International Journal of Engineering & Technology, 7 (4.31) (2018) 445-451

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Design Models for Mobile Augmented Reality Exergames: State-of-the-Art Review

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Abstract

The sedentary lifestyle is common in this digital age and a cause of concern as it encourages individuals to elicit sedentary behavior i.e. lower instances to being physically active. This lifestyle affects the major portion of the population; with obesity being a major risk and a factor for many cardiovascular diseases such as coronary heart rate disease, heart failure, stroke etc. Use of mobile devices may be linked to the increase of sedentary individuals; however, its usage could also be utilised to encourage fitness awareness among its users. Incorporating interactive digital applications such as exergames, a combination of exercise and games, to mobile devices could provide the means to encourage fitness activity for sedentary individuals through physical gameplay. This paper explores the current design models of exergames and how their usage can affect changes to the psychological and physiological states of the players as well as the promising directions for adapting their usage for the mobile environment through augmented reality immersion.

Keywords: *Augmented Reality; Design Model; Exergames; Mobile games; Sedentary lifestyle*

1. Introduction

With the widespread use of computers, Human-Computer Interaction (HCI) studies became more prevalent to analyse the interaction between people and computers. Researchers are interested in the physical, physiological and theoretical aspects of this interaction and continuously do so, as computer systems and their interactions evolve over time [1, 2].

As HCI technologies continue to advance, we are now seeing emerging computer systems that can place user's bodily movement in the centre of the experience, thus encouraging physical exertion as part of the interaction. This experience is especially attractive for interactive digital applications such as exergames, a game-based system that provide physical exercise through user's body interactions [3], as it encourages users to interact with technology by physically exerting to reach the games' goals [4, 5].

This paper investigates the debilitating concerns of the sedentary lifestyle in mobile device users. It is found that increase use of mobile device can lead to sedentary behaviours among its users, hence decreasing physical activity and poor outlook on fitness issues. We also explored promoting fitness activity through exergaming; the status and promising directions in research by adopting exergaming design models for use by sedentary individuals to physically exert in mobile exergaming.

2. Literature Review

The following discusses the areas of research interests in view of this paper.

2.1. Fitness Concern

Most people forego the importance of physical activity for the betterment of fitness and wellness, seeing it as a leisure-time pursuit over more concerning life matters. Other issues regarding participation in fitness activity may have to do with ensuring safety either on the activity itself or location where it is conducted. To alleviate this underwhelming attitude towards physical activity, there must be an understanding for this reaction towards physical activity, so we may be able to find ways to make the activity attractive and accessible for those who has the time and resources to do so.

2.1.1. Physical Activity & Exercise

Being physically active can be beneficial to both the physiological and psychological states of the human body. Physical Activity (PA) is defined as any bodily movement produced by skeletal muscles that results in Energy Expenditure (EE) that is measured in kilo calories (kCal) [6, 7]. Exercise is a subset of PA that is planned and structured for the improvement or maintenance of physical fitness.

PA can be performed in stages of exertions. Light-intensity PA (LPA) is achieved when a 50% of an individual's maximal heart rate (MHR) is achieved. MHR is calculated using the following formula [8] :

$MHR = 211 - (0.64 * age)$

Moderate-intensity physical activity (MPA) is achieved at 60% MHR. Vigorous-intensity physical activity (VPA) at 80% MHR, however at 90% MHR and above, the PA is deemed risky and activity must be toned down [9].

Physical exercise can be performed in many ways, for example cardio-intensive exercises (cardio) such as running and swimming,

as well as body conditioning exercises that helps the body to develop muscle strength. Body conditioning exercises can also be used to provide recovery after intense cardio. They mainly target three main areas of the human body: upper body (e.g. push-ups), lower body (e.g. lunges) and core (e.g. sit-ups) [10].
According to the recommendation by Garber et al. [9] and supported by the American College of Sports Medicine (ACSM) to date, healthy adults need to perform MPA for a minimum of 30 mins on five days each week, or VPA for a minimum of 20 mins on three days each week, or the combinations of these two. This is the minimum dose to promote and maintain health, help people steer away from over 25 diseases linked to physical inactivity and also alleviate a sedentary lifestyle [11]. Unfortunately, most of the public fail to meet the requirements in effort to reap these benefits [12].

2.1.2. Sedentary Lifestyle

A sedentary lifestyle is one where a person does little or no physical activity in his/her daily routine. Activities requiring little effort such as using mobile devices for reading or gaming are usually done whilst sedentary i.e. sitting or lying down.
In a report by Lian et al. [13], more than 60% of the Malaysian adult population leads a sedentary lifestyle due in part to minimum daily physical exertions and poor eating habits. In comparison, more than 66% of the adult population in U.S.A. are found to be overweight or obese [14], which is a major risk factor for many cardiovascular diseases such as coronary heart rate disease, heart failure, stroke etc . This put Malaysia almost on par with the U.S.A. in terms of poor health concerns.
Bouchard et al. [15] summarised that sedentary behaviour, physical activity and cardio respiratory fitness have strong associations with premature mortality. Mansoubi et al. [16] concurred in their extensive review that highly sedentary behaviour was associated with lower levels of physical activities in adults. To encourage some level of physical activity, entertaining games that incorporate bodily movement, such as traditional games and video games, can be used to attract sedentary individuals to delve into some physical activities.
Sedentary Behaviour (SB) is defined as any waking behaviour, characterised by an energy expenditure of less than or equal to 1.5 metabolic equivalents (METs) while in a sitting or reclining posture [17]. METs is used to represent the intensity of a physical activity by measuring the amount of oxygen consumed and calories burn at rest [18]. The METs values of selected activities surmised by Haskell et al. [19] is presented in Table 1.

Table 1: MET Equivalents of Common Physical Activities [19]

Intensity	SB	LPA	MPA	VPA
METs	< 1.5	1.5 – 3.0	3.0 – 6.0	> 6.0
Activity	Sitting	Walking slowly	Walking at brisk space (4 mph)	Walking, jogging & running (> 4.5 mph)

MPA can be accomplished for 30 minutes per day as per ACSM guideline, yet a person can still be sedentary for most of the time by sitting for pro-longed period at a computer or attending lectures.

2.1.3. The Mobile Device “Pandemic”

Video games, computers, television, mobile devices and sedentary occupations have all contributed to the growth in SB and obesity.
Lepp et al. [20] claimed that mobile device use is similar to traditional sedentary behaviour, as it disrupts physical activity and reduce cardiorespiratory fitness. Kim et al. [21] in their study found that mobile device addiction, specifically smartphone addiction, had a detrimental effect on one’s physical health as it had a negative impact on the addict by reducing overall physical activity, which leads to a decrease in muscle mass and increase in fat mass thus affecting one’s health.
Most concerning is that Barkley et al. [22] found that mobile device usage is directly linked to sedentary behaviour in college students. There are evidence, though limited, that supports the notion that sedentary behaviour displaces light intensity physical activity (LPA) [16]. This is highly worrying, as per Table 1, SB has the least amount of METs value compared to LPA.
However, even though mobile device usage may encourage a sedentary lifestyle, there are attempts to initiate some form of fitness activity through use of mobile devices. This can be seen from a study by Hebden et al. [23] on mobile devices such as smartphones, which is able to provide a convenient, inexpensive means to deliver health intervention programmes. In their study, they looked on to the effectiveness of delivering periodic messages on health issues via smartphones to a group of university staff and students over a 12-week period. By the end of the study they find that there were some short-term positive changes in weight, nutrition and physical activity to participants in the intervention group. The key point here is *short-term* as it was found that the both participants in the intervention and control groups reverted to their previous routines after the study concluded. This indicates that further study needed to be done to ensure participants continue being aware of their health concerns over time.
Krebs & Duncan [24] did a survey concerning Mobile Health (mHealth) applications (apps) use. They found that more than half of their respondents used mHealth apps on their smartphones, however, of that population slightly more than half committed to using the apps. Those who forego using the apps do so due to loss of interests and costs. The authors surmised that going forward, clinical trials are essential to test the effectiveness of mHealth apps to increase their appeal and usage.
This sentiment by Krebs & Duncan is supported by the works of Piette et al. [25]. After extensively reviewing the benefits of mHealth interventions, they find that its use may assist in improving sedentary behaviours and disease management. They postulate that development of mHealth programmes must be based on behavioural theories and integrate artificial intelligence advancement to adapt readily to the changing needs of the users.

2.2. Exergames

What is exergames? Mueller et al. [26] defined it as an interactive digital game that utilises physical exertion for interaction where the physical effort is a key, if not the dominant, determinant in reaching the game’s goal. Though exergames are interactive and provide real time feedback during game play, Klock & Gasparini [27] stressed the importance of an application’s usability to ensure efficiency and continued usage.
Exergames has the capability to measure the EE and other fitness data of its players during game play. The feature to monitor players’ fitness activities (heart rate, kCal, walking pace) were collected from exergames in the works of [28], [29], [30]. With availability of these information, players can appreciate their fitness activity.

2.2.1. Mobile Exergames

Exergames can either be played on-site or be mobile-capable. On-site exergames are games that are usually played indoors as it utilises static equipment on-site (treadmill, stationary bikes, accelerometers etc). Mobile exergames on the other hand uses the mobile capability of mobile device, thus mobilising the exergames experience.
According to Niggs et al. [31], 90% of American adults have mobile phones, with 64% owning smartphones. Mobile devices are found to be able to promote physical activity through health intervention and gaming apps. Other advantages of mobile device usage include self-monitoring and access, decreasing barriers of transportation and time, and portability as well as being cost-effective, accessible and convenient.

Recent mobile devices such as smartphones comes equipped with Global Positioning System (GPS), as well as other advance sensors such as camera, accelerometer and gyroscope [32]. Smartphones are easily accessible to anyone and [33] reviewed mobile exergames such as "Geocaching", "Ingress", "NikeFuel", "Run Zombies!" and "Runtastic Pumpit" that uses these built-in sensors in the smartphones to make for an appealing mobile exergames experience.

In "Geocaching" and "Ingress", the gameplay is inundated with graphics and themes and is subjective to the player's ability to physically exert during gameplay i.e. within the fitness level the players are willing to exert. For "NikeFuel" instead, the game required players to physically exert via running to meet daily or weekly goals.

2.3. Augmented Reality

Augmented reality (AR) is a user interface technology in which a camera-recorded view of the real world is augmented with computer-generated content such as annotations, graphics, animations and three-dimensional (3-D) objects.

Milgram & Kishino [34] introduced the virtuality continuum by defining the term Mixed Reality (MR). AR is part of this MR environment. According to the authors, the MR environment encompases the real-world environment from one end of a spectrum and virtual environment on the other, and their relativity influences one another within the spectrum. Refer Figure 1 for the virtuality continuum.

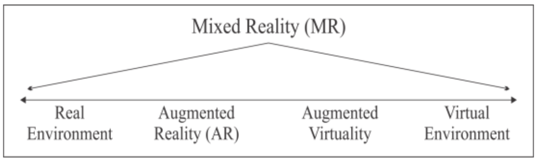

Fig. 1: The Virtuality Continuum [34]

The use of AR had been developed extensively in fields such as urban planning [35], education [36] and entertainment [37]. Papagiannakis et al. [38] used their study of AR-capable mobile application to teach on heritage architectural buildings. In early days, AR hardware requires cumbersome equipment such as head-mounted displays and portable computers. However, as technology advances, so does AR and we now see smartphones powerful enough to run AR technology smoothly.

Incorporating AR in exergames can engage and entertain players due to presence of the interface that mixes augmented content and the real world. Desai et al. [39] used AR based games to engage and motivate patients during rehabilitation, by making it an entertaining experience. Pokemon Go is the most visible entertaining mobile game that utilises AR technology in its gameplay. A study by Nigg et al. (2016) found that playing Pokemon GO increased MPA to VPA by about 50 minutes per week and reduced sedentary behaviour by about 30 minutes per day [31].

Kim et al. [40] developed a mobile AR Exergames that includes 3D element to the system. Laine & Suk [41] expanded Kim et al.'s work by successfully creating an AR exergames for school children learning about the importance of healthy living.

2.4. Theories and Models Used for Games and/or Exergames

Intrinsic motivation as well as hedonic motivation can be used differently depending on the domain of study as players can either be drawn to particular games based on realistic graphics or powerful narrative elements [42]. Well-designed games can increase the intrinsic motivation of players. The following sub-sections discusses the popular models and theories used for games and/or exergames. We first begin with the Self-Determined Theory which delves on the motivational issues to involve in physical activity, then the Flow Model and later models that evolve the Flow Model to fit into the changing needs and technology of the time. These models and designs are popular for on-site exergames; however, their uses are not widely recorded in the mobile exergames scenario.

2.4.1. Self-Determined Theory

To encourage players' participation in games, a design motivation for Exergames need to be assessed and understood. One theoretical perspective that appears useful for understanding various motivational issues in physical activity settings is Self-Determination theory (SDT) [43]. SDT is used to understand human behaviour and what motivates people's choices for personality development and behavioural self-regulation. Through SDT, it is found that there are three innate psychological needs: competence, autonomy, and relatedness. When these three needs are satisfied, self-motivation and mental health are enhanced. The opposite is true when these needs are not met.

2.4.2. Flow Model

Csikzentmihalyi [44] proposed the Flow Model (FM) theory in 1975, where he stated that engagement in an activity is achieved when players are "in the zone" i.e. when no external factors defer progress. The FM is used extensively in social science area that comprise of art, creativity etc., however, its theory is also deeply rooted in the basis of early gaming concepts. Refer Figure 2 for the Model of the Flow State.

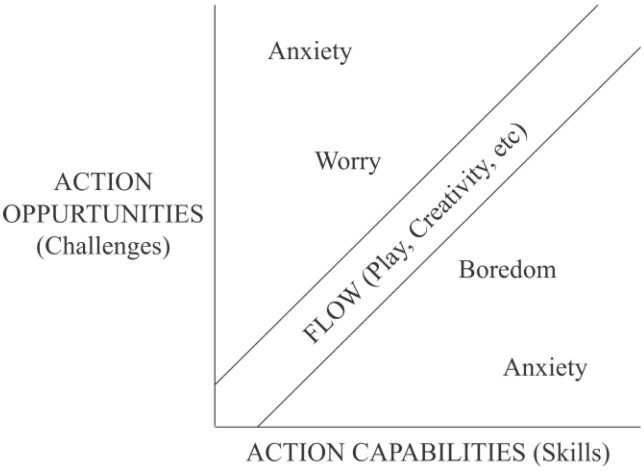

Fig. 2: Model of the Flow State [44]

Figure 2 is a graph that explains the Flow State. It provided the components derived by Csikzentmihalyi for the FM, as annotated in Table 1, which is further explained in the following sub-section. The graph explains that there are five states experienced by the user during play/activity, when action opportunities (challenges) are set up against action capabilities (skills). Going across the graph, the explanation is thus so: when challenges are high, and skills are low, the resulting state is anxiety. When challenges are slightly higher than skills, the state is worry. Flow state is achieved when both challenges and skills balance with one another. The experience is then autotelic, or intrinsically rewarding. When skills are greater than challenges, the state is boredom. The last state is anxiety again when skills are much greater than challenges.

When designing games intrinsic motivator are associated with the psychological concept of flow. Flow theory could also be the state between boredom and worry, it can be reached if an exercise is challenging, but not too difficult.

2.4.3. Game Flow Model

Using the FM as basis, The Game Flow Model (GFM) [45] was

introduced by Sweetser & Wyeth in 2005. It is a model for player enjoyment, comprised of a set of criteria derived from games user experience literature and structured into eight elements that can be mapped to Csikszentmihalyi's FM. The GFM was revisited in 2017 by the authors and found to be current and still relevant [46].
Of the eight elements in the GFM only seven can be mapped to the Flow Model which are game, concentration, challenge, control, clear goals, feedback and immersion. The element that could not be mapped was social interaction. Refer Table 2 for the mapping of Flow to the GameFlow elements.

Table 2: Mapping of Flow to GameFlow Elements [45]

Gameflow	Flow
The Game	A task that can be completed
Concentration	Ability to concentrate on the task
Challenge / Player Skills	Perceived skills should match challenges, and both must exceed a certain threshold
Control	Allowed to exercise a sense of control over actions
Clear Goals	The task has clear goals
Feedback	The task provides immediate feedback
Immersion	Deep but effortless involvement, reduced concern for self and sense of time
Social Interaction	No corresponding element of flow

2.4.4. Dual-Flow Model

According to Sinclair et al. [47], the success of exergaming is brought on by two factors; the effectiveness of the exercise part of a fitness tool and the attractiveness of the game which functions as a motivator. They introduced the Dual-Flow Model (DFM), which encompasses the dimensions of attractiveness and effectiveness of an exercise. The attractiveness was modelled by the FM. It is a psychological model balancing the player's perceived skill with perceived challenge. The other dimension, effectiveness, is the physiological counterpart of flow – the physical balance between fitness (skill by the body in doing exercise), and intensity (challenges of the exercise to the body). This model is used for guiding design in the development of an exergames system. Refer Figure 3 for the DFM for Exergaming.
The 'attractiveness' part of the model simplifies the Flow State model by Csikzentmihalyi. In their interpretation, Sinclair et al. divided the diagram of 'challenge versus skill' into four quadrants. Each quadrant represented the state of achievement during play. Anxiety sets in when challenge is higher than skill, whereas boredom is reached when skill is higher than challenge. When there is a lack of challenge and skill, a state of apathy results. Flow is achieved when both challenge and skill are balanced.

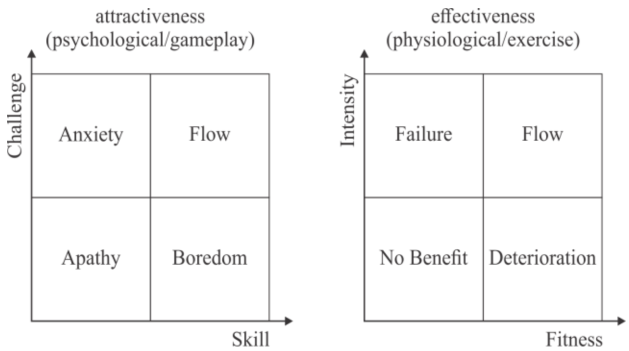

Fig. 3: The Dual Flow Model for Exergaming [47]

The 'effectiveness' of the model looks on the physiological aspect. The diagram is similar to 'attractiveness' by replacing 'challenge versus skill' to 'intensity versus fitness'. However, the quadrants are represented by different states of achievement. When fitness and intensity match up, physiological flow is achieved, and fitness can be improved through continued participation. When fitness is low, and intensity is high, a state of failure occurs, and the player can drop out from exercising. Deterioration is possible when there is low intensity when player's fitness is high. There is no benefit to achieve when there is less intensity and fitness is low.
The DFM, is a good reference to start for designing exergames, however more detailed design principles are needed when using it for specific environment i.e. mobile exergames. The DFM was further extended by [48] to include team flow dimension.

2.4.5. ISCAL Model

Zhang et al. (2012) [49] introduced a new design model for exergames. Their reasoning is that because exergames follow stricter scenarios than commercial games to enable more effective and immersive experiences for the players, the key features of the common design for exergames should include Immersion, Scientificalness, Competitiveness, Adaptability and Learning. This is a shorter list of components when compared to the Dual-Flow Model theory. Refer Table 3 on the Components of ISCAL Model.

Table 3: Components of ISCAL Model [49]

Components	Explanation
Immersion	the subjective impression that one is participating in a ''realistic'' sports experience
Scientificalness	performing the physical exercise scientifically to ensure that the exercise is effective and avoid over-exercise
Competitiveness	the feeling of ''getting better'' at something against real players or non-player competitors
Adaptability	the adjustment of the difficulty of the game dynamically to adapt to each player's fitness level and performance
Learning	players perform some mental exercise, such as learning certain facts of culture and knowledge in the rest period during exercise

2.4.4. Pleasurable Persuasive Model

Han et al. [29] proposed a Pleasurable Persuasive Model (PPM) for exergame system to encourage users to engage in a long-term physical activity. Using an existing persuasive theory, Fogg's Behaviour Model (FBM) whereby change of behaviour will only happen unless the collaborative product of ability, motivation and triggers occurred simultaneously, Han et al. adapted a combination of psychological driven and physiological adaptation design requirements on an e-fitness system. The PPM can be used to motivate users to continue exercise over time. The four design strategies: Pleasure, Guidance, Encouragement and Reminder ensures that the players will be encouraged to exercise both effectively and regularly. Including the persuasive element can better extend the longevity of user's retention and engagement over time.
Refer Figure 4 on the relationship between PPM, regular physical activity, and FBM.

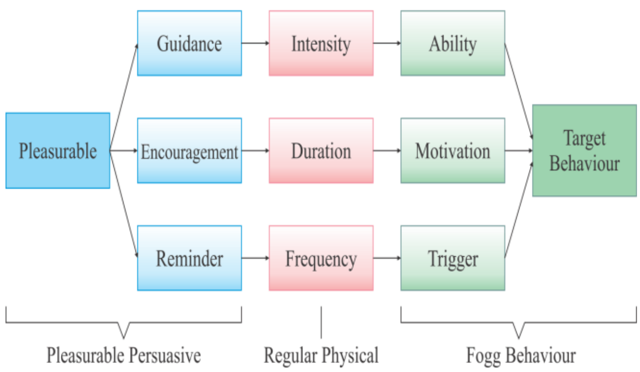

Fig. 4: The Relationship between Pleasurable Persuasive Model, Regular Physical Activity, and Fogg's Behaviour Model [29]

2.4.5. Summary of the design models

Refer to Table 4 for a summary of all the design models discussed previously.

Table 4: Summary of the discussed design models and theories for gaming and examples of its use in exergaming.

Model	Description	Exergames example		
		Game Name	Play Environment	Medium of Presentation
Self-Determined Theory (SDT)	Understanding the various motivational issues in physical activity. The 3 innate psychological needs: competence, autonomy, and relatedness; which when satisfied yield enhanced self-motivation and mental health.	Spaceship Launch [50]	On-site	Video Game
Flow Model (FM)	Intrinsic motivator is associated with the psychological concept of flow. Flow theory could also be the state between boredom and worry, it can be reached if an exercise is challenging, but not too difficult	Labyrinth Run [51]	On-site	Video Game
		*Exermon [52]	Mobile	Video Game
GameFlow Model (GFM)	It is a model for player enjoyment, comprised of a set of criteria derived from games user experience literature and structured into eight elements that can be mapped to the Flow Model	Astrojumper [53]	On-site	Virtual Reality
		*Exermon [52]	Mobile	Video Game
Dual-Flow Model (DFM)	Encompasses the dimensions of attractiveness (a psychological model balancing the player's perceived skill with perceived challenge) and effectiveness (the physiological counterpart of flow – the physical balance between fitness and intensity) of an exercise.	Game Bike [47]	On-site	Video Game
		*Exermon [52]	Mobile	Video Game
ISCAL Model	The key features of the common design for exergames should include Immersion, Scientificalness, Competitiveness, Adaptability and Learning.	Virtual Network Marathon [49]	On-site	Virtual Reality
Pleasurable Persuasive Model (PPM)	Used to motivate users to continue exercise over time. The four design strategies: Pleasure, Guidance, Encouragement and Reminder ensures that the players will be encouraged to exercise both effectively and regularly.	Expresso Bike [29]	On-site	Video Game

*(Note: * indicate that the exergame compiled questionnaires consisting of statements that reflects on three different design models.)*

3. Discussion

The sedentary lifestyle is now commonplace in this current digital age. The appeal of mobile devices, such as smartphones, that can relate information and provide entertainment at the touch of a fingertip, had unfortunately encourage a sedentary lifestyle to its users. Worst is that its usage fosters SB, by disrupting physical activity that could cause a reduction in cardiorespiratory fitness. Which is ironic, considering that mobile devices were initially conceptualised to enable mobility for ease of usage anytime and any day. When compared to LPA, SB has the least METs value. As explained in earlier section, SB is in a state of minimal physical effort such as sitting or lying down.

As the population of the developed and developing countries continue to rely heavily onto the convenience of owning mobile devices, there are efforts to negate the damaging effect of SB to mobile device owners. Health and fitness apps could be installed on mobile devices for use to encourage healthy living such as health intervention apps that provide timely health information to its users or playing mobile games that directly or indirectly encourages physical activity. One popular mobile game is Pokemon Go, a game that incorporated AR immersion in its gameplay which unsuspectingly resulted in indirect physical activity when players are found willing to literally walk the extra mile to collect points. However, the game was developed for players' enjoyment and not integrated with health interventions for players to gain any fitness insight to their activities.

Exergames played on-site have exercise equipment such as treadmill, stationary bikes etc., and/or sensors that can detect the player's bodily movement such as Wii-Fit and Kinect sensors, to make for an engaging experience to players. However, adopting the same exergames design models to the mobile scenario proved that some elements to the design model could not be carried over owing to limited interaction with mobile devices and lack of equipment. The challenge here is to ensure mobile exergames are as effective as on-site exergames even without the need for bulky equipment. All the gameplay can be achieved via interactions with the mobile device.

A well designed exergame could balance the two main features of exergaming: gaming pleasure and physical activity. Thus, to achieve these two, various design models were used as guidelines during game development. The Flow Model has long established the concept of psychological flow state, the state in which players are in the zone when no external factors defer progress. Components from this model were studied for compatibility with video gaming and found viable for further adoption and evolution over time with the emergence of GFM and DFM amongst others. While GFM was introduced for the video games culture, the DFM was specifically proposed for use on exergames. The DFM looked on achieving the flow state in attractiveness and effectiveness during gameplay, which corresponds to the player's psychological and physiological states respectively. Another model that was proposed for exergames is ISCAL model. It looked on the common design model for exergames, which identified the five key components for game design since exergames usually follow a rigid scenario compared to commercial games.

For example, to incorporate design of exergame that are both engaging and effective, Laine & Hae used Zhang et al.'s ISCAL model as reference when developing their mobile AR exergames. Their resulting game could only meet 3 of the 5 components of the ISCAL model, which are Immersion, Scientificalness and Competitiveness. The components Adaptability and Learning were not met as the authors consider these components unsuitable for their game platform at the time of study.

Thus, how can each of the components in the ISCAL model be realised fully in mobile AR exergames? As mentioned, AR interfaces the real world with augmented content such as annotations, graphics, animations and three-dimensional (3-D) objects. Apart from providing engaging graphics during gameplay, AR could also be used to provide suggestive annotations to the players that guides, encourages and provide reminders to players.

It is noted that the design models discussed above does not have a 'Persuasive' element in their components. Compared to the element 'Feedback', it has little to do with providing guidance, encouragement and reminder to the players. The current design models for exergames could be bettered further by implementing the 'Persuasive' element into its components when adopting its use in the mobile scene. Sedentary individuals may have negative or even painful feeling on exercise and find it a challenge to maintain enough activities. By incorporating the 'Persuasive' element from PPM by Han et al., the challenge to encourage regular physical activities for sedentary individuals can be tackled by emotionally engaging them.

The 'Persuasive' element can be incorporated into mobile exergames since mobile devices are ubiquitous tools compared to equipment used for on-site exergames. Thus, utilising the AR content to provide 'Persuasive' element to mobile exergames may provide the appeal for a more rounded gameplay and encourage sedentary individuals to spend less time being sedentary by physically exerting whilst using mobile devices.

4. Conclusion

The sedentary lifestyle is in the increase as there is less effort in being physically active. This may be aggravated by dependency of technological aides be it in the working place, at home or anywhere in between. The sedentary lifestyle affects more than 60% of the Malaysian adult population; with obesity being a major risk and a factor for many cardiovascular diseases (CVD) such as coronary heart rate disease, heart failure, stroke etc.

As the use of mobile devices is deemed essential in our daily operations, its usage can be varied for use in health and fitness programmes such as health interventions or mobile games that could results in positive physical activity. A mobile game that include health interventions to its players can be used to encourage sedentary individuals to be more pro-active with their fitness concerns even after gameplay. Incorporating AR immersion to mobile games via graphics and annotations can stimulate players by providing them with health information and fitness data, thus increasing their awareness of their fitness needs.

Understanding the current design models of exergames could support towards the proposal for the design model of mobile exergames. Though there is an abundance of mobile exergames in the market, they were not researched extensively against the existing design models, which is more suited for on-site exergames. Wang et al [52] compiled questionnaires for their exergames "Exermon" consisting of statements that reflect on three different design models i.e. FM, GFM and DFM, proposing a mobile exergame concept that focus on physical, motivation, engagement and enjoyment effects on playing the game.

The 'Persuasive' element may be the key component to be incorporated or adapted into enhancing existing design model via AR immersion

Thus, a design model for mobile AR exergames that can encourage sedentary individuals to physically exert during gameplay that are both enjoyable and productive by understanding their fitness intensity through the fitness data collected whilst playing, is the way forward to reduce SB in mobile dependant individuals. It is hoped that by being more physically active, this may assist sedentary individuals to alleviate illnesses related to CVD.

Acknowledgement

We thank the HCI Research Group, Faculty of Computer Science & Information Technology, UPM for funding this paper.

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