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EFFECTS OF GAME-BASED CHILDHOOD OBESITY PREVENTION FRAMEWORK AMONG PRESCHOOL CHILDREN

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ABSTRACT

This research was carried out to validate a framework of game-based childhood obesity prevention. A mobile game titled *Fight Obesity 2.0* was produced through a five-step gamification approach as an instance of the prevention framework. The game incorporated constructive alignment of intended prevention outcomes and structural game elements. The lean production strategy was deployed to produce a viable serious game with its paratextual materials. The design of the game was validated by 38 game designers through a playtesting session, while the content knowledge was validated by two pediatricians, one from China and another in Malaysia. The game also passed the age rating test under the International Age Rating Coalition. The effects of *Fight Obesity 2.0* in actual prevention context was investigated through a non-equivalent control group pre-test / post-test quasi-experiment. Edumetric tests were conducted with 60 children at the kindergarten in the National Child Development Research Centre. After having a month of exposure to game playing, the experimental group performed significantly better in the post-test as compared to their performance in the pre-test and the performance of the control group in the post-test. In terms of gender difference, female children performed significantly better than the male. Twenty-one null hypotheses were tested to examine the effects of the game upon children's food preferences, conception on the relationship between obesity and physical exercise, and the danger of obesity among children. In conclusion, the game was found to be effective in changing the children's food preference, from liking unhealthy food to disliking unhealthy food. These results were verified by findings revealed through a one-week non-participant observation in the kindergarten and semi-structured interviews conducted with the kindergarten supervisor. The implication of this research suggest that a serious game (designed and developed based on the framework game-based childhood obesity prevention) can make significant positive effects in changing the food preferences among preschool children. However, further studies would be needed to examine how the framework can afford preschool children to comprehend the relationship between physical activities and obesity, and the danger of childhood obesity.

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KESAN KERANGKA KERJA PENCEGAHAN OBESITI KANAK-KANAK BERASASKAN PERMAINAN DALAM KALANGAN KANAK-KANAK PRASEKOLAH

ABSTRAK

Kajian ini dijalankan untuk mengesahkan satu kerangka kerja pencegahan obesity kanak-kanak berasaskan permainan. Sebuah permainan mudah alih berjudul *Fight Obesity 2.0* telah dihasilkan melalui pendekatan gamifikasi lima langkah gamifikasi sebagai satu contoh kerangka pencegahan. Permainan ini menggabungkan penjajaran konstruktif antara hasil pencegahan yang diingini dengan struktur elemen permainan. Strategi produksi sandar telah digunakan untuk menghasilkan permainan serius yang berdaya maju bersama dengan bahan parateksnya. Reka bentuk permainan ini telah disahkan oleh 38 orang pereka permainan menerusi satu sesi uji-main, manakala isi kandungannya telah disahkan oleh dua orang doktor pakar kanak-kanak. Permainan ini juga melepasi ujian pemeringkatan umur di bawah Gabungan Pemeringkatan Umur Antarabangsa. Kesan *Fight Obesity 2.0* dalam konteks pencegahan sebenar telah dikaji melalui satu ujian-pra / ujian-pasca kuasi-eksperimen bagi kumpulan kawalan yang tidak setara. Ujian metrik pendidikan telah dilakukan ke atas 60 orang kanak-kanak di sebuah tadika di Pusat Penyelidikan Pembangunan Kanak-Kanak Negara. Selepas menerima pendedahan bermain permainan selama sebulan, kumpulan eksperimen menunjukkan peningkatan prestasi yang ketara dalam ujian-pasca berbanding dengan prestasi mereka dalam ujian-pra dan prestasi kumpulan kawalan dalam ujian-pasca. Kanak-kanak perempuan menunjukkan prestasi yang lebih baik berbanding kanak-kanak lelaki. Dua puluh satu hipotesis nul telah diuji bagi melihat kesan permainan terhadap kanak-kanak dari segi pemilihan makanan, pembentukan konsep ke atas hubungan antara obesiti dan senaman fizikal, dan bahaya obesiti dalam kalangan kanak-kanak. Kesimpulannya, permainan ini didapati berkesan dalam mengubah pemilihan makanan kanak-kanak, daripada suka makanan yang tidak sihat kepada tidak suka makanan yang tidak sihat. Dapatan kajian ini telah disahkan dari hasil kajian yang diperolehi melalui tinjauan tanpa penyertaan selama seminggu di tadika berkenaan dan temu bual separa berstruktur yang dibuat bersama penyelia tadika. Implikasi kajian ini mencadangkan permainan serius (yang direka bentuk dan dibangunkan berdasarkan kerangka kerja pencegahan obesity kanak-kanak berasaskan permainan) mampu menghasilkan kesan positif yang signifikan dalam mengubah pilihan makanan dalam kalangan kanak-kanak prasekolah. Walau bagaimanapun, kajian lanjutan perlu dilakukan bagi mengkaji bagaimana kerangka kerja berkenaan membolehkan kanak-kanak prasekolah untuk memahami hubungan antara aktiviti fizikal dan obesiti, dan bahayanya obesiti kanak-kanak

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LIST OF ABBREVIATIONS

2D	Two dimensional
ACB	Australian Classification Board
APK	Application Package
BMI	Body Mass Index
CK	Content knowledge
ClassInd	*Classificação Indicativa* or the Brazilian Advisory Rating
DASH	Dietary Approaches to Stop Hypertension
EMV	Ethics, Moral & Values
ESF	European Social Fund
ESRB	Entertainment Software Rating Board
fMRI	Functional magnetic resonance imaging
FYP	Final year projects
GT	Game technology
HRQoL	health-related quality of life
IARC	International Age Rating Coalition
IBS	Irritable Bowel Syndrome
MINDS	Malaysian Invention and Design Society
MTE	Malaysia Technology Expo
MyRA	Malaysia Research Assessment
NCDRC	National Child Development Research Centre

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PC	Personal computer
PECIPTA	International Conference and Exposition on Invention by Institutions of Higher Learning
PEGI	Pan European Game Information
PS	Prevention strategy
QA	Quality assurance
R&D	Research and development
SME	Subject Matter Expert
SNES	Super Nintendo Entertainment System
SOP	Standard operating protocol
SUMI	Software Usability Measurement Inventory
TAM	Technology Acceptance Model
UCG	User generated content
UPSI	Sultan Idris Education University
USK	*Unterhaltungssoftware Selbstkontrolle* or Entertainment Software Self-Regulation
WHO	World Health Organization

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APPENDIX LIST

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B Test Questions Set for the Pre-test and the Post-test

C Application to Conduct Research at Tadika NCDRC

D Approval Granted to Conduct Research at Tadika NCDRC

E Follow-up Observation Checklist

F Screen Shots of *Nutrition Your Life*

G Screen Shots of *Fight Obesity*

H IARC Rating Questionnaire for Digital Games

I Information Sheet for Playtesting

J Consent Form

K Usability Measurement Inventory

L Data Collected in the Quasi-Experiment

M BMI for Boys

N BMI for Girls

O Food Choice Stated by the Children in the Pre-test

P Food Choice Stated by the Children in the Post-test

Q Semi-structured Interview Questions (Kindergarten Supervisor)

R Information Sheet for Interview with Pediatricians

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CHAPTER 1

INTRODUCTION

1.1 Overview

The aim of this research is to create a game-based obesity prevention framework for use in the design, development and validation of serious games for childhood obesity prevention. This framework can be referred by parents, preschool teachers or caretakers, and medical doctors when using games for preventing obesity among preschool children. A game-based childhood obesity prevention framework was developed based on the standard operating procedure of treating childhood obesity in China and then validated by pediatricians in Malaysia and China. A nonequivalent control group pre-test / post-test quasi-experiment was conducted in a kindergarten, followed by a non-participant observation of selected children in the kindergarten. Towards the end of the research, validation from pediatricians was obtained for the prevention framework.

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This thesis consists of six chapters. The first chapter provides an overview of the research, including its background, aims, specific research questions and hypotheses. The second chapter is the literature review of recent studies on childhood obesity treatment and the use of games in medicine and health care. The third chapter presents the methodology and the research design of this study. Chapter four depicts the design, development and validation of a mobile game titled *Fight Obesity 2.0* for this research. Chapter five juxtaposes the findings and discusses how these hypotheses were tested. The last chapter is the conclusion, in which it summarizes all conclusive propositions made throughout this research and explains the overall contribution and limitation of this research.

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1.2 Background of the Research

The origin of this research comes largely from an observed phenomenon of childhood obesity in Malaysia. According to a Malaysian pediatric medical officer in Sabah, Dr. Alya Hamzan, one in every five school-going Malaysian children is overweight or obese (Khoo, 2014). In this sense, an academic research in treating childhood obesity should be cross-disciplinary in nature, hence the genesis of this educational study in Malaysia, conducted through a perspective of a former pediatrician from China. Coincidentally, the issue of childhood obesity in Malaysia is as serious as the problem faced by China, in which 18.8% of people under 20 years old were overweight in 2013 (Wang, 2014). This prompted the urge and the need to carry out an academic study for preventing and treating childhood obesity in both China and Malaysia.

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Being able to conduct this study at the National Child Development Research Centre (NCDRC) in Sultan Idris Education University (UPSI) was indeed an occurrence of serendipity. The idea of pursuing a doctorate degree in child and adolescent development under NCDRC was a result of the voluntary work experience in NCDRC as a preschool Mandarin teacher. The interaction with and observation on the children in NCDRC provided an authentic exposure to the daily living of Malaysian children. This in turn formed the confidence and interest to carry out an academic study on childhood obesity in the Malaysia context, rather than in China.

Meanwhile, prior to the conduct of this study, active involvement in three game production and consultancy projects had provided a positive ground to conduct a game-based obesity prevention study in Malaysia. The involvement began in 2013, when a Mandarin communication learning app was designed and developed in UPSI (see Tan, Lin & Wang, 2013). This was followed by collaboration with game developers in the United States of America (USA) in order to set up the KNeoWORLD game-based learning portal (http://kneoworld.com/home). In particular, the localization of contents for Mainland China market was accumulated through this experience. After that, a game production opportunity was offered by Dr Nurul Fazmidar Mohd Noor from Universiti Malaya to participate in a project titled "Examining how Malaysian School Children Learn Theory of Inventive Problem Solving through a Mobile Game" (project code: CG044) between November 2013 and October 2014. The results of the study demonstrated how constructive alignment could be set to align intended learning outcomes with game elements in order to embed problem-solving skills in game playing (Tan, Nurul Fazmidar & Wang, 2014).

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In fact, the alignment approach could also be made between intended treatment outcomes with game elements in order to counter overweight or obese problems in game playing. In other words, with appropriate alignment, games can be used beyond entertainment.

In the field of serious games, specially designed games are useful in four fields of practice, which are education, business, health and military (Sawyer & Smith, 2009). In the practice of education and health, games have been proven to be naturally engaging to children (Milteer & Ginsburg, 2012). With the shift of multimedia paradigm from personal computer to mobile devices, children are born to be digital natives of mobile gadgets and apps. Nonetheless, the phenomena put parents and teachers in a dilemma, in which they realise the needs of children for games but they worry about the negative effects inherited in games as provoked by mass and social media. In fact, academic researchers could help parents and teachers to walk out of the dilemma by presenting them with findings of empirical studies, as opposed to relying on hearsay to make judgment.

In a nutshell, this study attempts to put a game-based obesity prevention idea into practice, and then examines its effectiveness through a quasi-experimental study on preschool children in Malaysia. The fundamental assumption made in this study is that game playing can make overweight and obesity prevention fun and engaging, which in turn leading to pleasant instead of fearful experience among children who receive treatment. In particular, the assumption has been proven through the playtesting session conducted in this research (see section 3.5.1).

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1.3 Problem Statement

Obesity has become a global epidemic since year 2000 (WHO, 2015), particularly in developing countries. Childhood obesity is associated with a higher chance of obesity, premature death and disability in adulthood (WHO, 2015). As depicted by Sahoo et al. (2015), preschool childhood obesity has been found correlated to obesity in later years of childhood, thus preventing and treating preschool obesity are particularly important. Also, obese children commonly encounter difficulties in breathing (Niehoff, 2009), increased risk of hypertension (Raj, Sundaram, Paul, Deepa, & Kumar, 2007), early markers of cardiovascular disease (Aris, et al., 2017), insulin resistance (Niehoff, 2009), and negative psychological effects (Rawana, Morgan, Nguyen, & Craig, 2010; Goldfield, Moore, Henderson, Buchholz, Obeid, & Flament, 2010; Tanofsky-Kraff, Yanovski, Wilfley, Marmarosh, Morgan, & Yanovski, 2004; Zametkin, Zoon, Klein, & Munson, 2004). Therefore, childhood obesity is causing serious financial and mental pressure to a family and a society.

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According to a systematic review done by Seburg, Olson-Bullis, Bredeson, Hayes, and Sherwood (2015) to compare the effectiveness of primary care-based childhood obesity prevention against treatment intervention, only one effective (out of 31) study was prevention study, as opposed to seven effective treatment intervention studies. In other words, most existing prevention and treatment intervention did not yield the desired positive effects (see section 2.2.3), thus failing to stop the rising numbers of children who face overweight or obesity problem. So, novel approaches, as revealed by Dias, Tibes, Fonseca, and Zem-Mascarenhas (2017) in preventing and

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treating childhood overweight and obesity, are urgently sought after (Deckelbaum & Williams, 2001). These approaches involve the use of behavioral treatment with contemporary computing technologies, and will be discussed further in section 2.4. There are indeed games designed for tackling obesity issues, but those games are generally meant for teenagers or adults. Treating adult obesity is different from treating childhood obesity due to the differences in physiological and psychological characteristics. As a result, designing game contents to prevent and treat obesity would also be different between adults and children (see section 3.4). The game-based childhood obesity prevention framework proposed in this study addresses these differences by including the roles which should be played by kindergarten, parents and overweight or obese child.

The potentials of games, particularly games for health, had been recognized by researchers as efficient and effective means of childhood obesity prevention (Elsevier Health Sciences, 2010; Lison et al., 2015). However, as elaborated by Thompson (2014), the key challenge of using games in preventing childhood obesity was to identify the right balance between "serious-ness" of components that promote behaviour change and "fun-ness" of components that entertain children. In fact, this was a research gap encountered by most of researchers who attempted to design and develop games for childhood obesity prevention, hence the genesis of this PhD study to fill in the research gap.

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1.4 Research Aim and Objectives

This research aims to validate a framework of game-based childhood obesity prevention. A provisional framework was proposed based on the standard operating protocol (SOP) practiced in hospital by pediatricians for treating and preventing obesity among preschool children. Figure 1.1 is a time chart of visits by patients in a SOP for treating childhood obesity in hospital. As depicted by Forslund et al. (2014), this SOP was deduced based on the Upppsala Longitudinal Study of Childhood Obesity (ULSCO), and it is widely practiced in Europe. It consists of five sets of procedure: 1) First visit; 2) Feedback; 3) Treatment; 4) Annual follow-up; and 5) Treatment. The ULSCO protocol covers seven areas of diagnosis, which are goals, nutrition, sleep, well-being / welfare, stress, physical activity and relationships / network (Forslund et al. 2014). The universality of this SOP and its areas of diagnosis lay the foundation for the development of the framework of game-based childhood obesity prevention in this research (see section 2.5).

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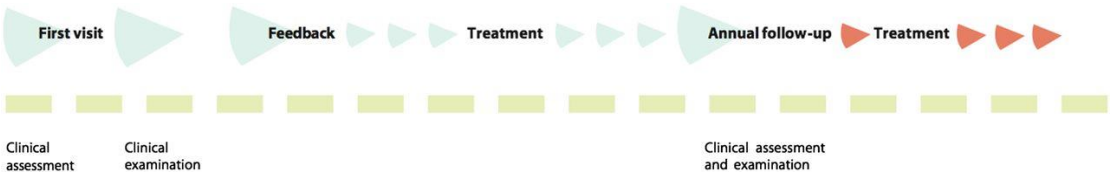

Figure 1.1. Time Chart of Visit by Patients in Hospital. Source: Forslund et al. (2014)

A serious game was designed, developed and validated for use as a research instrument in a quasi-experimental study which was conducted in Tadika NCDRC. A nonequivalent control group pre-test / post-test quasi-experiment was carried out with

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60 preschool children in Tadika NCDRC to the following achieve four research objectives:

1. To design, develop and validate a mobile game for use in childhood obesity prevention among preschool children.

2. To compare the differences of preschool children's food preference before and after playing a childhood obesity prevention game.

3. To compare the differences of preschool children's conception on the relationship between obesity and healthy lifestyle before and after playing a childhood obesity prevention game.

4. To compare the differences of preschool children's conception on the danger of childhood obesity before and after playing a childhood obesity prevention game.

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1.5 Research Questions and Hypothesis

The game-based childhood obesity prevention framework covers three aspects in preschool obesity prevention. The first aspect is about preschool children's food preference; the second aspect is related to preschool children's conception on healthy lifestyle; and the third is about preschool children's conception on the danger of

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childhood obesity. These aspects were operationalised into the following four research questions:

1. How to design, develop and validate a mobile game for use in childhood obesity prevention among preschool children?

2. Is there a significant difference of preschool children's food preference before and after playing an obesity prevention game?

3. Is there a significant difference of preschool children's conception on the relationship between obesity and physical exercise before and after playing an obesity prevention game?

4. Is there a significant difference of preschool children's conception on the danger of obesity before and after playing an obesity prevention game?

The first research question was planned to be answered by identifying suitable gamification approach and game production methods. As for the remaining three questions, three null hypotheses and three alternative hypotheses were formulated for statistical testing in search for answers, as :

1. H_0: Preschool children's food preference shows no significant difference before and after playing an obesity prevention game.

2. H_1: Preschool children's food preference shows significant positive change after playing an obesity prevention game.

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3. H_0: Preschool children's conception on the relationship between obesity and physical exercise show no significant difference before and after playing an obesity prevention game.

4. H_1: Preschool children's conception on the relationship between obesity and physical exercise show significant improvement after playing an obesity prevention game.

5. H_0: Preschool children's conception on the danger of obesity shows no significant difference before and after playing an obesity prevention game.

6. H_1: Preschool children's conception on the danger of obesity shows significant improvement after playing an obesity prevention game.

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1.6 Significance of this Study

The field of child and adolescent development is essentially a multi-disciplinary field where the body of knowledge of health science and social sciences converge to generate new knowledge—a fundamental requirement of awarding a PhD under Malaysian Qualification Framework (Malaysian Qualifications Agency, 2015).

The outcomes of this original research would contribute to the above-mentioned field by broadening the boundary of knowledge through an in-depth thesis,

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which will be presented and defended according to UPSI standards. Alongside to the thesis, internationally refereed publications had been written based on the findings of this empirical study.

1.7 Research Scope and Limitations

This study is conducted under the academic settings, in which it combines health science and social sciences (see Figure 1.2). Therefore, this game-based treatment study should be considered as a healthy early child development study, as classified by WHO (Irwin, Siddiqi & Hertzman, 2007).

Although a prototype mobile game titled '*Fight Obesity 2.0'* was designed and developed to validate the game-based obesity prevention framework, this is essential not a computer science study. Nonetheless, the algorithm, mechanics and programming technicality of the game has been taken care of by professionals in the game industry. The game contents were validated by Google Play through the International Age Rating Coalition (IARC). In terms of limitation, this study was constrained by three matters, namely the participants, the device used to conduct the study, and the mobile game.

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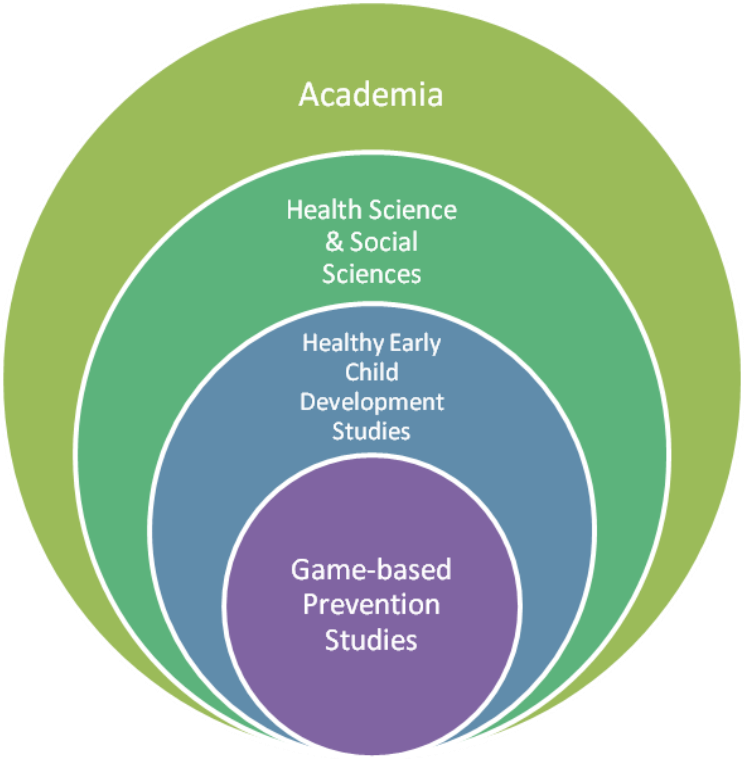

Figure 1.2. Scope and Position of Game-based Prevention Studies in Academia

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1.7.1 The Participants

This study was limited to Malaysian preschool children aged five and six years old, as opposed to all age groups in preschool childhood. This limitation was set to align with the age setting by NCDRC regarding the use of digital multimedia contents. The As depicted by the Centers for Disease Control and Prevention (2015), preschoolers should be able to notice a difference between girls and boys, and also recall part of a story—cognitive skills required to accumulate content knowledge on childhood obesity prevention. Child development milestones are attached in Appendix A for reference. Also, children younger than four years old generally do not have sufficient cognitive capacity to conceptualise the relationship between obesity and food

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preference, physical exercise and consequences of being obese (Centers for Disease Control and Prevention, 2015).

The participants of this study were recruited from the National Child Development Research Centre (NCDRC) because the centre is the only one of its kind in Malaysia, where the environment, facilities and facilitation would be unique for conducting game-based obesity prevention research.

1.7.2 The Device Used

Due to the physical bodily limitations possessed by preschool children, the mobile devices used in the quasi-experimental study would be limited to 7-inch tablet, instead of using smartphones with smaller screen or bigger size tablets with heavier weight. Only identical tablets would be used to collect data with the participants.

1.7.3 The Mobile Game Used

The operating system of the device used will be limited to only Android system because the mobile game was designed and developed specifically for this platform. In terms of game contents, the game levels were limited to three to match the needs for testing all hypotheses.

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1.8 Operational Definitions

1.8.1 Body Mass Index

Body mass index (BMI) is a simple index of weight-for-height that is commonly used to classify overweight and obesity in adults (WHO, 2015). It is defined as a person's weight in kilograms divided by the square of his height in meters (kg/m^2).

1.8.2 Childhood Overweight

Overweight is defined as abnormal or excessive fat accumulation that may impair health (WHO, 2015). A BMI greater than or equal to 25 is overweight. Childhood overweight occurs when a child is above the normal weight for his or her age and height (WHO, 2015). Body mass index (BMI) is a measure used to determine childhood overweight and obesity. According to BMI-for-age criteria, a BMI greater than 2SD (standard deviations above the WHO growth standard median) is overweight (0-5 years), a BMI greater than 1SD (equivalent to BMI 25 kg/m^2 at 19 years) is overweight (5-19 years).

1.8.3 Childhood Obesity

Obesity is defined as abnormal or excessive fat accumulation that may impair health (WHO, 2015). A BMI greater than or equal to 30 is obesity. Childhood obesity occurs when a child is above the normal weight for his or her age and height. According to

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BMI-for-age criteria, a BMI greater than three standard deviation is obesity (0-5 years), a BMI greater than two standard deviations (equivalent to BMI 30 kg/m^2 at 19 years) is obesity (5-19 years old).

1.8.4 Mobile Game

For this study, a mobile game, namely *Fight Obesity 2.0* was used as a game-based childhood obesity prevention. It is a digital two dimensional (2D) role-playing game, to be played by preschool children aged between five and six years old.

1.8.5 Prevention

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The word “prevent” literally means “keeping something from happening or making someone or something unable to do something” (Anderson, Prohaska & Satariano, 2015). In this research, the term “prevention” is considered as a part of the treatment algorithm, that is to prevent recurrence of overweight or obesity (National Institutes of Health, 2000).

1.8.6 Game-based Prevention

In this research, game-based prevention is a form of player-centred prevention that uses serious games for health purposes.

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