study is distinct in explaining how these user needs moderate the relationship between

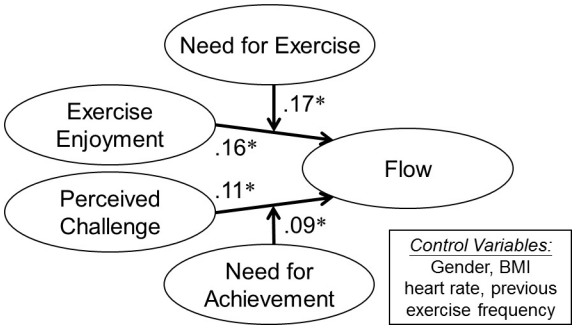

Fig. 2. Analytical results. *Note*. * denotes $p < .05$.

perception (i.e., exercise enjoyment and perceived challenge) and an enjoyable experience (i.e., flow) among exergame users.

This study contributes to the flow theory by being the first to identify two novel moderators, i.e., need for exercise and need for achievement. Moreover, this study further clarifies the mechanism underlying such moderations, i.e., how such moderators strengthen the positive impacts of exercise enjoyment and perceived challenge on the flow experience perceived by exergame users. Such a clarification deepens our understanding of the boundary conditions for such impacts, and how to boost such impacts, and therefore assists practitioners to effectively design exergames.

5.2. Theoretical implications

Belchior et al. (2016) compared the flow experience between an off-the-shelf game and a brain training game, and found that groups using both the off-the-shelf game and the brain training game experienced flow increasingly over a period. Specifically, participants using the off-the-shelf game significantly improved the level of flow. In line with Belchior et al. (2016), our study also investigated flow experience in games. However, our study is unique in identifying the novel moderators (i.e., need for exercise and need for achievement) that can facilitate the formulation of flow experience. These newly identified moderators should encourage future works to explore means for facilitating the formulation of the flow experience.

Song et al. (2013) found that competitive individuals can acquire positive experiences (i.e., intrinsic motivation, mood, and evaluation of the game) in a competitive exergaming context. In accordance with Song et al. (2013), our study investigated how exergaming contexts could provide a positive experience. However, our study is new in clarifying how perceived challenges impact flow (i.e., positive experience). Furthermore, our study found that intrinsic motivation (i.e., the need for achievement) can strengthen such an impact. Our findings indicate that competitive individuals have an enhanced need for achievement and concentrate on overcoming challenges, and thus easily experience flow.

Bronner et al. (2015) found that flow experience could be positively related to physical exertion during exergame playing. Moreover, Bronner et al. (2015) found that an imbalance between skill and challenge, core elements of flow, could induce low physical exertion. The present study is in concordance with theirs in examining the flow experienced by exergame users, but uniquely identifies how need for achievement and need for exercise can be two important moderators on the relationship between perceived challenge and flow, as well as the relationship between exercise enjoyment and flow. These two novel moderators provide new insights into the roles of user needs in the formation of flow.

Huang et al. (2017d) found that playing exergames can trigger positive mood states (i.e., vigor and happiness). Moreover, Huang et al. (2017c) found that playing exergames can improve physical fitness after a 12-week gaming program. In addition, Nguyen et al. (2016) found that playing exergames could improve the participants' attitude toward and intention to do other forms of exercise. Huang et al. (2017a) explored flow from the perspective of temperament and character while our study investigated flow by using personal motivations in the context of exergames. Compared with the above studies, the present study is new in examining the novel moderators (i.e., need for achievement and need for exercise). Moreover, most hypotheses in the present study are unique to those studies.

5.3. Implications for exergame providers

This study was conducted in the context of exergames that use body movement. Therefore, the findings of this study should be generalizable to other games that require the use of body movement, indicating their impact on games for health. Findings herein can also apply to other exergames, virtual reality (VR) games, and augmented reality (AR) games, as all these invite users to use their body movements to control or interact with avatars or objects in the games, i.e., sharing a similarity with doing conventional exercise. Therefore, the findings of this study could be generalized to the aforementioned contexts.

The findings of this study offer novel insights for exergame providers to increase the flow experience of gamers and make various associated decisions, including game challenge design, new function integration, sound and visual effect integration, and in-game reward system construction. The implications for exergame providers are listed below.

This study found that exercise enjoyment was positively related to flow. This study recommends that exergame providers utilize this finding to design exergame software that integrates exercise and fun, to trigger enjoyment. First, exergame providers could simplify a variety of complex exercises and portray them vividly in exergames. Second, they could incorporate compelling audio and visual effects to create a highly enjoyable gaming experience. For example, during play, audio-visual effects could add applause from a virtual audience. Moreover, the exergame software could be designed to detect the perspiration, oxygen consumption, and running speed of the gamer, So that the game could respond by making adjustments tailored to the gamer's physical state, to enhance enjoyment. Furthermore, exergames could be designed to include a report of energy consumed during play.

This study found that the need for exercise strengthened the positive impact of exercise enjoyment on flow. The finding could foster the development of strategies to design new functions in exergames. Exergame providers could remind users to regularly check their fitness-related information, e.g., weight and body fat percentage, so as to boost their need for exercise. Individuals with a higher need for exercise could be encouraged to buy exergaming software since exergames can be played without the need for sporting equipment or a dedicated sporting venue, and in the gamer's home, without the need to spend time travelling to and from a sporting venue.

This study found that perceived challenge was positively related to flow. Hence, exergame providers could divide in-game challenges into levels that could be adjusted to meet gamers' abilities. For example, the software could adjust the levels of challenge to meet the gamers' current abilities and gradually enhance the levels of challenge. When gamers overcome an increased level of

challenge, they can experience flow.

This study found that need for achievement strengthens the positive impact of perceived challenge on flow. Since individuals with a strong need for achievement have a strong desire to succeed, gaming providers could avoid easy gaming tasks and design more challenging tasks to offer a sense of achievement. Moreover, exergame providers could hold regular exergaming contests in public or online, to attract the participation of users with a need for achievement. Once individuals with a high need for achievement win or overcome the challenge set in the exergame, the exergame provider could reward them. Such activities may give them a sense of achievement and a flow experience during playing.

5.4. Research limitations and future research directions

This study adopted the survey research method and collected both psychological and physical data. This approach should be acceptable because it fits the research purpose and is consistent with recent studies on flow (e.g., Liao and Teng, 2017; Liu et al., 2016). However, this approach is known as limited in directly examining causality. Future studies could replicate this study by using experimental and longitudinal designs. Such replication may verify or provide further insights on the relations examined herein.

The participants in this study were all university students. This sample should be sufficient for examining flow theory in the context of exergames. However, future research could extend the findings of this study by including individuals with varied age ranges (i.e., children, teenagers, or the elderly) and incorporate the length of exergame playing time into their frameworks.

6. Conclusions

This study is the first to examine how user needs (i.e., need for achievement and need for exercise) can strengthen the impact of exercise enjoyment and perceived challenges on flow in health-enhancing technological applications, i.e., exergames. Our findings advanced flow theory by adding these two novel moderators for explaining the formulation of flow experience among exergame users. This advancement offers exergame providers insights showing that they could activate and fulfill the two user needs in the design of their exergames. Such need fulfillment could effectively create and enhance gamers' flow experience. Flow experience can encourage users to repeatedly play exergames and thus can further benefit their health. Future studies may incorporate additional elements from the flow theory, i.e., frustration, apathy, and boredom, for deepening the understanding of how to enhance flow experienced by exergame users.

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