Exergames for subthreshold depression among older adults

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**EXERGAMES FOR SUBTHRESHOLD DEPRESSION
AMONG OLDER ADULTS**

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**WEE KIM WEE SCHOOL OF COMMUNICATION AND
INFORMATION**

2017

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A thesis submitted to the Nanyang Technological University
in partial fulfilment of the requirement for the degree of
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ABSTRACT

The number and percentage of older adults continue to increase dramatically around the world. Subthreshold depression is not often highlighted in the field of gerontology, although it has a high prevalence rate among older adults. Subthreshold depression refers to a cluster of depressive symptoms in which the number, duration, or quality are insufficient to meet the diagnosis of a major depression. Among older adults, subthreshold depression is at least two to three times more prevalent than major depression and leads to many negative outcomes. Among the various depression treatments, which range from biological to psychosocial interventions, exercise is considered to be an effective and cost-efficient non-clinical intervention for subthreshold depression. Exergame is a special type of exercise, wherein the exercise activities are combined with video gaming. Several recent attempts to investigate the feasibility and preliminary effects of exergames as a depression intervention have been conducted. However, because of the lack of rigorous controlled studies in this domain, the true effectiveness of exergames on subthreshold depression remains unclear especially on older adults. Hence, it is important to investigate the anti-depressive effects of exergames and the potential influencing factors of using exergames as depression therapy for older adults with subthreshold depression.

The current research sought to understand the application and effectiveness of exergames for subthreshold depression. A systematic review and meta-analysis of ten existing studies were conducted to investigate the anti-depressive effects of exergames. An overall significant effect size of Hedges' $g = 0.23$ was identified among eleven trials, which supported the positive effects

of exergames on alleviating depression. Findings from the subgroup analysis further identified several significant moderators , such as demographic factors, number of sessions, depression severity, and player interaction. The systematic review also provided the basis and guidance to develop two controlled studies, Study One and Study Two, to empirically investigate the effects and influencing factors of exergames on subthreshold depression among older adults.

From the previous depression studies and psychological theories, such as Theory of Flow and Social Cognitive Theory, Study One hypothesised that exergames have a superior anti-depressive effects over traditional exercise. A controlled study with repeated measures was conducted to test the differences in the effects of exergames and traditional exercise over six weeks among 50 older adults in Singapore. Results from the two-way MANOVA indicated that participants in exergames had significantly lower subthreshold depression and higher positive affect over the intervention period than those in traditional exercise. No significant exercise platform effects were reported on self-efficacy over time.

Study Two further investigated the potential effects and mechanism of play mode in exergames. A conceptual model was built based on previous theories and game studies. The model implied that play mode might affect depression through the mediation effects of social support and loneliness. This implication was tested using a between-group study with two different conditions of single-player or multiple-player (two players) exergames among 52 Singaporean older adults for six weeks. Findings demonstrated that multiple-player condition led to better improvements on subthreshold

depression and loneliness among older adults, when compared to single-player condition. The examination of the conceptual model further supported the mediation role of loneliness in the association between play mode and subthreshold depression. Although social support was not confirmed to be a significant mediator, the findings suggested its potential moderation effects, which should be tested in the future research.

This research has several main contributions. First, findings were promising to suggest the implementation of exergames as a regular health programme for older adults, in both general and clinical practices. Second, the introduction of play mode effects opened the theoretical discussion on optimising the anti-depressive effects of exergames and encouraged the multiple-player mode. Lastly, the research highlighted challenges and future directions in this new domain, which include examining the effects of demographic factors, such as age group, gender, and physical conditions, exploring the effects of playing with different people, and calling for more Asian-focused studies.

CHAPTER ONE

INTRODUCTION

1.1 Background

Our world has been experiencing significant ageing. Since the mid-20th century, the rising proportions of older adults in the total population has become a major global demographic trend (United Nations, 2013). A recent report from the United Nations (2015) indicated the number of older adults aged 60 and above is 901 million in 2015, taking up 13% of the entire population. The report predicted that this number would be doubled in 2050, reaching nearly 2.1 billion. Population ageing takes place almost everywhere. However, its intensity and depth vary across countries and regions. In Europe, older adults will become a much larger age group of the population in 2060, when the current 18.0% will increase to 28.0% in 2060 (European Union, 2014). Those aged 80 and over will also increase from 5.0% to 12.0%, becoming almost as large as the young population in 2060. The ageing population of the United States is 43.1 million in 2012, and will double in 2050 (Ortman, Velkoff, & Hogan, 2014). The population of older adults in Asia has reached 330 million in 2014 and is expected to double the original number by 2034 (United Nations, 2014). Population ageing has raised many public concerns on the well-being of older adults (Cheng, Chi, Fung, Li, & Woo, 2015; Read, Grundy, & Foverskov, 2016). Although recent medical advances have resulted in significant improvements in their physiological well-being, older adults continue to suffer

from serious psychosocial disorders (Cheng, Fung, & Chan, 2009; Chou & Chi, 2000).

Depression is the most frequent cause of emotional suffering in late life and has become one of the major public health concerns around the world (Blazer, 2002). Late-life depression has been found to be a risk factor for poor health (Han, 2002), disability (Lenze et al., 2001), mortality and suicide (Mann, 2002). Barua and colleagues (2011) reviewed studies published in the past 50 years on the prevalence of geriatric depression, and determined that approximately 10.3% of the elderly population suffered from depression around the world.

However, an even larger group of older adults has been reported to have depressive symptoms that do not reach the minimum diagnostic criteria for major depression. These symptoms are often defined as ‘subthreshold depression’ (Lavretsky & Kumar, 2002; Lyness, King, Cox, Yoediono, & Caine, 1999). Findings from many nationally surveys indicated that people aged 55 and above had a high prevalence of subthreshold depression (Beekman, Deeg, Braam, Smit, & van Tilburg, 1997; Hailemariam, Tessema, Asefa, Tadesse, & Tenkolu, 2012; Leung, Cheung, Kao, & Gulati, 2015; Reynolds, Pietrzak, El-Gabalawy, Mackenzie, & Sareen, 2015). Although the severity of subthreshold depression is less than major depression, recent research indicated that the effects of subthreshold depression on quality of life is similar to that of a major depression (Wagner et al., 2000). Older adults with subthreshold depression also have higher risk of developing major depression (Andreescu, Chang, Mulsant, & Ganguli, 2008; Lyness et al., 2006). The negative

consequences of late-life subthreshold depression have indicated the need for effective and efficient treatments.

Antidepressants are frequently used in clinical practice. However, whether they are suitable to be used in subthreshold depression is still questionable (Fournier et al., 2010; Hermens et al., 2007), and they are less acceptable for older adults (Gum et al., 2006; Hindi, Dew, Albert, Lotrich, & Reynolds 3rd., 2011). Clinicians also avoid prescribing medication for frail elderly patients with depression when these patients are already on multiple medications (Reynolds & Kupfer, 1999). Psychosocial interventions are a significant supplement to pharmacotherapy and are effective depression treatments that address medication drawbacks. Previous studies (American Psychiatric Association, 2010; Ayers, Sorrell, Thorp, & Wetherell, 2007; Manepalli, Desai, & Sharma, 2009) have indicated that psychosocial interventions can be understood as a therapeutic endeavour that involves certain forms of therapies from the psychological and social perspectives. Various forms of psychosocial interventions have been supported to have significant effects on depression, including psychotherapy (Dunn, 2007), reminiscence therapy (Chin, 2007), music therapy (Hanser, 1990), and physical exercise (Greist et al., 1979; McCann & Holmes, 1984).

Among the different types of psychosocial interventions, exercise (or physical activity) is an effective but often underused treatment for mild or subthreshold depression (Brenes et al., 2007). Exercise offers physical improvement compared with other psychosocial interventions, which is important for older adults. Exercise also incurs less cost and human assistance, and has fewer restrictions on space and time. The use of exercise as a potential

therapeutic strategy for depression has been studied for a long time (Barbour & Blumenthal, 2005; Trivedi, Greer, Grannemann, Chambliss, & Jordan, 2006). Meta-analysis reviews have supported the positive effects of exercise on reducing depression among various age populations (Daley, 2008; Josefsson, Lindwall, & Archer, 2014), including older adults (Blake, Mo, Malik, & Thomas, 2009; Sjösten & Kivelä, 2006). Most previous studies on elderly exercise focused on treatment efficacy on major depression, and only few have focused on the treatment of subthreshold depression. A pilot clinical trial from Brenes et al. (2007) tested the effects of an exercise programme on older adults with minor depression for over sixteen weeks. The outcomes indicated a significant trend for the superiority of exercise over the usual care conditions in improving clinician-rated depression scores among the senior participants. Therefore, exercise appears to be a cheap, convenient, and effective treatment for older adults with subthreshold depression.

Recent advances in digital game technology have resulted in the rapid growth in the popularity and use of 'exergame' as an alternative to traditional exercise (Li, Lwin, & Jung, 2014a; Vernadakis, Papastergiou, Zetou, & Antoniou, 2015). According to American College of Sports Medicine (2013), exergame refers to technology-driven physical activities that requires physical effort from the players to play the game. Oh and Yang (2010, p. 10) have a detailed exergaming definition as 'an experiential activity in which playing exergames or any videogames requires physical exertion or movements that are more than sedentary activities and also include strength, balance, and flexibility activities'. Exergames were observed to have similar or even higher energy expenditure than traditional exercise (Hurkmans, Ribbers, Streur-Kranenburg,

Stam, & van den Berg-Emons, 2011; Monedero, Lyons, & O'Gorman, 2015). Several studies have been conducted to investigate the effectiveness of exergames on physiological well-being (Sun, 2013; Vernadakis, Gioftsidou, Antoniou, Ioannidis, & Giannousi, 2012). Recent efforts have further extended these studies to investigate the potential benefits of exergames on psychological and mental well-being (Keogh, Power, Wooller, Lucas, & Whatman, 2013; Wollersheim et al., 2010).

1.2 Research Gaps

The current research was motivated by the high prevalence and negative outcomes of subthreshold depression among older adults. While major depression still relies on professional treatments such as medications and psychotherapy, it is possible and important to look for alternative interventions that are suitable and effective to alleviate subthreshold depression for the ageing population. Several recent exergaming studies investigated the feasibility and preliminary effects of exergames as an alternative depression intervention in general and clinical healthcare practice (Chao, Scherer, Montgomery, Wu, & Lucke, 2015a; Rendon et al., 2012; Yuen, Holthaus, Kamen, Sword, & Breland, 2011). Exergames for depression is still very much in its infancy (Rosenberg et al., 2010), there still remains numerous research gaps in this domain.

First of all, some early studies have investigated the effects of exergame on depression, but the overall effect has yet to be addressed in literature. Some exergaming studies have reported significant reduction on depression (Chao et al., 2015a; Rosenberg et al., 2010), but others have reported conflicting results

(Meldrum et al., 2015; Mhatre et al., 2013). These studies were also conducted in different contexts, different participants, and with different methodologies. A clear overall picture is lacking on the existing studies conducted in this new research field.

Secondly, exercise has positive effects on depression among older adults (Blake et al., 2009; Bridle, Spanjers, Patel, Atherton, & Lamb, 2012), which include subthreshold depression (Brenes et al., 2007; Ciechanowski et al., 2004). It is reasonable to assume exergames may have similar effects on subthreshold depression because they also involve physical exercise. However, compared with the traditional form of exercise, exergames involve various digital features, such as virtual reality, attractive visual and audio feedback, which allow exercise activities to be more interactive and fun (Chao, Scherer, & Montgomery, 2015b). Whether these digital features in exergames influence their effects on subthreshold depression among older adults is unclear. The lack of knowledge in this domain calls for empirical research to examine whether exergames may have different effects over traditional exercise.

Lastly, a gap also exists in the lack of investigation in the potential factors that influence the effects of exergames. Several factors were highlighted in recent studies, such as design of controllers (Park et al., 2014b), exercise intensity (McNarry & Mackintosh, 2016), and avatar appearance (Li et al., 2014a). However, most of these factors associate either exerciser motivation or physical improvements of exergames. There is still no particular study to-date exploring the factor that may have a link to depression. Knowledge gained from this will contribute to exergaming literature by providing support on how to

promote exergames as an effective depression intervention for the ageing population.

Considering the gaps discussed above, the current research focuses on the potential application of exergames to address subthreshold depression among older adults. To specify, It aims to a) investigate whether exergames are effective in addressing subthreshold depression among older adults; and b) If so, explore the factors that may optimise the effects.

This study was carried out in the context of Singapore. Singapore is one of the rapidly ageing societies around the world. The proportion of people aged 65 years in the entire population increased from only 2.5% in 1965 to 10.5% in 2013 (Department of Statistics, 2013). The average life expectancy in Singapore has been extended to 82.3 years, being one of the highest in the world (Department of Statistics, 2013).

Tan and Wong (2008) indicated that a significant number of older adults in Singapore suffer from mental disorders although their physical health status has been improving. A population-based survey in Singapore (Nyunt, Chiam, Kua, & Ng, 2009) reported that 13.0% out of the 1,092 older adults have depressive symptoms. Tiong et al. (2013) found that depression prevalence was about 21.1% among elderly nursing home residents in Singapore, and that the prevalence rate for subthreshold depression was 14.4%, which was more than twice of that for major depression (6.7%). Chuan et al. (2008) reported that the prevalence rate of subthreshold depression was 20.0% in the Singaporean elderly population. Therefore, depression, especially subthreshold depression, is an important health concern for many older Singaporeans. Despite the high

prevalence of subthreshold depression among Singaporean older adults, very few local studies have focused on interventions for this group of people. Theng et al. (2009) indicated that exergame has high acceptance among older adults in Singapore. Therefore, Singapore may be a good context to explore whether exergame can be a suitable and effective intervention for reducing subthreshold depression among older adults. Findings from the current thesis may also inspire future relevant studies in other regions of the world.

1.3 Thesis Overview

This thesis was developed primarily by the motivations described in this chapter. Subthreshold depression in older adults is the target problem for the current thesis because of its high prevalence and negative outcome. The potential effects of exergames on depression has led to an important research aim of investigating anti-depressive effects and influencing factors of exergames on older adults with subthreshold depression. The thesis studies started with a systematic review and meta-analysis to synthesis the existing studies of exergames and depression. The findings helped identify gaps and directions for the following two empirical studies that investigate the effects of exergames on subthreshold depression among older adults. Figure 1.1 presents the thesis flowchart and how the three included studies were connected to address the aim of this thesis.

Chapter Two offers an overview of the previous literature on understanding subthreshold depression among older adults. The review was conducted to provide background knowledge for the entire research and involved studies. Various resources were utilised in this process and they

include but are not limited to books, journals, seminar and conference proceedings and web-based materials. The chapter reviews the facts and existing interventions for subthreshold depression among older adults, and further focuses on the effects of exercise and exergames on depression.

A systematic review and meta-analysis of research on exergames for the treatment of depression were reported in Chapter Three. These steps provided a clear overall picture of existing studies conducted in this new research field. The findings highlighted several important gaps, including the needs to a) examine the exergame effect on older adults with depression, particularly on subthreshold depression; b) determine the differences in the true effects of exergames and traditional exercise; c) explore the effects of player interaction on the depression in the exergame setting.

Chapter Four introduced and adopted relevant theories from the fields of human-computer interaction, social and behavior science, and build the theoretical framework of the thesis. The specific hypotheses of exercise platform effect and play mode effect were developed in the context of exergames and psychosocial well-being, which were then utilised in the two empirical studies.

Two empirical studies were conducted based on these gaps and implications. Chapter Five describes Study One which investigated the differences in the effects of exergames and traditional exercise over time, to address the above gap a and b identified in Chapter Three. It involved a between-group (exergame versus traditional exercise) controlled study on a sample of community-dwelling older adults in Singapore. It examined benefits

of exergames on the psychosocial well-being in older adults with subthreshold depression. After examining the true effect of exergames on subthreshold depression among older adults, a following step would be to further investigate what potential factors influence the effects of exergames. Inspired from gap c, play mode was found to be a possible factor that possibly affects the exergaming effect on depression. Chapter Six illustrates Study Two which investigated whether and how play mode, single-player and multiple-player modes, affects subthreshold depression among older adults. The conceptual influencing model was also tested to explore the possible mediation role of social support and loneliness on the association between play mode and depression.

Finally, Chapter Seven summarises the main findings of the four involved studies and provides the general discussion of the thesis research. Challenges and future research detections are also discussed in the domain of exergames for geriatric depression.

Figure 1.1. Thesis flowchart.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides a general overview of the literature and relevant studies related to subthreshold depression, particularly, its definition, prevalence, negative effects, and existing treatments. Chapter Two also reviews exercise as a potential intervention for subthreshold depression. It includes recent studies on exergames, which are a novel form of exercise combining video games and exercise training.

2.1 Subthreshold Depression and Older adults

2.1.1 Depression

The Diagnostic and Statistical Manual, Fourth Edition, Text Revision (DSM-IV-TR; American Psychiatric Association, 2000) states that a person is diagnosed to have major depression when the he/she ‘exhibits one or both of two core symptoms ‘depressed mood and/or loss of interest or pleasure in life activities’ for at least two weeks and ‘at least five of the following symptoms that cause clinically significant impairment in social, work, or other important areas of functioning almost every day: feelings of worthlessness or inappropriate guilt; diminished ability to concentrate or make decisions; fatigue; psychomotor agitation or retardation; insomnia or hypersomnia; significant decrease or increase in weight or appetite; and recurrent thoughts of death or suicidal ideation.’ (American Psychiatric Association, 2000, p. 356). The International Classification of Diseases, Tenth Edition ((ICD-10; World

Health Organisation, 1992) also set the diagnoses of this disorder based on the presence of a certain number of depressive symptoms. The World Health Organization reports that major depression will become the second most important public health concern in 2020 because of the effects of major depression on disability and mortality (Muñoz, Beardslee, & Leykin, 2012). Older adults are identified as a high-risk population for depression (Sutin et al., 2013).

2.1.2 Subthreshold Depression

Major depression has been recognised as a highly prevalent mental disorder in clinical practice and community settings. However, an even larger group of people demonstrated depressive symptoms below the clinical criteria of major depression (Fils et al., 2010; Vuorilehto, Melartin, & Isometsä, 2005).

Clinicians and health professionals have encountered difficulties in diagnosing and helping this group of people when utilising the rigid criteria from DSM-IV and ICD-10. However, researchers were aware of the limitations in coverage and thus began to use the concept of ‘subthreshold depression’ to represent those who suffer from a cluster of depressive symptoms, in which the number, duration, or quality are insufficient to meet the diagnosis of major depression (Bali & Jiloha, 2008).

Unlike major depression, classification systems have no clear and accepted definition of ‘subthreshold’ depression (Pincus, Davis, & McQueen, 1999). In a systematic review on the definitions of subthreshold depression, most of the studies defined it based on the conditions in DSM-IV, in which ‘depressed mood or loss of interest but having less than five more symptoms or

not reporting significant impairment’ (Rodríguez, Nuevo, Chatterji, & Ayuso-Mateos, 2012, p. 2). Similarly, National Collaborating Centre for Mental Health from United Kingdom (2010) indicated that subthreshold depression is closest being ‘minor depression’, a research diagnosis (but not an accepted definition) in DSM-IV that can be understood as “at least two but less than five symptoms are required of which one must be depressed mood or diminished interest”. As a result, the current thesis adopted the most common definition and defines subthreshold depression as ‘Two to four depressive symptoms in DSM-IV, including at least one core symptom of either depressed mood or loss of interest’. Applying this definition makes the concept clearer, and also help define the criteria and measurement of subthreshold depression.

Extensive studies in clinical and research literature have identified several subdivisions or alternative names of the broad category of subthreshold depression, including ‘subsyndromal depression’, ‘subsyndromal symptomatic depression’, ‘nonspecific depressive symptoms’, ‘subclinical depression’, ‘minor depression’, ‘dysthymia’, and ‘recurrent brief depression’ (Al-Windi, 2005; Bali & Jiloha, 2008; da Silva Lima & de Almeida Fleck, 2007; Judd, Rapaport, Paulus, & Brown, 1994; Rodríguez et al., 2012). Moreover, some scholars distinguished subthreshold depression from depressed mood or anhedonia, whereas others included these symptoms in the ‘subthreshold’ definition (Fergusson, Horwood, Ridder, & Beautrais, 2005). With the substantial overlaps among these concepts, the concept of ‘subthreshold depression’ in current thesis included subsyndromal symptomatic depression, mild depression, subclinical depression, subdysthymic depression, minor depression and dysthymia.

Given the practical difficulty and inherent uncertainty in deciding thresholds for significant symptom severity, there is no standard measurement or scale to detect subthreshold depression in both research and clinical practice. In the systematic review of Rodríguez et al. (2012), the assessment of subthreshold depression in all included studies were still closely associated with the symptoms in DSM-IV or ICD-10. Many studies assessed subthreshold depression through the measurement of depression scales and/or mental disorders scales, such as Composite International Interview for Primary Health Care (CIDI-PHC; Rucci et al., 2003), Hamilton Depression Rating Scale (HDRS; Tamburrino, Lynch, Nagel, & Smith, 2009), and The Primary Care Evaluation of Mental Disorders (PRIME-MD; Al-Windi, 2005). Among these measurements, the Patient Health Questionnaire (PHQ-9; Spitzer et al., 1994) was frequently used in the studies of subthreshold depression (Martin, Rief, Klaiberg, & Braehler, 2006; Pols et al., 2017; Schmitz et al., 2014). PHQ-9 was developed as a fully self-administered version of the original PRIME-MD. One advantage of the PHQ-9 is its exclusive focus on the 9 diagnostic criteria for DSM-IV depressive disorders. In other words, its disorders divided into threshold disorders according to DSM-IV and subthreshold conditions. Therefore it was a suitable measurement for subthreshold depression with an operational definition developed from DSM-IV.

Subthreshold depression has received considerable attention in recent decades. A previous study (Wagner et al., 2000) demonstrated that people suffering from subthreshold depression experience almost the same degree of psychosocial impairments (such as negative feelings and lack of interest) as those diagnosed with major depression. However, the nature of subthreshold

depression has led to the low rate of treatment rates (Sherbourne et al., 1994). People with subthreshold depression are often undiagnosed and seldom think they are ‘bad enough’ to see a doctor or seek proper treatment. Diagnosing and treating depression during the ‘subthreshold’ stage are important to prevent the condition from evolving to moderate or severe depression.

2.1.3 Subthreshold Depression in Older Adults

The number and percentage of older adults has continued to increase dramatically around the world (Christensen, Doblhammer, Rau, & Vaupel, 2009; Doyle, McKee, Rechel, & Grundy, 2009). Significant changes not only appear in physical functioning such as declines in vision, hearing, mobility, and cognitive abilities (Czaja & Lee, 2003; Fisk, Rogers, Charness, Czaja, & Sharit, 2004), but also occur in the psychosocial (psychological and social) aspect of late life. Older adults experience significant negative life events, such as loss of friends and family members, lack of social interaction, or inadequate economic resources (Antonucci & Akiyama, 1993; Folkman, Lazarus, Pimley, & Novacek, 1987). A substantial number of studies have shown that the accumulation of negative life events has been strongly associated with psychosocial problems among older adults (Kraaij, Garnefski, & Maes, 2002; Kraaij, Pruyboom, & Garnefski, 2002). Depression and subthreshold depression are perhaps the most common psychosocial disorders in late life (Berkman, Berkman, & Kasl, 1986; Blazer, Hughes, & George, 1987).

Compared to major depression, subthreshold depression has a much higher prevalence rate across all age groups. Meeks and colleagues (2011) discussed that subthreshold depression among older adults was at least two to

three times more prevalent than major depression. Their findings also suggested that the prevalence of subthreshold depression was lower in community settings and highest in long-term care settings. Moreover, many older adults suffering from subthreshold depression are at high risk of having a major depressive episode (Andreescu et al., 2008; Beekman et al., 2002). A community-based Dutch study (Schoevers et al., 2006) showed that the chance of developing major depression in three years among older adults with subthreshold depression was 29.3% higher than non-depressed peers.

Many prospective studies have demonstrated the significant negative outcomes of subthreshold depression in late life (Creed et al., 2002; Li & Conwell, 2009; Montross et al., 2008). In a study of a large sample of 646 older inhabitants, Beekman and colleagues (1997) found that subthreshold depression are strongly associated with general functioning impairment, and even disability. Similar to major depression, older adults with subthreshold depression were at a high risk for limitations in activities of daily living (Hybels, Pieper, & Blazer, 2009; Li & Conwell, 2009). Montross et al. (2008) found that subthreshold depression increase suicidal ideation among middle-aged and older patients. associated with increased costs and reduced health-related quality of life. A study of medical inpatients (Creed et al., 2002) indicated that cases of subthreshold depression incurred greater mean health care costs than the control cases. The same study also revealed that subthreshold depression led to greater impairment of health-related quality of life among these inpatients (Creed et al., 2002). Hence, promoting treatments on older adults with subthreshold depression is of great importance in daily healthcare. However, few studies have been conducted to test the treatment

effects for subthreshold depression (Oxman & Sengupta, 2002) and that on older adults.

2.2 Interventions for Addressing Depression and Subthreshold Depression

Various types of approaches have been utilised to address depression. Based on previous reviews and meta-analysis studies (Allan & Ebmeier, 2013; Blazer, 2002; Chin, 2007; Cole & Vaughan, 2005; Daley, 2008; Morgan & Jorm, 2008), these approaches can be categorised into two main interventions: biological and psychosocial interventions.

2.2.1 Biological Interventions

Biological interventions are treatments that aim to reduce the depressive symptoms on biological aspects. They are often used in current clinical practice. The common biological interventions include medications, electroconvulsive therapy, and light therapy.

Medications. Medication is the most frequently used treatment in current clinical practice. Generally, antidepressant drugs are prescribed to reduce depressive symptoms (Blazer, 2002). Common antidepressant medicines are tricyclic antidepressants and selective serotonin reuptake inhibitors, which are effective in treating major depression among older adults (Forlenza, Junior, Hiralal, & Ferreira, 2000; Kyle, Petersen, & Overo, 1998; Mulsant et al., 2001). However, evidence suggested that antidepressant medicines are less efficacious in treating less severe depressions, such as subthreshold depression (Ackerman, Greenland, Bystritsky, & Small, 2000; Oxman & Sengupta, 2002). Moreover, the drawbacks of antidepressants have also been documented, and include

physical and psychological side effects, such as the deterioration of emotional and mental conditions and impaired psychomotor abilities and cognitive functioning (Chang & Chen, 2005; Lai & Good, 2005; McCaffrey, 2008). Clinicians also avoid prescribing medication for frail elderly patients with depression who are taking multiple medications (Reynolds & Kupfer, 1999).

Electroconvulsive Therapy. Electroconvulsive therapy (ECT) is a procedure in which electric currents are passed through the brain to intentionally trigger a brief seizure. This approach has been shown to be more effective than antidepressant medicine in the treatment of severe depression (Flint & Rifat, 1998). ECT has therapeutic benefits but remains controversial because of potential structural and functional brain damage, which include seizure induction, cognitive side effects, memory dysfunction and effects on cerebral physiology (Prapotnik et al., 2006). ECT is not recommended for patients with mild or moderate depression because of these risks and side effects (Brosse, Sheets, Lett, & Blumenthal, 2002).

Light Therapy. Light therapy or phototherapy consists of exposure to daylight or specific wavelengths of light. This type of therapy was also found to alleviate depression. It can help reset a patient's 'biological clock' (circadian rhythms), which controls sleeping and waking. However, its benefit may be limited to depressive disorders that follow a seasonal pattern (Golden et al., 2005; Terman et al., 1989).

2.2.2 Psychosocial Interventions

Besides biological interventions, psychosocial interventions are an important supplement in depression treatments. They address the psychological and social

causes of depression. The common psychosocial interventions include psychotherapy, music therapy, reminiscence therapy, pet therapy, and exercise.

Psychotherapy. Psychotherapy has been empirically validated as an effective non-pharmacological intervention for depressed older adults (Beekman et al., 2006; Ciucurel & Iconaru, 2012; Teri, Logsdon, Uomoto, & McCurry, 1997). Patients received therapeutic education from therapists or other health professionals through the intervention process, based on the disorder assessment, coping, problem solving, and normalising of symptoms. Cognitive Behaviour Therapy (CBT) and Interpersonal Therapy (IPT) are the most frequently studied psychotherapies. Many systematic reviews and meta-analysis studies have been conducted to confirm the positive effects of psychotherapies on depression in late life (Cole & Vaughan, 2005; Pinquart, Duberstein, & Lyness, 2007; Pinquart & Sörensen, 2001). Some researchers further tested the potential use of psychotherapy in the treatment of subthreshold depression (Lynch, Tamburrino, & Nagel, 1997; Spek et al., 2007b; Willemse, Smit, Cuijpers, & Tiemens, 2004; Williams et al., 2000). Spek and colleagues (2007b) found that an internet-based CBT has a higher effect size than waiting-list condition in treating subthreshold depression in a randomised control trial among older adults. Mossey et al. (1996) confirmed the positive treatment effects of interpersonal counselling on subdysthymic depression among hospitalised elderly, which is a feasible, acceptable and effective intervention in short-term depressive symptom reduction. A recent study (Poppelaars et al., 2016) found that both non-computerised and computerised CBTs reduced subclinical depression among adolescent girls. However, the implementation of psychotherapy has several barriers despite its

effectiveness. High financial cost, long waiting lists, and the requirement of professional therapists have limited the growth of this depression treatment. Moreover, social stigma may also prevent some patients from actively adopting psychotherapy (Brosse et al., 2002).

Music Therapy. Music therapy is also used in the treatment of depression, particularly for children and young people (Hendricks, Robinson, Bradley, & Davis, 1999). Some studies have also explored the treatment effects among geriatric depression. Chan et al. (2010), Hanser (1990) and Raglio et al. (2012) reported trials on using music therapy to reduce anxiety and improve moods for depressed older adults. Listening to music can be an effective depression therapy in the short term; however, evidence to support its ability to reduce depression over days or weeks is still lacking (Morgan & Jorm, 2008).

Reminiscence Therapy. Reminiscence therapy is another popular psychosocial intervention. It involves the discussion of past activities, events, and experiences with another person or group of people to reduce social isolation and depression. Previous meta-analysis studies (Chin, 2007; Hsieh & Wang, 2003) have supported the effects of reminiscence therapy on older adults with depression. However, similar to psychotherapy, reminiscence therapy requires assistance and arrangement from professional therapists.

Pet Therapy. Pet therapy is a form of depression intervention that seeks to enhance social contact and relationships between different species (Colombo, Buono, Smania, Raviola, & De Leo, 2006). Pet therapy gives a person feelings of companionship and acceptance, thus reduces the feelings of loneliness and depression. Findings from two randomised controlled trials have both supported

the view that depression symptoms are significantly lessened in the people who lived with birds (Colombo et al., 2006; Jessen, Cardiello, & Baun, 1996).

However, there are some concerns on the risks of this type of animal-assisted therapy, including the potential for allergic reaction or attack (Brodie, Biley, & Shewring, 2002). Moreover, the pets and their handlers should both be trained for therapy scenarios.

Exercise Therapy. Good evidence shows that exercise is helpful for reducing depression symptoms. The effects of different forms of exercise on alleviating depression among older adults have been supported in geriatric literature. These effects include dancing (e.g. Eyigor, Karapolat, Durmaz, Ibisoglu, & Cakir, 2009), progressive resistance training (e.g. Palleschi et al., 1998), Tai Chi (e.g. Frye, Scheinthal, Kemarskaya, & Pruchno, 2007), and ‘Qigong’ (Tsang, Mok, Yeung, & Chan, 2003). However, research has yet to determine the most appropriate intensity and type of exercise required to have effects on depression (Morgan & Jorm, 2008).

Many interventions have been used to address depression, however, their application to subthreshold depression among older adults may vary significantly. The next section compares the fitness of these interventions for the target population of the current research.

2.2.3 Comparison of Interventions

Table 2.1 provides the comparison among these existing interventions. Major depression still relies on professional treatments, such as medications and psychotherapy. However, treatments for subthreshold depression may vary considerably in their effectiveness and feasibility. Seeking alternative

interventions suitable and effective to alleviate subthreshold depression is important. Based on the literature review in Section 2.2.1, biological interventions appear to be less efficacious or not recommended in treating subthreshold depression for older adults (Ackerman et al., 2000; Brosse et al., 2002; Oxman & Sengupta, 2002).

Psychotherapy and reminiscence therapy rely heavily on professional therapists' assistance and have requirements on time and space. Music therapy and pet therapy were not tested in subthreshold depression, and also have concerns such as short-term effects or potential harm on human (Brodie et al., 2002; Morgan & Jorm, 2008).

Exercise therapy has fewer social and financial impediments when compared with other treatments (Brosse et al., 2002). It can be performed anytime and anywhere without excessive financial cost and professional therapists' assistance. More importantly, exercise leads to a series of physical benefits for older adults, which include improvements in cardiovascular diseases (see the review Sattelmair, Pertman, & Forman, 2009), fall (see the review Simek, McPhate, & Haines, 2012) and cognitive functions (see the review Colcombe & Kramer, 2003). The positive effects of exercise on subthreshold depression among older adults have also been confirmed (Brenes et al., 2007).

Table 2.1

Comparison among Existing Depression Interventions

	Effectiveness for subthreshold depression among older adults	Concerns
<i>Biological Interventions</i>		
Medications	Less efficacious in treating subthreshold depression (Ackerman, Greenland, Bystritsky, & Small, 2000; Oxman & Sengupta, 2002)	Side-effects; Avoid for frail elderly patients already taking multiple medications (Reynolds & Kupfer, 1999)
ECT	Not recommended for mild depression (Brosse, Sheets, Lett, & Blumenthal, 2002)	Potential structural and functional brain damages (Prapotnik et al., 2006)
Light therapy	Benefit may be limited to depressive disorder that follows a seasonal pattern (Golden et al., 2005; Terman et al., 1989)	No serious concerns
<i>Psychosocial Interventions</i>		
Psychotherapy	Positive treatment effects (Lynch, Tamburrino, & Nagel, 1997; Spek et al., 2007b; Willemse, Smit, Cuijpers, & Tiemens, 2004; Williams et al., 2000)	High financial cost, long waiting lists, and requirements of professional therapists
Music therapy	No evidence	Effects may not last for long time (Morgan & Jorm, 2008)
Reminiscence therapy	No evidence	Requirement of professional therapists
Pet therapy	No evidence	Potential for allergic reaction or attack (Brodie, Biley, & Shewring, 2002)
Exercise therapy	Positive treatment effects; (Brenes et al., 2007; Ciechanowski et al., 2004) Recommended for people with subthreshold depressive symptoms (National Institute for Health and Clinical Excellence in England, 2004)	No serious concerns

2.3 Exercise as Depression Intervention

Table 2.1 shows that exercise is a promising depression treatment for older adults with subthreshold depression. The relationship between exercise and depression has long been studied. Since the early 1900s, scientific researchers

have found that some moderate intensity exercise can result in a happier mood and alleviate depression (Franz & Hamilton, 1905; Vaux, 1926). Nevertheless, their results could not confirm a causal relationship between exercise and depression because the majority of these early attempts used a case or cross-sectional study design. The research interest in anti-depressive effects of exercise remains, and more experimental studies have been conducted in recent years to test this association.

2.3.1 Anti-depressive Effects

Numerous randomised controlled trials (RCTs) have been carried out to test the effects of exercise on depression by comparing it with other non-exercise interventions, such as pharmacotherapy, education, psychotherapy, no intervention (i.e., waiting-list) or placebo (Stanton & Reaburn, 2014). McNeil and colleagues (1991) reported that walking exercise alleviated the overall symptoms of depression and was more effective than social support and waiting-list conditions. Daley (2008) assessed the review studies and meta-analyses published in the past several decades to provide a synthesis of evidence regarding the effectiveness of exercise on depression. The findings from this ‘review of reviews’ suggested that ‘exercise as treatment for depression is more effective than no treatment, as effective as traditional interventions in some instances, possibly a promising approach to postnatal depression, and has equivalent adherence rates to medication’ (Daley, 2008, p. 140). A similar conclusion was obtained from a recent Cochrane review (Rimer et al., 2012). It indicated that exercise has a moderate effect compared with no treatment and appears to be as efficacious as anti-depressive medications and psychological interventions.

The common types of exercise programmes employed in previous literature are aerobic exercise, such as walking or jogging (Craft & Perna, 2004); however, the efficacy of non-aerobic exercise has also been assessed. Levinger et al. (2010) found that resistance training alleviates depression scores in individuals with multiple numbers of metabolic risk factors for Type II diabetes. Previous studies also supported the anti-depressive effects of exercise in depressed individuals, healthy adults, and those with comorbid medical conditions (Brosse et al., 2002). Moreover, Stanton and Reaburn (2014) reviewed the influences of exercise variables on its anti-depressive effects, which includes exercise frequency, intensity, session duration, exercise mode, intervention duration, delivery of exercise, level and quality of supervision and compliance. Their study recommended the use of supervised aerobic exercise with moderate intensity three times a week for a minimum of nine weeks in the treatment of depression.

2.3.2 Exercise and Subthreshold Depression among Older Adults

The use of exercise for depression among older adults has received increasing attention because most studies in exercise have demonstrated a positive improvement in depression. Park and colleagues (2014a) conducted a systematic review on 18 RCTs and confirmed the significant anti-depressive effects of exercise programmes on older adults aged 65 and above. Another systematic review from Blake et al. (2009) observed a short-term positive outcome for depression among older adults with exercise interventions, although medium-term to long-term effects were less clear. A meta-analysis study (Bridle et al., 2012) supported the medium-term (i.e., 3 to 12 months) effects of exercise on the older adults diagnosed with clinical depression.

In addition to the significant effects on major depression, exercise was also recommended to people with subthreshold depressive symptoms by the National Institute for Health and Clinical Excellence in England (2004). However, few studies have tested the efficacy of exercise interventions for older adults with subthreshold depression despite the recommendation and the high prevalent rate of subthreshold depression (Brenes et al., 2007). In a pilot clinical trial, Brenes et al. (2007) tested the feasibility and efficacy of an exercise programme on older adults with subthreshold depression. The exercise programme consisted of both aerobic and resistant training sessions three times a week for 16 weeks. The outcomes indicated the superiority of exercise over the usual care in improving clinician-rated depression scores among older adults with subthreshold depression. Ciechanowski et al. (2004) reported another RCT, which employed a home-based programme that combined exercise and psychotherapy among seniors diagnosed with minor depression or dysthymia. The intervention resulted in significantly lower severity and greater remission of depression at 6 and 12 months compared with the usual care conditions.

The lack of literature on this the efficacy of exercise on subthreshold depression among older adults is mainly caused by two reasons. First, while most of the previous studies focused on the treatments for major depression among older adults, the therapeutic need is often unmet for subthreshold depression among older adults (Cherubini et al., 2012). Second, psychotherapy and drug were still the common interventions tested for treating subthreshold depression among older adults (Gellis & Bruce, 2010; Lawlor & Hopker, 2001). Hence, it is worthwhile to have more studies on investigating the effects

of exercise as a non-clinical intervention for older adults with subthreshold depression.

2.4 Influencing Mechanisms between Exercise and Depression

Extensive research has consistently obtained results that supported the strong association between exercise and depression. However, the influencing mechanisms underlying the anti-depressive effects of exercise are not well understood (Brosse et al., 2002; Craft & Perna, 2004; Daley, 2008). A variety of biological and psychosocial mechanisms have been hypothesised by prior researchers to explain the effects of exercise on depression. Several prominent hypotheses include endorphin hypothesis, monoamine hypothesis, thermogenic hypothesis, and self-efficacy hypothesis. These possible explanations provide important information as to how exercise works on alleviating depression and are helpful in the implementation of exercise as a depression treatment. However, to the best of our knowledge, the evidence to-date have not involved direct investigations of the causal pathways described in these hypotheses among depressed patients. Hence, more rigorous studies that systematically examine these influencing mechanisms are necessary.

2.4.1 Biological Mechanisms

Endorphin hypothesis (Steinberg & Sykes, 1985) is the most well-known biological explanation, and points out the mediation effects of β -endorphins. It proposes that exercise triggers the release of β -endorphins, which consequently result in the improvement of mood and feeling of well-being. Several physiological studies have demonstrated an increased release of β -endorphins following exercise (Bortz, Angwin, & Mefford, 1981; Farrell, Gates, &

Maksud, 1982). The β -endorphins are endogenous opioids released primarily from the adenohypophysis (McNally & Akil, 2002) and are part of the mood regulating chemicals commonly triggered by stress (Janal, Colt, Clark, & Glusman, 1984). An increase in blood level of β -endorphins during exercise is associated with positive emotions and affect (Brosse et al., 2002), which are highly possible links to reducing depression.

Other biological mechanisms include monoamine and thermogenic hypotheses. Monoamine hypothesis (Pierce, Kuppart, & Harry, 1979) suggested that exercise results in an increase in some brain neurotransmitters, such as dopamine, serotonin and noradrenaline. Some biochemical evidence showed that brain neurotransmitters decreased less in depressed patients (Delgado & Moreno, 2000; Hirschfeld, 2000). Therefore, monoamine hypothesis posited that exercise reduces depression by improving the dysregulations in monoamine systems. Thermogenic hypothesis (Petruzzello, Landers, & Salazar, 1993) stated that the reduction in depression is associated with a rise in core body temperature after exercise. DeVries (1981) explained this hypothesis by stating that the increase in temperature of some brain regions can result in relaxation and reduction of anxiety.

These biological mechanisms focus on different bodily chemicals or systems but more or less highlighted the mediation role of 'positive affect'. Positive affect refers to the extent to which an individual subjectively experiences positive moods such as joy, interest, and alertness (Miller, 2011). Fredrickson (1998, 2001) raised the *broaden-and-build theory* to elaborate the effects of positive affect on some enduring personal resources. She found that experiences of positive affect can help building individuals' enduring

psychosocial resources. Many empirical studies have demonstrated that depression was significantly associated with enduring psychosocial resources, such as coping ability, stress resilience (e.g., Lazarus, 1991; Lazarus & Folkman, 1984), and social relationships and networks (e.g., Stice, Ragan, & Randall, 2004; Travis, Lyness, Shields, King, & Cox, 2004). Building these resources make people's lives fulfilling, thereby warding off depression. Furthermore, many studies have supported the negative association between positive affect and depression (Forbes, Williamson, Ryan, & Dahl, 2004; Nelis, Holmes, & Raes, 2015). Therefore, changes in body chemicals after exercise may lead to positive affect, but recurrent experiences of the positive affect appears to reduce depression.

2.4.2 Psychosocial Mechanisms

Studies from psychosocial aspects have documented the enhancement of self-efficacy in exercise performance (Fox, 2000; Taylor & Fox, 2005). These studies suggested that exercise, such as weight training or aerobic exercise, increases self-efficacy in different age populations (Holloway, Beuter, & Duda, 1988; McAuley, Bane, & Mihalko, 1995). Bandura (1997) defines self-efficacy as the strength of belief in one's own ability to complete tasks and reach goals. Social cognitive theory (Bandura, 1997) states that people with high self-efficacy can regulate their own functioning and exercise control over difficult tasks or negative life events. People with low self-efficacy may often be depressed because they doubt their own ability to solve problems and believe that problems are tougher than they really are. The negative relation between self-efficacy and depression have been examined in many studies with different age groups (Adam & Folds, 2014; Ehrenberg, Cox, & Koopman, 1991;

Tillema, 2001), which include older adults (Davis-Berman, 1988; Marino, Sirey, Raue, & Alexopoulos, 2008). The self-efficacy hypothesis suggests that the anti-depressive effects of exercise are mediated by improved self-efficacy.

Some researchers (Gleser & Mendelberg, 1990; Leith, 1994) have proposed distraction hypothesis. They suggested that exercise serves as means of distraction from negative emotions and depressing thoughts. Studies have supported the anti-depressive effects of exercise when compared with other distraction activities, such as relaxation and health education (Doyle, Chambless, & Beutler, 1983; Klein et al., 1985).

2.5 Exergames

With the advent of digital technology, exergames, which combine digital gaming and physical exercise, have become common daily exercise programmes (Oh & Yang, 2010). Exergames require users to perform physical exercises to control the game, which makes physical exercise more interesting and challenging. Therefore, they are often considered a potential means to promote, motivate and encourage physical activity (Li et al., 2014a; Sun, 2013).

2.5.1 Features of Exergames

Different from traditional video games, exergames have a unique feature of using sensing technologies. Many exergames involve motion sensing input devices, such as infrared projectors and/or cameras, which enable users to control and interact in game playing through natural gestures or movements. The most popular exergaming platforms in the market are the Nintendo Wii¹

¹ <http://wii.com/>

and Microsoft Kinect for Xbox². They offer console-based devices and games that make exergaming possible in home settings. For example, *Wii Sports*³ is a sports game played on Nintendo Wii platform, designed to demonstrate the motion-sensing capabilities of the Wii Remote. It is a collection of five sports simulations including are tennis, baseball, bowling, golf, and boxing. Players use the Wii Remote to mimic actions performed in real life sports, such as swinging a tennis racket (GamePro, 2006). *Your Shape: Fitness Evolved*⁴ is another exergame used in Xbox Kinect platform. The game uses "player projection" technology to tracking the player's shape and form, and dynamically tailor routines for the players in the virtual resistance training.

Other types of exergaming platforms include portable devices with different types of sensors, such as mobile phones and tablets. Buddhharaju & Pamidi (2013) designed a novel exergame on mobile platform called *ExerPad*, in which users need to physically move and jump to score points in this mobile game. *CodeRunner* is a location-based adventure exergame played on smartphones, which encourage players to walk in real-world streets to find clues and solving mysteries of espionage (Boulos & Yang, 2013).

Compared with traditional exercise settings, exergames have various types of motivational features. They involve visual and audio performance feedback and use virtual reality and animated graphics to simulate real or imaginary worlds during game playing. These features in exergames make

² <http://www.xbox.com/en-SG/xbox-one/accessories/kinect-for-xbox-one/>

³ <http://www.nintendo.com/games/detail/1OTtO06SP7M52gi5m8pD6CnabbW8CzxE>

⁴ <http://marketplace.xbox.com/en-SG/Product/Your-Shape-Fitness-Evolved/66acd000-77fe-1000-9115-d8025553084f>

exercise activities increasingly interactive, meaningful, and enjoyable (Chao et al., 2015b).

2.5.2 Health Benefits of Exergames

Rapid growth in popularity and use of exergames is seen in healthcare promotion. Exergames are often implemented in public settings, such as communities (Baranowski, Maddison, Maloney, Medina Jr, & Simons, 2014), schools and work environment (Maddison et al., 2013). Previous studies (Boulos, 2012; Daley, 2009) have assessed the potential health benefits of exergames on children and young adults because they are the target group for digital games. Vernadakis et al. (2015) suggested that the use of Xbox Kinect exergame improved object control skills of elementary school children compared with the traditional training programme. In another study by Mellecker and McManus (2008), a large increase in energy expenditure and cardiovascular responses were shown among 18 children in active exergaming.

Besides young generation, recent research in this domain extended to the potential effects of exergames on older population. Exergames are recommended for older adults because of the light-to-moderate exercise intensity, according to a systematic review (Peng, Crouse, & Lin, 2013). Studies have examined the effects of exergames on physiological functions among older adults, such as improvement in balance (Bateni, 2012; Mhatre et al., 2013). Particularly, in a randomized controlled study of 36 older adults, Toulotte, Toursel, & Olivier (2012) found that Wii Fit exergames were as effective as adapted physical activities in improving the balance of independent seniors. A review from Klompstra et al. (2013) supported that older adults with

heart failure experienced improved physical fitness after performing exergames. Evidence from a two-week pilot study demonstrated that exergames was able to significantly improve upper extremity function for post-stroke patients (Mouawad, Doust, Max, & McNulty, 2011). Previous studies released that exergames can improve cognitive ability among older adults (Chao et al., 2015b; Pessoa et al., 2014). Anderson-Hanley et al. (2012) conducted a cluster randomized clinical trial to compare the effects between cybercycling and traditional exercise, on cognitive function in older adults for 3 months. Their findings suggested that cybercycling exergame led to better cognitive function than traditional exercisers, and had greater potential for preventing cognitive decline. A pilot study from Chan et al. (2010) has shown the older adults in virtual reality cognitive training programs have better improvements on repetition and memory than those in usual programs. The psychosocial effects of exergames among older adults were also explored, including improvements in loneliness and mood (Kahlbaugh, Sperandio, Carlson, & Hauselt, 2011; Wollersheim et al., 2010). Albores et al. (2013) reported that older patients with chronic obstructive pulmonary disease have significant improvements in emotion after a twelve-week Wii Fit training. In six-week longitudinal field experiment in Singapore, older adults playing Wii games had a positive impact on loneliness, self-esteem, and positive affect, compared to those playing traditional board games (Jung, Li, Janissa, Gladys, & Lee, 2009). In recent years, the anti-depressive effects of exergames has drawn a considerable attention from researchers (Meldrum et al., 2015; Mhatre et al., 2013; Rendon et al., 2012).

2.5.3 Exergames as Potential Depression Intervention

Interest in examining the application and effectiveness of digital interventions on addressing depression has been increasing in recent years (Richardson, Stallard, & Velleman, 2010; Spek et al., 2007a). Identifying its effects on depression is a worthwhile and interesting endeavour. However, the application of exergame on addressing depression is a relatively new research domain and the its overall effect and influencing factors remain unclear.

Although more and more recent attempts were carried out to investigate the effects of exergames as a novel depression intervention, their findings were much different. Some studies reported a significant reduction on depression (Chao et al., 2015a; Rosenberg et al., 2010), whereas some reported conflicting results (Meldrum et al., 2015; Mhatre et al., 2013). In addition, these studies were conducted in different contexts and with different methodologies. Hence, an overview of exergame studies in depression literature is highly necessary to explore the true anti-depressive effects of exergames and identify research trends.

Further, some potential moderators have been identified in previous review studies on digital interventions. A recent systematic review by Li et al. (2014b), for example, reported that older adults have lower depression improvement than other aging groups. Richards and Richardson (Richards & Richardson, 2012) indicated that the number of sessions moderated the anti-depressive effects of digital interventions in their meta-analysis. These factors may also affect the effectiveness of exergames on depression.

2.6 Summary

This chapter provides a literature review of subthreshold depression among older adults and its possible treatments. Subthreshold depression is a common mental disorder with high prevalence and many negative effects among older adults. The current interventions for addressing depression have been reviewed. Exercise was observed to be one of the most effective interventions recommended by previous studies, because of its anti-depressive effects explained by both biological and psychosocial hypotheses. The psychosocial benefits of exergames as the novel form of exercise found support in recent studies. However, the review highlighted that the overall effect of exergames on depression remains unclear. There is also need to investigate the different anti-depressive effects between exergames and traditional exercise. The knowledge and research gaps identified in this chapter serve as motivation and background for developing studies in the thesis described in the following chapters.

CHAPTER THREE

EXERGAME ON DEPRESSION: A SYSTEMATIC REVIEW AND META-ANALYSIS

Section 2.5 of the literature review identified an increasing number of studies that examined the effects of exergames on depression. However, their findings varied significantly from each other. These studies were conducted in different contexts, with different methodologies. The overall effect of exergames on depression remains unclear. An overview of the existing studies is necessary to address this research gap and contribute to the new domain of exergames for depression. In order to address the aims of thesis, the first step of the research is to discover the overall effect of exergames on depression based on the existing studies.

The chapter⁵ describes a systematic review and meta-analysis aimed to address the above research question. A systematic review was conducted to synthesise existing studies and identify research trends from an overall perspective. A meta-analysis was further also carried out on identified studies to discover the overall effect size of exergames on treating depression and explore possible moderators that may affect its effectiveness. The systematic review and meta-analysis further provided theoretical and practical implications for Study One, which is described in Chapter Five.

⁵ The content of this chapter has been published as Li, J., Theng, Y.L. and Foo, S. (2016). Effect of exergames on depression: A systematic review and meta-analysis. *Cyberpsychology, Behavior, and Social Networking*, 19(1), 34-42. doi:10.1089/cyber.2015.0366.

3.1 Methods

3.1.1 Identification and Selection of Studies

The scope of the systematic review was limited to studies that investigated the effects of exergames on depression. Based on the definition from American College of Sports Medicine (2013), the inclusive criteria for a qualifying ‘exergame’ were: a) involving technology-driven game playing (i.e., video game in digital platforms such as console, smartphone and tablet), and b) requiring participants to be physically active or exercise beyond simple hand finger movements to play the game. This study included exergames from both existing market products and researcher-designed interventions. Moreover, eligible studies had to contain an evaluation of the treatment’s effects on participants’ depression symptoms, using a reliable and valid depression scale. No limitations were placed on the participants’ depression symptoms to achieve a complete picture of its effects on different depression severity. The inclusive studies can even include healthy participants or those with other chronic or mental illnesses.

Comprehensive literature search was conducted among major bibliographic databases in computer technology, psychology and medical science, including ACM Digital Library, PsycINFO, PubMed and Cochrane Central Register of Controlled Trials. The ACM Digital Library is the most comprehensive collection of articles and bibliographic records in fields of computing and information technology. It consists of more than 40,000 full-text articles, over forty journals and 2,000 proceedings volumes. PsycINFO is one of the most highly utilized databases in behavioral and social science research,

with more than four million bibliographic records and over 2,500 scholarly journals. PubMed consists of more than eleven million bibliographic citations and abstracts from nearly 4,500 journals in the fields of medicine, nursing, dentistry, veterinary medicine, pharmacy, allied health, health care systems, and pre-clinical sciences. The Cochrane Central Register of Controlled Trials is a highly concentrated source of reports of randomised and quasi-randomised controlled trials, the majority of which are taken from bibliographic databases (mainly MEDLINE and Embase) and other published and unpublished sources. Potential studies were identified by the combination of intervention terms ('exergame' or 'exer-gaming' or 'exercise game' or 'digital exercise' or 'active videogame' or 'virtual reality game' or 'Wii' or 'Wii Fit' or 'Kinect') and disorder terms ('depression' or 'depress' or 'emotion' or 'mood' or 'mental'). Reference lists from included studies and relevant reviews were also inspected. The final studies were identified, and this systematic review extracted the characteristics from each study, including details of participants (i.e., culture, total number, included criteria, and mean age), intervention (i.e., format, duration, and number of sessions), and experiment (i.e., study design, and depression measurement).

3.1.2 Meta-Analysis Procedure

Considering the small number of identified and published studies to-date, the meta-analysis involved studies that used independent groups and other studies that used matched groups (or pre-post designs). In the book *Introduction to Meta-Analysis*, Borenstein et al. (2009) stated that no technical barriers exist in the use of studies with different designs in the same analysis. From a statistical perspective, effect size has the same meaning regardless of the study design

(Borenstein et al., 2009, p. 30). Therefore, the effect size and variance from each study were computed using different formulas and all studies were included in the same meta-analysis. Comprehensive meta-analysis software (version 3.0; Biostat, Inc., Englewood, NJ) was applied for data analysis. Given the small sample size in most of the involved studies, Hedges' g was used to estimate effective size because it can adjust for small sample bias (Hedges & Vevea, 1996). The effect size (Hedges' g) for each study reflects the outcome difference between intervention and control treatments or between pre- and post-test conditions. The results were then pooled using a random effect model (Piasta & Justice, 2010).

A series of subgroup analyses were tested in the mixed effect model (i.e., random effect model within subgroups but fixed effect model across subgroups) according to the types of population, number of session, depression severity and player interaction. I^2 -statistic was used to assess the heterogeneity of the pooled effective sizes, according to Higgins and Green (2009). The I^2 -value indicates the percentage of total variation across trials caused by their heterogeneity rather than by chance. A value of 0% indicates no observed heterogeneity, 25% as low heterogeneity, 50% as moderate heterogeneity, and 75% as high heterogeneity.

3.2 Results

The primary search yielded a total of 1,099 articles by May 2015. A follow-up search in February 2017 yielded 131 new articles published after the primary search. Eleven studies met the criteria for inclusion in the final systematic review. One study (Kempf & Martin, 2013) was excluded from meta-analysis

because of uninterpretable data. Thus, ten studies were included in the final meta-analysis process. For one study (Yu & Kim, 2015) with two control conditions (Qi-gong and treat-as-usual), two trials were yielded in the meta-analysis due to the limited number of suitable studies found in the literature. The number of subjects in the intervention condition of this study was divided equally for two trials, to avoid unit of analyses errors (Ramsay & Gates, 2005). The final meta-analysis includes ten studies with eleven trials. Figure 3.1 shows a flowchart of the selection of studies used in the systematic review and meta-analysis.

Figure 3.1. Flowchart for included studies in systematic review and meta-analysis. *Note: One study yielded two trials in the final meta-analysis.

3.2.1 Results from Systematic Review

Table 3.1 outlines the selected characteristics of the eleven studies (a total of twelve trials) included in the review. Two open trial studies examined the effects of exergames in *Nintendo Wii Sports* (or *Wii Sports*) on depression. The *Wii Sports* game package includes virtual sport games, such as tennis, bowling, baseball, golf and boxing. Participants were required to use their arm or body motions to simulate actions similar to those done in actual sports. Findings from Herz et al. (2013) demonstrated that *Wii Sports* serves as a useful therapy to alleviate depression among patients with Parkinson's disease (PD) after a four-week period. Similarly, Rosenberg et al. (2010) observed a significant improvement in depressive symptoms among older adults with subsyndromal depression after 12 weeks of playing *Wii Sports*.

Table 3.1

Characteristics of the Included Studies

Study	Participants					Intervention			Experiment		
	N	Gender*	Ethnicity	Physical mobility	Inclusion	Age: M (SD)**	Information on exergames	Duration	Player interaction	Study design	Depression measurement
Chao et al. (2015a)	30	F: 75%	Caucasian in the U.S.	Ability to ambulate independently or with the use of assistive devices	Older adults age 65 or greater; local residents	86.63 (4.18)/ 83.75 (8.04)	Nintendo Wii Fit exercise incorporating self-efficacy theory (aerobic, strength, balance, and yoga exercises)	30 minutes per session; 2 sessions per week; 4 weeks; 8 sessions	Partner interaction	Quasi-experimental CG: Health education programme	GDS
Chao, Musanti, Zha, and Katigbak (2017)	12	F: 100%	African American in the U.S.	Healthy	Older adults aged 55 years and above	64.17 (6.74)	Wii Fit U (balance games, yoga poses, strength training, aerobics, and dance games)	1 hour per session; 2 sessions per week; 12 weeks; 24 sessions	Partner interaction	Pre-post study	GDS
Meldrum et al. (2015)	71	F: 62%	Irish	Gait and balance impairment	Adult patients; diagnosed with unilateral peripheral vestibular loss who had dizziness/vertigo, and gait and balance impairment	57.83 (13.6)/ 50.47 (15.53)	Nintendo Wii Fit Plus exercise (gaze stabilization exercises, balance exercises, and a graded walking programme)	15 minutes per day; 5 out of 7 days; 8 weeks; 40 sessions	No interaction	RCT CG: Exercise in foam balance mat	HADS-D
Kempf and Martin (2013)	220	F: 54%	German	No regular physical activity	Older adults patients aged 50–75 years; diagnosed with diabetes duration < 5 years	62 (11)/ 60 (9)	Nintendo Wii Fit Plus exercise	12 weeks	No interaction	RCT CG: TAU	PAID, WHO-5, ADS-L

Mhatre et al. (2013)	10	F: 60%	Unknown in the U.S.	Healthy	Adult patients; diagnosed with PD	67.1 (range: 44–91)	Nintendo Wii Fit exercise (marble tracking, skiing, and bubble rafting)	30 minutes per session; 3 sessions per week; 8 weeks; 24 sessions	Unknown	Pre-post study	GDS
Herz et al. (2013)	20	F: 35%	95% Caucasian in the U.S.	Early- to mid-stage PD	Adult patients; diagnosed with early- to mid-stage PD	66.7 (7.2)	Nintendo Wii Sports (tennis, bowling, and boxing)	1 hour per session; 3 session per week; 4 weeks; 12 sessions	No interaction	Pre-post study	HAM-D
Rendon et al. (2012)	40	N/A	Unknown in the U.S.	Healthy	Older adults aged 60–95; community-dwelling	85.7 (4.3)/83.3 (6.2)	Nintendo Wii Fit exercise (lunges, single leg extensions, and twists)	35 to 45 min per session; 3 sessions per week; 6 weeks; 18 sessions	No interaction	RCT CG: TAU	GDS
Rosenberg et al. (2010)	19	F: 68%	Mixed Caucasians and others in the U.S.	Healthy	Community-dwelling older adults; diagnosed with Subsyndromal depression;	78.7 (8.7)	Nintendo Wii Sports (tennis, bowling, baseball, golf, and boxing)	35 min per session; 3 sessions per week; 12 weeks; 36 sessions	Unknown	Pre-post study	QIDS
Shin et al. (2015)	35	F: 25%	Korean	Chronic hemiparetic upper limb dysfunction	Adult patients	53.37 (11.8)/54.67 (13.4)	Game-based virtual reality rehabilitation, and occupational therapy	30 minutes playing, 30 minutes OT, per session; 5 sessions per week; 4 weeks; 20 sessions	No interaction	RCT CG: Occupational therapy	HAM-D
Yu and Kim (2015)a	31	F: 100%	Korean	Healthy	Community-dwelling older adults; Over the age of 65	72.95 (5.20)/74.55 (5.59)	Xbox Kinect Adventures	50 minutes per session; 2 sessions per week; 8 weeks; 16 sessions	Unknown	RCT CG: Qi-gong	GDS

Yu and Kim (2015)b	31	F: 100%	Korean	Healthy	Community-dwelling older adults; Over the age of 65	72.95 (5.20)/ 74.20 (4.96)	Xbox Kinect Adventures	50 minutes per session; 2 sessions per week; 8 weeks; 16 sessions	Unknown	RCT CG: TAU	GDS
Yuen et al. (2011)	15	F: 100%	African American in the U.S.	Sedentary	Patients diagnosed with systemic lupus erythematosus experiencing moderate to severe fatigue	46.7 (14.4)	Nintendo Wii Fit exercise (Yoga, aerobic, and strengthening exercise)	30 min per session; 3 sessions per week; 10 weeks; 30 sessions	No interaction	Pre-post study	HADS-D

Note: ADS-L, Allgemeine Depressionsskala; CG, Control Group; GDS, Geriatric Depression Scale; HADS-D, Hospital Anxiety and Depression Scale - Depression; HAM-D, Hamilton Depression Scale; PAID, Problem Areas in Diabetes; PD, Parkinson Disease; QIDS, Quick Inventory of Depressive Symptoms; RCT, Randomised Controlled Trial; SD, Standard Deviation; TAU, Treatment As Usual; WHO-5, WHO Well-Being Index.

*F represents the percentage of female participants.

**Data from the intervention and the control arms are presented, if any.

Six studies were identified to investigate exergames from *Nintendo Wii Fit* or its successors, *Wii Fit Plus* and *Wii Fit U*. Unlike *Wii Sports* games, *Wii Fit* exergames focus less on entertainment and more on the improvement of physical fitness. They consist of many physical activities using the *Wii Balance Board* peripherals, such as yoga poses, strength training, aerobics, and balance games. Three studies reported significant effects of *Wii Fit* exergames on alleviating depression (Kempf & Martin, 2013; Rendon et al., 2012; Yuen et al., 2011); but three studies did not observe significant depression changes in their studies (Chao et al., 2017; Meldrum et al., 2015; Mhatre et al., 2013). In addition, instead of using existing *Wii Fit* exergames, Chao et al. (2015a) examined the anti-depressive effects of improved *Wii Fit* exergames that incorporated self-efficacy theory for assisted-living older adults. Their findings show that the improved *Wii Fit* exergames had significant improvements on depression when compared with a health education programme.

Yu & Kim (2015) tested the effect of *Kinect Adventures* from another popular exergaming platform, *Xbox Kinect*. In the gaming of *Kinect Adventures*, players are required to continuously perform movements including bending and stretching of the trunk, stretching of the upper limb, running in situ and so on. In their study, exergames were performed among Korean older adults from community senior centers for 8 weeks, comparing to other two conditions of *Qi-gong* exercise and no-treatment (Yu & Kim, 2015).

Only one study by Shin et al. (2015) applied a non-commercial exergaming platform called *RehabMaster*TM, which is a game-based virtual reality rehabilitation system that involves 10 minutes of 'rehabilitation training'

and 20 minutes of ‘rehabilitation games’. Results indicate that the intervention has specific effects on reducing depression among patients with chronic stroke.

It is worth noting that the identified studies were published in or after the year 2010. Only five studies (six trials) employed randomised controlled trials to compare the effects of exergames to a control condition, such as occupational therapy (Shin et al., 2015) or treat-as-usual (Kempf & Martin, 2013; Rendon et al., 2012). Particularly, two studies (Meldrum et al., 2015; Yu & Kim, 2015) compared exergames with exercise performed in traditional setting. The target population in six studies were identified as older adults, whereas the rest were general generation. Four studies recruited Caucasian-dominant participants (Chao et al., 2015a; Herz et al., 2013; Kempf & Martin, 2013; Meldrum et al., 2015), and only two study were conducted among Asian (Shin et al., 2015; Yu & Kim, 2015) and African populations (Chao et al., 2017; Yuen et al., 2011). Further, some studies involved a high percentage of female participants (Chao et al., 2017; Chao et al., 2015a; Rosenberg et al., 2010; Yu & Kim, 2015; Yuen et al., 2011). In terms of the inclusive criteria for participants, only three studies focused on patients with depression or related mental disorder such as Parkinson Disease. With the exception of two studies (Kempf & Martin, 2013; Meldrum et al., 2015), all the other studies used a small sample size of less than 50 participants. The intervention duration among the majority of the studies were around 30 minutes per session although the total session number varied considerably (ranging from 8 to 40 sessions). Although participants in most of the studies have no interaction to their peers (e.g., play exeragmes at home), two studies (Chao et al., 2017; Chao et al., 2015a) have particularly indicated social interaction among the players.

Participants in these two studies received encouragement from their partner when performing the exergames. Lastly, the common depression assessments used in the studies were Geriatric Depression Scale (GDS), Hospital Anxiety and Depression Scale - Depression (HADS-D), and Hamilton Depression Scale (HAM-D).

3.2.2 Results from Meta-Analysis

The meta-analysis on ten studies (a total eleven trials) resulted in an overall effect size of $g = 0.23$, (95% CI [0.02, 0.44]) based on a random effect model. A Z-value of 2.16 ($p < .05$) further indicated the statistical significance of the anti-depressive effects of exergames. Effect sizes and 95% CIs of each individual studies are plotted in Figure 3.2. No significant heterogeneity was detected among studies, with $I^2 = 0\%$.

Subgroup analyses, which test whether these factors influenced outcomes, were performed based on several key characteristics of the studies. Table 3.2 displays the results of these analyses.

Figure 3.2. Effect sizes in meta-analysis. Effect sizes were obtained through the random effect model.

Demographic factors. Significant subgroup differences were reported across different groups of age, gender, culture, and physical mobility. The results indicated that these demographic factors were significant moderators on the anti-depressive effects of exergames. A significant effect size was observed on older adults ($g = 0.43$, $z = 3.14$, $p < .001$). This effect size was larger than the non-significant effect size found on general adults ($g = 0.06$). Moderate heterogeneity was also observed in general adults group, whereas no heterogeneity was observed in older adults group. Studies with more female participants (more than 60%) tended to have larger effect size ($g = 0.30$) than others. However, neither effect sizes reached at a statistically significant level. The high heterogeneity among female-dominant studies should also be considered when interpreting this conclusion. Although the effect sizes are similar between Caucasian participants ($g = 0.31$) and those from other cultures ($g = 0.27$), exergames were found to have a significant effect on people from

non-Caucasian culture ($p < .05$). High heterogeneity observed in Caucasian studies may cause the non-significant effect size on participants from this culture. Findings also indicated that different physical mobility led to different effects of exergames on depression. Participants with relatively good mobility had a larger and significant overall depression reduction in exergames ($g = 0.33, z = 2.69, p < .05$) than those with athletic dysfunction ($g = 0.05, z = 0.27, p > .05$). Moderate heterogeneity was found within the two subgroups of physical mobility.

Number of Session. The effect size in a small number of sessions ($g = 0.34$) was larger than that in a large number of sessions ($g = 0.16$), and was also observed to be statistically significant ($z = 2.48, p < .05$). Moderate heterogeneity was found in studies with a large number of sessions but not in those with a small number of sessions. Significant subgroup differences were also reported across the two subgroups.

Depression Severity. Exergames have a larger effect size on participants with depression or related mental disorders ($g = 0.29$) than participants without depression-related illness ($g = 0.19$). However, neither of the effect sizes reached a statistically significant level. Moreover, the high heterogeneity was found within the studies of depression and related mental disorders ($I^2 = 69.82\%$). Significant subgroup differences were reported among participants with different depression severity.

Table 3.2

Subgroup Analyses of Included Trials

Subgroup	<i>N</i>	Hedges' <i>g</i>	95% CI	<i>Z</i>	<i>I</i> ² (%)	Subgroup differences
Age						**
General adults	5	0.06	[-0.23, 0.35]	0.42	44.68	
Older adults	6	0.43	[0.19, 0.68]	3.14***	0	
Gender						**
Female-dominant (> 60%)	7	0.30	[-0.01, 0.62]	1.89	52.14	
Balance or less female	3	0.11	[-0.22, 0.45]	0.68	27.53	
Unknown	1	0.24	[-0.37, 0.84]	0.76	0	
Culture						*
Caucasian-dominant	4	0.31	[-0.18, 0.79]	1.24	71.97	
Others	5	0.27	[0.02, 0.52]	2.12*	0	
Unknown	2	-0.03	[-0.52, 0.47]	-0.11	27.66	
Physical mobility						**
Healthy	8	0.33	[0.09, 0.56]	2.69*	22.03	
Impairment	3	0.05	[-0.34, 0.45]	0.27	56.25	
Number of session						**
Small (< 20 sessions)	5	0.34	[0.07, 0.61]	2.48*	0	
Large (≥ 20 sessions)	6	0.16	[-0.17, 0.49]	0.96	60.36	
Depression severity						*
Depression and related mental disorders	3	0.29	[-0.24, 0.81]	1.08	69.82	
Non-depressed	8	0.19	[-0.04, 0.42]	1.65	19.74	
Player interaction						*
Partner interaction	2	0.41	[-0.02, 0.84]	1.85 [#]	0	
No interaction	5	0.14	[-0.12, 0.40]	1.06	30.81	
Unknown	4	0.27	[-0.24, 0.79]	1.04	64.33	

Note. All subgroup analyses were conducted in mixed effects analyses. CI, confidence interval;

N, number of trials.

[#]*p* < .10. **p* < .05. ***p* < .01. ****p* < .001.

Player Interaction. Studies with player interaction released a large effect size ($g = 0.41$) which is approaching statistically significant ($p = .06$). No heterogeneity was found within this subgroup. In contrast, studies with no interaction have a small effect size ($g = 0.14$) and moderate heterogeneity. Significant subgroup differences were also reported across the subgroups of player interaction.

3.3 Discussion

This first phase of research systematically reviews existing literature on exergames used for depression and examines their effect sizes via meta-analysis. Clear and consistent evidence has indicated an increasing research interest in the recent years on the potential effects of exergames on depression, with all the eleven identified studies published in the past seven years (between 2010 and early 2017). Nevertheless, the limited number of studies identified in this review reflects that the application of exergames in the treatment of depression remains a new concept. Findings from meta-analysis suggests a significant overall effect size ($g = 0.23$) with low heterogeneity among ten included studies. Consequently, exergames have been proven to have positive effects on alleviating depression. Compared with other recent meta-analyses, the effect size of exergames was much larger than that in aerobic exercise (Bartley, Hay, & Bloch, 2013) but smaller than those in other traditional forms of exercise (Ensari, Motl, & Pilutti, 2014; Silveira et al., 2013). Furthermore, the effect size of exergames was similar to that in other psychosocial therapy, such as psychotherapy (Cuijpers, Muñoz, Clarke, & Lewinsohn, 2009). However, only six out of the eleven trials applied RCT study design and thus, the conclusion from this meta-analysis should be interpreted with caution. Since

RCTs are considered to be the ‘golden standard’ for evidence-based study (Ventegodt, Andersen, Brom, Merrick, & Greydanus, 2009), high-quality RCT studies are needed to discover the true power of exergames as a depression intervention. Moreover, only two RCTs in the review compared exergames to traditional exercise. Since exergames is considered as a new form of exercise with novel features, the findings of this review call for more studies to examine whether exergames may have different effects over traditional exercise.

3.3.1 Possible Moderators

Findings from subgroup analysis provide a comprehensive picture of the various factors that moderate the effects of exergames on depression. The findings suggest that exergames have larger anti-depressive effects on older adults than on general adults. Although exergames were initially designed for younger generations, an increasing percentage of older adults engage in exergames playing. The health benefits of exergames for older adults have received much attention from researchers recently. Some early attempts in the exergame domain compared the age difference in physiological responses and enjoyment level (Graves et al., 2010; Mullins, Tessmer, Mccarroll, & Peppel, 2012), but no study to-date has reported on the differences on the anti-depressive effects between young and old populations. The current review determined that older adults may benefit more from exergames than general adults in terms of depression improvement. A possible explanation is the different causes of depression across age groups. Young and middle-aged adults often feel depressed because of negative events in work, family, or sexual relationship (Greca & Harrison, 2005), whereas older adults develop depression mainly because of physical illness or social isolation (Cole & Dendukuri,

2003). Exergames can promote both physical well-being and social interaction, and thus may serve as a better anti-depressive treatment for the older population.

Furthermore, females with good physical mobility had good depression treatment from exergames. Some studies (Graves, Stratton, Ridgers, & Cable, 2007; Lam, Sit, & McManus, 2011; Sun, 2013) have shown that gender is a strong predictor of exergame motivation and performance. Sun (2013) suggested that males perceived exergames to be more enjoyable than females, whereas Graves et al. (2007) found that males are more physically active than females in exergames. Nevertheless, knowledge on the gender difference in the psychosocial effects of exergames remains limited. A recent study from Donker et al. (2013) reported that females had good depression outcome in digital psychotherapies. Additional research is necessary to explore the possible explanations for the moderating effects of gender on the relationship between exergames and depression. Culture may be another important moderator suggested by the finding. Previous studies have often used socio-cultural variance to explain the differences in depression outcomes (Lesser et al., 2011) and exergame performance (Staiano, Abraham, & Calvert, 2012). More in-depth investigations must be conducted to understand how culture influence the effect of exergames on depression. As expected, exergames have better anti-depressive effects on individuals with better physical mobility. Thus, people who are already physically flexible can take advantage of exergames and receive psychosocial benefits compared with those with poor mobility.

Studies in the exercise domain have investigated the different treatment effects between depressed and non-depressed samples (Chou et al., 2004;

Mather et al., 2002; Penninx et al., 2002). Earlier reviews have suggested that the depressed participants gain more effects from exercise than non-depressed ones (Lawlor & Hopker, 2001; Sjösten & Kivelä, 2006). The results of the meta-analysis further extended the conclusion to the exergame domain by indicating that exergames have larger effects on depressed participants, which include those with depression-related mental disorders, than non-depressed ones. Nevertheless, the variances in disorder types diagnosed across studies (including lupus, Parkinson's disease, and unilateral peripheral vestibular loss) may limit the validity of the conclusion. Moreover, there was one study evaluating the effect on subthreshold depression (Rosenberg et al., 2010). Considering the high effect size of this study ($g = 0.72$), it is possible that exergame may have superior effect on subthreshold depression. It is not surprising that studies with player interaction have larger improvement on depression than those with no interaction. Social interaction is found to have important association with depression in the previous studies (Nezlek, Imbrie, & Shean, 1994a; Steger & Kashdan, 2009). The findings have supported the application of this association in the exergaming environment: players who receive social interaction and support from their partner are likely to demonstrate lower depression than those with player interaction.

In addition, exergames with a smaller number of sessions have a more promising outcome than those with a larger number of sessions. This finding is different from the common assumption that longer intervention duration leads to more positive results. Some researchers have highlighted the potential use of short psychosocial interventions in depression treatment (van Straten, Cuijpers, & Smits, 2008; Warmerdam, van Straten, Twisk, Riper, & Cuijpers, 2008). One

possible explanation is that the novelty of exergames accounts for positive effects on depression, which may decrease as time passes. However, the results must be confirmed in future research because the meta-analysis involved studies with different study designs and measurement instruments.

3.3.2 Gaps and Implications

The systematic review and meta-analysis have identified several research gaps in the domain of exergames and depression, thus implied important research trends for future studies. Firstly, the findings shown in the systematic review indicated that exergames for depression is a new but rapidly developing research area. Large-scale and well-designed RCT studies are necessary to assess the effectiveness of exergames on depression across diverse populations with different conditions. Particularly, future studies using traditional exercise as a control group will be recommended. The findings will contribute to the exergame literature by understanding its true effect on depression. Secondly, findings on moderators has highlighted some important directions in the area of exergames on depression. For example, exergames were supported to be particularly effective on those who are older adults, with depression symptoms, and having social interaction with other partners. Therefore, more research attentions are needed to further explore these factors. Lastly, other moderators such as gender, culture, physical mobility, provide new and valuable information for the implementation of exergames. These implications inform health professionals and policy makers to restructure the clinical practice in terms of the selection of inclusion and exclusion criteria, and choice of stratification variables to maximise the anti-depressive effects of exergames. However, because of the limited number of studies and the use of different

study designs, the findings and conclusions from the systematic review and meta-analysis should be confirmed in rigorous experimental controlled studies. They supported the view that exergame is a particularly suitable and effective depression intervention for older female participants with good physical mobility and depression symptoms.

The findings of this review have also brought valuable recommendations for developers and designers of exergames. Although all the included studies investigate the effects of exergames on depression, only two of them applied exergame that was specially designed for rehabilitation purpose. The fact has called for more attentions to design and evaluate suitable features in exergames that meet the needs for depression treatment. Inspired from Chao et al. (2015a), exergames designers may work with depression therapists to incorporate depression theories and existing treatment practices into the game design. For example, cognitive behaviour therapy can be adopted in the topic and environment of future exergames. These new features may optimise the treatment effect on depression. Meanwhile, the results suggested that increasing social interaction within exergame playing may contribute to more depression reductions. Consequently, more features can be designed to encourage social communication and interaction, such as incorporating multiple-player mode or building peer sharing system. Lastly, designing for ageing population is another recommendation suggested by the findings. Since commercially available exergames on the market are not suitable for senior audience (Shubert, 2010), several studies have discussed the guidelines for designing appropriate exergames for older adults (Brox, Luque, Evertsen, & Hernández, 2011; Gerling, Schulte, & Masuch, 2011; Planinc, Nake, & Kampel, 2013), such as

setting suitable game difficulty and providing elderly-friendly user interface. Developers and designers can follow these guidelines to improve the usability and effectiveness of future exergames that used for older adults with depression.

3.4 Summary

The systematic review and meta-analysis provided an overall understanding of the anti-depressive effects of exergames. A comprehensive literature search was conducted among major bibliographic databases in computer technology, psychology and medical science. Key study characteristics of participants, interventions and experiments were extracted in the systematic review. Both studies using independent and matched groups were included in the meta-analysis. Among the eleven studies included in the review, nine applied exergames of Nintendo Wii or Wii Fit. A random effect meta-analysis on ten studies (eleven trials) resulted in an overall significant effect size of $g = 0.23$. Demographic factors, number of sessions, depression severity, and player interaction were significant moderators for effectiveness.

The current meta-analysis provided support for the findings of positive effects of exergames on alleviating depression. Particularly, it highlighted several important gaps and directions for the future studies including the needs to: a) examine the effect of exergames on older adults with depression, particularly on subthreshold depression; b) determine the differences in the true effects of exergames and traditional exercise; c) explore the effect of player interaction on the depression in the exergame setting. Based on the gaps and

implications from systematic review and meta-analysis, two empirical studies were conducted and described in Chapters Five and Six, respectively.

CHAPTER FOUR

THEORETICAL FRAMEWORK AND HYPOTHESES

Exergaming is a highly application-focused domain. Most of the previous investigations have only targeted on the practical aspect of exergaming. The development of theoretical framework in this field has been relatively slow. A single theory for exergames has not been suggested after nearly a decade of research (Sheehan & Kooiman, 2015). Researchers have tried to bring existing theories from other domains into exergaming. Previous studies were conducted to examine the relevance of several theories to exergaming, such as those from the fields of psychology, computer or behavior science (Di Tore & Raiola, 2012; Staiano & Calvert, 2011; Sun, 2012).

The systematic review and meta-analysis in Chapter Three has highlighted several research gaps in the field of exergame and depression, particularly on platform effect and player interaction effect. In order to address these gaps, it is important to review the related literature and theories to develop hypotheses for testing. This chapter explored relevant theoretical perspectives from the fields of human-computer interaction, social and behavior science, and developed specific hypotheses in the context of exergames and psychosocial well-being.

4.1 Exercise Platform: Exergames Versus Traditional Exercise

Since exergames are digital forms of exercise, it is worthwhile to investigate whether exergames have different effects as compared to traditional forms of

exercise. The greatest advantage that exergames have over traditional forms of exercise is the combination of physical exercise with video gaming. The gaming activities in exergames may attribute to enhance motivation towards exercise adherence (Chao et al., 2015b; Jorgensen, Laessoe, Hendriksen, Nielsen, & Aagaard, 2013). Moreover, recent studies have also began to examine whether individuals who play exergames could lead to different health effects as compared to those from traditional exercise. For instance, Wu, Li, and Theng (2015) found that older adults playing Kinect Sport Bowling exergames have higher social presence than those playing indoor bowling. Russell et al. (2010) compared psychological outcomes of interactive video game (exergames) with traditional aerobic exercise in twenty male and seventeen female volunteers, and found that exergames provided similar acute psychological benefits to traditional exercise when performed at a self-selected intensity. However, there were few studies conducted to investigate the effects between exergames and traditional exercise on subthreshold depression and related psychosocial variables. The below sections provided the theoretical background for the assumptions of exercise platform effect on depression and related psychosocial attributes.

4.1.1 Positive Affect

In psychology, Csikszentmihalyi (1990, 1997) established the *Theory of Flow* to describe a sense of deep immersion in an intrinsically rewarding activity that evokes a loss of self-consciousness. This emotional experience, called ‘flow’, occurs when a person becomes engaged in controllable but challenging tasks or activities that require considerable skill and which are intrinsically motivating (Csikszentmihalyi & Csikszentmihalyi, 1988). Flow experiences may occur

during reading, sports, involvement in creative arts or music or involvement in certain types of work. Researchers often applied the concept of flow into gaming studies, and has indicated that video games have similar characteristics for creating a context for flow (Pavlas, 2010; Sweetser & Wyeth, 2005).

According to the *Theory of Flow*, there are several conditions that have to be met to achieve a flow experience (Csikszentmihalyi, 1990; Sweetser & Wyeth, 2005), including: a) a task to accomplish; b) concentration on task; c) clear task goals; d) clear and immediate feedback; e) sense of control over actions; f) a deep but effortless involvement. Compared to traditional exercise, exergames with the advent of motivational features may better fulfil these conditions for flow, thus leading to higher flow experience in the exercise performance. For instance, exergames can lead to higher *concentration* by providing more interesting visual and audio stimuli that quickly capture the players' attention and maintain their focus throughout the virtual game playing. Exergames can also provide better *immediate feedback* via interactive status, score and progress indicators at appropriate timings. Furthermore, compared to the open environment in common traditional exercise settings, exergames can provide a controlled game environment where players will experience *deep involvement* and become less aware of their surroundings.

In a recent study comparing exergaming and traditional gym-based exercise on healthy adults (Barry, van Schaik, MacSween, Dixon, & Martin, 2016), those in the exergaming group were more focused on what they had to achieve (concentration on task), felt at ease in playing the game (sense of control over actions), had clear feedback during the game (clear feedback), and altered their perception of time and felt immersed in the activity (a deep but

effortless involvement). Therefore their findings also suggested a significant higher flow experience among healthy adults in the exergaming group over those in traditional exercise group (Barry et al., 2016). Similar results were found in another study of Robinson et al. (2015), in which several dimensions of flow experience of the Wii Fit™ was superior to traditional balance training among a group of individuals with multiple sclerosis.

Studies suggested that the flow experience is closely associated with a few positive mental outcomes, including feelings of enjoyment and higher intrinsic motivation (Csikszentmihalyi & Csikszentmihalyi, 1988; Csikszentmihalyi, Rathunde, & Whalen, 1993), and even results in positive affect in the long run (Rheinberg, Manig, Kliegl, Engeser, & Vollmeyer, 2007; Sahoo & Sahu, 2009). Rogatko (2007) examined that engaging in flow promoting activities (high flow condition) would lead to increased positive affect among fifty-seven college students. Another study from Fritz & Avsec (2007) further confirmed that several aspects of flow, i.e., clear goals, challenge-skill balance, concentration on the task, and autotelic experience are important predictors of positive affect, explaining 36% of its variance. In the same way, if exergames create a higher level of flow experience over traditional exercise, it will lead to further perceptions of enjoyment, fun and even positive affect in exercise activities.

Putting all the evidences together, it is reasonable to assume that exergames lead to higher positive affect than traditional exercise, through an increase of flow experience among players.

4.1.2 Self-Efficacy

Self-efficacy may be another psychological attribute affected by digital gaming platform. Self-efficacy refers to the ‘beliefs in one’s capacity to organize and execute the courses of action required to produce given attainments’ (Bandura, 1997, p. 3). Self-efficacy is one of the most widely researched concepts in understanding and promoting health behavior. In the domain of exercise and physical activity, self-efficacy has been established as a determinant of adopting and maintaining regular exercise behaviors (Anderson, Wojcik, Winett, & Williams, 2006; McAuley & Blissmer, 2000). Some recent gaming studies have investigated the relationship between exergames and self-efficacy (Song, Peng, & Lee, 2011; Staiano, Beyl, Hsia, Katzmarzyk, & Newton, 2017; West, 2013). For example, Staiano et al. (2017) found that dance exergaming led to significant improvement in self-efficacy among overweight and obese adolescent girls when compared to no-treatment condition. But few studies were found to test the different effects on self-efficacy between exergames and traditional exercise.

Self-efficacy was developed by Albert Bandura’s as part of *Social Learning Theory* (Ashford & LeCroy, 2010), which has progressed into the *Social Cognitive Theory* in the year 1986 (Levin, Culkin, & Perrotto, 2001). *Social Cognitive Theory* explained that human motivation and behaviour is the result of the interaction among three types of factors: behaviour factors, personal factors (e.g., cognitive, affective, biological events), and environmental factors (Crothers, Hughes, & Morine, 2008). The three factors are constantly influencing each other. Self-efficacy lies at the center of *Social Cognitive Theory*, because it is developed from external experiences (e.g.,

behaviour and environmental factors) and self-perception (personal factors) and is influential in determining the outcome of many behaviours and personal events.

According to Bandura (1997), there are four main sources of information that affect individual's self-efficacy: enactive mastery experiences, vicarious (observational) experiences, social persuasions and physiological and psychological states. Among them, enactive mastery experiences provides the strongest information for the development of self-efficacy. In other words, if an individual perceives their previous experience to be a success, they will likely have greater self-efficacy toward similar future tasks. Mastery is specifically designed into the context of video games, including many exergames.

Compared to traditional exercise settings without any supportive information, exergames provide interactive features (such as visual and audio hints) to guide the task accomplishment. Meanwhile, the difficulty and movements of physical activities are modified in some exergames to create the potential for a mastery experience, which are often hard to achieve in the authentic exercise setting (particularly for sports). Furthermore, the exergames settings are more controlled than traditional exercise settings, with the removal of various environmental factors that could potentially make mastery more difficult.

As a result, it is reasonable to assume exergames promote self-efficacy through higher mastery experience than that of traditional exercise.

4.1.3 Depression

There is much research studying positive affect in the field of depression.

Fredrickson (1998, 2001) built *Broaden-and-Build Theory* of positive emotions,

proposing that positive emotions such as interest, love, enthusiasm and contentment, broaden the momentary thought–action repertoire, leading to engagement in activities that yield positive emotions. Since positive emotions broaden the attentional focus, they distract individuals from stressors so that they may pick up other positive elements from the current environment. Fredrickson therefore predicted that positive affect leads to an upward spiral of wellbeing and decreased stress-sensitivity. Thus, the experience of positive affect may serve as an important protective factor against depression. Wichers et al. (2012) further indicated that positive affect plays an important role in resilience against depression by neutralizing the effects of genetic vulnerability to depression. The negative association between positive affect and depression has been examined in the older populations (Anas & Akhouri, 2013; Danhauer et al., 2013).

Self-efficacy has been observed to be another psychosocial factor associated closely with depression. The negative relation between self-efficacy and depression has been examined in many studies with different age groups (Adam & Folds, 2014; Ehrenberg et al., 1991; Tillema, 2001), including older adults (Davis-Berman, 1988; Marino et al., 2008). People with high self-efficacy are believed to regulate their own functioning and exercise control over difficult tasks or negative life events (Bandura, 1997). Conversely, people with low self-efficacy may often be depressed because they doubt their ability to solve problems and believe that problems are tougher than they really are.

As a result, positive affect and self-efficacy were supported to be negatively associated with depression from the existing literature. Applying these evidences together with the two assumptions proposed earlier in Section

4.1.1 and 4.1.2, it is reasonable to assume that exergames might have advantageous effects on lowering depression.

4.2 Play Mode: Single-Player Versus Multiple-Player

Recent game literature identified several factors that may influence the impacts of exergames. These factors cover both hardware (such as controller design and exergames platform) and software features (such as game types and virtual avatars design). For instance, Park et al. (2014b) examined how the design of exergames controller affected user experience and performance. Platform effects were explored in O'Donovan et al.'s study (2012), in which playing on the Xbox Kinect was reported to elicit greater energy expenditure than playing on the Wii. In the study testing the effect of virtual avatars, Li et al. (2014a) found that overweight children assigned to avatars of normal body size had better exercise motivation and game performances than those assigned to avatars of larger body size. Mellecker & McManus (2014) studied whether physical activity levels were different among three exergames of Gamercize, Kinect River Rush, and XaviX J-Mat.

These studies examined the effects of exergames factors on attitudes, performance and physical conditions. However, to our knowledge, there is no particular study investigating the factors that influence the exergames' impact on depression. Findings of systematic review (Section 3.2.2 in Chapter Three) have shed light on one of the potential factors. It indicated that participants with player interaction tended to lower level of depression during exergame playing, compared to those with no interaction. By reviewing the literature of video

gaming, a common way to manipulate player interaction is through applying different play modes.

Play mode is an important theme in game studies. Play mode is usually categorised in video games history into two types: single-player mode and multiple-player mode. ‘Single-player mode’ refers to a particular game mode designed to be played by a single player, whereas ‘multiple-player mode’ refers to that designed to be played by two or more players simultaneously. Many previous studies have investigated the effects of play mode on players’ motivation, performance and in-game experience (Chen, Wang, & Lin, 2015; Peng & Hsieh, 2012; Smyth, 2007). Some researchers have further explored its effects on psychological and social attributes (Isbister, 2010; Li & Counts, 2007). While there was only one exergaming study that investigated the play mode effects on players’ energy expenditure and heart rate (O’Donovan et al., 2012), there were no previous studies examining the effects of play mode on depression in the exergaming context. The below sections provided the theoretical perspective for the assumptions of play mode effect on depression and related psychosocial attributes.

4.2.1 Social Support

Social support is one of the psychosocial outcomes that may be affected by play mode in video games. Social support refers to the resources that people are able to call on through the relationships they have with others (Cohen & Hoberman, 1983; Haber, Cohen, Lucas, & Baltes, 2007). Social support is one of the important rewards that people exchange in social activities (Thibault & Kelley, 1952). The concept of social support has been introduced into the virtual social

communities, such as bulletin boards (Coulson, Buchanan, & Aubeeluck, 2007) and online forums (Whitlock, Powers, & Eckenrode, 2006). Many researchers have further examined the social support derived from video games with multiple players (Trepte, Reinecke, & Juechems, 2012; Zhang & Kaufman, 2016).

In contrast with those in single-player games, players in multiple-player games need to learn and apply their social skills to achieve game goals. While interacting with others, players enhance their in-game social networking and interaction in these virtual social communities. This phenomenon is more obvious in games designed specifically for engaging cooperation and mutual assistance (Ewoldsen et al., 2012). In these collaborative games, players in a team assist each other and share successes and failures together. These social interactions strengthen group cohesion and interdependent bonds among teammates (Banks, 2012; Isbister, 2010), and foster strong feelings of virtual support and new friendships (Smyth, 2007). These virtual support and relationships in multiple-players gaming may affect and extend players' pre-existing relationships in real life (Williams, 2006). Gentile and Gentile (2008) argued that social skills learned and practiced in the gaming environment could be generalised into the real context, which may promote prosocial behaviour and enhance social support in daily life. Trepte et al. (2012) has presented a large-scale study to examine the theoretical framework of how social interactions in online multiple-player gaming affected offline social support. In their study, players' social proximity and mutual familiarity during online interactions were supported to foster both online bridging social capital (people feel informed and inspired by each other) and bonding social capital (emotional

support and understanding), while both social capital dimensions are positively related to offline social support.

The theoretical framework of gaming and social support provided above can be applied into the context of exergaming. It is reasonable to posit that exergames in multiple-player mode lead to higher levels of social support than those in single-player mode.

4.2.2 Loneliness

Loneliness refers to the subjective feeling state of being alone, separated, or apart from others (Tomaka, Thompson, & Palacios, 2006). It has also been conceptualised as an unfavourable balance between actual and desired social contact (Ernst & Cacioppo, 1999). Loneliness is related to quality and quantity in social relations, and closely associated with social isolation (Heylen, 2010). As a result, frequent social interactions and satisfaction with these interactions are linked to lower risk of loneliness.

Similarly, play mode in video games may affect loneliness. Li and Counts (2007) argued that multiple-player games could actually increase communication between teammates via digital and traditional channels. Furthermore, such game mode could create feelings of co-presence and make players feel more connected to each other (Lazzaro, 2004; Pagulyan, Keeker, Wixon, Romero, & Fuller, 2003). The co-presence and connection to others could therefore reduce loneliness. Kahlbaugh and colleagues (2011) investigated the effects of exergames on loneliness in elderly people. In their study, thirty-five older residents ($M = 82$ years) received personal visits from students who played a bowling game on Nintendo Wii console with them for an

hour for ten weeks. Results showed that older residents felt less lonely than they had at the start of the study. The decrease in loneliness was perhaps not due to playing the Wii itself, but by the interactions between older participants and students. In a large sample survey study, Lee and Ishii-Kuntz (1987) indicated that doing something together with other people reduced loneliness among older adults.

Consequently, comparing to single-player games without any social interactions, multiple-player game may lead to lower level of loneliness.

4.2.3 Depression

In social gerontology literature, psychologists often linked depression with social support and loneliness. Social support served as a “protective” factor to people’s vulnerability on the effects of stress on health. The most influential theoretical perspective on social support hypothesises that social support reduces the effects of stressful life event on health through either the supportive actions of others or the belief that support is available (Lahey & Cohen, 2000). The effect of social support can be also understood as buffering hypothesis (Cohen & Wills, 1985), which indicates the existence of one’s social network, as well as substantive interactions generated among social ties, can buffer people from negative and stressful events. Therefore, social support acts to reduce the chances of stressors and negative events that provoke depression.

Sizable ageing studies have established the relationship between social support and geriatric depression (Lee et al., 2012; Su et al., 2012; Verstraten, Brinkmann, Stevens, & Schouten, 2005). Given that a person’s social network decreases over time in late life (Antonucci, 1991), older adults receive less

emotional support from social networking. This could increase the risk of depression. Barg and colleagues (2006) found that high adequacy of social support that older adults receive corresponds to low depressive scores. In a study with forty elderly aged 60 years and above, Patil et al. (2014) found a significant negative correlation between perceived social support and depression ($r = -.413$; $p < 0.01$).

The feeling of loneliness is common for elderly people in their late life because of the lack of close family ties (e.g., living alone), impaired social support, and loss of mobility in social activities. Lonely people suffer from more depressive symptoms, as they have been reported to be less happy, less satisfied and more pessimistic (Singh & Kiran, 2013). Loneliness is one of the strongest predictors of depression according to Singh and Misra (2009). Depressive symptoms, such as anxiety and sadness, are highly identical with the symptoms of loneliness. Strong association between loneliness and geriatric depression was further confirmed in a large scale study of approximately 1,000 older adults (Aylaz, Aktürk, Erci, Öztürk, & Aslan, 2012). The longitudinal study of Cacioppo et al. (2006) supported that loneliness is a significant risk factor for depression among the ageing population. Another community study in Asia (Chi & Chou, 2001) substantiated the positive relationships between loneliness and geriatric depression ($r = 0.63$, $p < 0.01$) among 154 Hong Kong Chinese older adults.

Considering the close relationships with depression, social support and loneliness can be both proposed to have significant associations with subthreshold depression in late life.

4.3 Hypotheses

Seven hypotheses were developed based on the assumptions mentioned in the above section. Considering the target population of current research, they were proposed within the particular context of older adults with subthreshold depression. These hypotheses were used for testing in the two empirical studies (described in Chapter Five and Six) to address the overall research question.

Table 4.1 lists all the hypotheses proposed in the current research.

Table 4.1

Summary of the Hypotheses

No.	Hypothesis	Reference
H1	Compared to traditional exercise, exergames elicit more positive affect among older adults with subthreshold depression.	Section 4.1.1
H2	Compared to traditional exercise, exergames lead to higher self-efficacy among older adults with subthreshold depression.	Section 4.1.2
H3	Compared to traditional exercise, exergames lead to lower subthreshold depression among older adults.	Section 4.1.3
H4	Exergames with multiple-player mode provide higher levels of social support among older adults with subthreshold depression than exergames with single-player mode.	Section 4.2.1
H5	Exergames with multiple-player mode lead to lower levels of loneliness among older adults with subthreshold depression, than exergames with single-player mode.	Section 4.2.2
H6	Social support is negatively associated with subthreshold depression among older adults.	Section 4.2.3
H7	Loneliness is positively associated with subthreshold depression among older adults.	Section 4.2.3

4.3 Summary

This chapter presented the theoretical underpinnings for the development of hypotheses utilising in the two empirical studies. The platform effect and play mode effect of exergames were hypothesised based on the theories and literature in relevant field of psychology, human-computer interaction, and communication. It was proposed that exergames elicit more positive affect, higher self-efficacy and lower subthreshold depression among older adults, when compared to traditional exercise. Furthermore, compared to those with single-player mode, exergames with multiple-player mode were proposed to lead to better improvements of social support and loneliness among older adults, while the improvements of these two variables were associated with subthreshold depression. Chapter Five and Six will provide the detail of the two empirical studies conducted to test these hypotheses.

CHAPTER FIVE

STUDY ONE: EXERGAME VERSUS TRADITIONAL EXERCISE

The systematic review and meta-analysis in Chapter Three provides support for the promising effects of exergames in alleviating depression. Findings showed that exergames have particular benefits for those who are older adults and with depression, especially with subthreshold depression. Given the high prevalence and negative effects of subthreshold depression among older adults (discussed in Chapter Two), exergames may become a suitable and effective depression intervention for older adults with subthreshold depression. However, the limited number of studies found in systematic review highlighted the research gaps in this domain. As a result, conducting empirical studies examining the effect of exergames on older adults with subthreshold depression may be essential and worthwhile.

Moreover, among the limited number of studies identified in the systematic review, three of them were RCTs, and only two trials used traditional exercise as control condition. Although the anti-depressive effects of traditional exercise has been fully confirmed in previous studies, the true effects of exergame on older adults has yet to be proven fully. It is far less known whether exergames have superior effects over traditional exercise on subthreshold depression among older adults. Thus, the lack of knowledge in this domain calls for studies to investigate the differences in the effects of exergames and traditional exercise on addressing subthreshold depression among older adults.

This chapter⁶ describes an empirical controlled study (Study One) that aimed to distinguish the effects of exergames over traditional exercise on subthreshold depression of older adults.

5.1 Study Design

A mixed-design empirical controlled study with two factors (factor one: exergames versus traditional exercise; factor two: pre- and post-study) was carried out from January to April 2015 (IRB-2014-07-039, see Appendix A). The study was conducted to investigate the anti-depressive effects of the exercise platform, that is, exergames versus traditional exercise, on older adults with subthreshold depression over time.

5.1.1 Participants

The common definition of a ‘older adults’ refers to people with a chronological age of 65 years and above (World Health Organization, 2012). While this definition is somewhat arbitrary, it does not always adapt well to the projects with different purposes and situations. At the moment, there is no United Nations standard numerical criterion for older population. Previous studies have brought out different working definitions of older adults (Roebuck, 1979). In many nationally surveys that investigated the prevalent rate of major and subthreshold depression, the cut-off line for older adults were defined as 55 years and above (Beekman et al., 1997; Hailemariam et al., 2012; Leung et al., 2015; Reynolds et al., 2015). Findings from some of these studies indicated that people aged 55 to 64 years old had a higher prevalence of depression, or higher

⁶ The contents of this chapter have been presented at the 2016 International Communication Association conference, Fukuoka, Japan.

risk of developing depression episodes, than those aged 65 and above (Hailemariam et al., 2012; Reynolds et al., 2015). Extensive studies further have indicated that older adults aged 55 to 64 should be included in geriatric studies because they could provide insights into the needs of future older adults (Bures, 1997; Ministry of Community Development, 2006).

Consequently, age criteria for participants in the study included both older adult participants (aged 65 and above) and pre-older adult participants (aged 55 to 64). Patient Health Questionnaire - 9 (PHQ-9; Spitzer et al., 1994) was used as a screening tool for admission into the study. Based on its instructions (Kroenke & Spitzer, 2002), the total PHQ-9 score below '4' indicated 'none' depression, whereas '5' to '14' indicates 'mild to moderate' depression, and '15' to '27' indicates 'moderately severe to severe' depression. A PHQ-9 score of more than '15' has a sensitivity of 86% and a specificity of 99% for major depression (Sharp & Lipsky, 2002). Scores of 5-14 were commonly used as cut-off points for the diagnosis of subthreshold depression in many studies (Kroenke, Spitzer, & Williams, 2001; Pols et al., 2017; Schmitz et al., 2014). Followed by these studies, Study One only included those who scored 5–14 in PHQ-9 (diagnosis of subthreshold depression) in the final pool. Participants were excluded if:

- They were found to have serious or uncontrollable cognitive disorders (for example, severe dementia or Parkinson's disease) that made them unsuitable to participate in the study;
- They had intellectual disability or physical limitations that made them not fit to perform exercises;

- They had received within the last three months or were already receiving antidepressant medications or other forms of psychosocial therapies for depression.

Participants were recruited from four Senior Activity Centres (SACs) and Community Clubs (CCs) in Singapore. The SACs are non-profit, voluntary welfare institutes that provide recreational and social activities regularly for older adults living nearby. The CCs are public facilities that offer a wide range of programmes to cater to local residents from all walks of life. The participating SACs and CCs were a) Gek Poh Ville Community Club, b) Care Corner Special Day Care for the Elderly, c) Care Corner Seniors Activity Centre and d) Asian Women's Welfare Association. These centres are located in the western, southeastern, and northern part of Singapore. Proposed participants were approached and identified through the help of administrators and nursing staff in the SACs and CCs. Individuals who showed interest in the study were included if they fulfilled all admission criteria listed above. Participation in the study was voluntary, and informed consent (see Appendix B) was obtained for all participants before the study. Each participant was awarded SGD\$15 equivalent of shopping voucher after they completed all sessions.

5.1.2 Stimulus Selection

Two different exercise conditions, namely, exergames and traditional exercise, were implemented in the study. Each condition consisted of two similar exercise forms to increase generalisability of the certain conditions.

Exergames. The platform used in the exergame condition was Nintendo Wii. The Wii console involves a remote controller that can be used as a

handheld pointing device and detect movement in three dimensions. Nintendo Wii was chosen because it is one of the most popular devices for performing exergames. The device transfers video games into a form of exercise, and therefore engages players in substantial amount of physical activities. According to previous studies (Ganesan & Anthony, 2012; Theng et al., 2009), the features of Wii include having a suitable platform to motivate exercise among older adults. Increasing studies have investigated the effects of Wii in healthcare domain, including elderly care (Chao et al., 2015b; Wollersheim et al., 2010). Two exergames in Wii Sports (Nintendo, 2006), namely, Wii bowling and Wii golf, were used in this condition. They were selected because of two reasons. First, according to the American College of Sports Medicine (Chodzko-Zajko et al., 2009), older adults were encouraged to perform physical activities that maintain or increase balance and flexibility through slow movements. The two Wii exergames allow slow movements that match these typical physical activities recommended for older adults. Second, referring to existing work, older adults preferred mini games with shorter duration and require simple and single direction control (Gao & Mandryk, 2011; Theng, Chua, & Pham, 2012). Simple sport games, such as bowling and golf, were commonly recommended in previous studies as suitable exergames for older adults (e.g., Gerling et al., 2011; Hsu et al., 2011; Kahlbaugh et al., 2011). Third, both bowling and golf are self-paced, such that players could take the time they need to perform. The games reduce concerns for safety, energy expenditure, and aged-related problems for older players. Figures 5.1 and 5.2 illustrate the screenshots and scenarios of two exergames in this condition. All game difficulties were set to a suitable level that meets the skills of older adults.

Figure 5.1. Screenshot (left) and scenario (right) of playing Wii bowling.

Figure 5.2. Screenshot (left) and scenario (right) of playing Wii golf.

Traditional Exercise. To allow for unbiased comparison between digital and non-digital platforms, the exercise programmes selected in this condition have similar nature of ‘sport games’ with those in exergame conditions. However, considering the physical limitations and safety of older adults, authentic sport games (e.g., real bowling on a bowling alley) may not be suitable for the participants in this study. Instead, two ‘simulated simple ball games’, indoor bowling and basketball shooting, were used in this condition. With consideration for safety, a special bowling ball and basketball were

selected with light and soft material. They were designed with reduced sizes and weight to prevent unnecessary injury to older adults. Under this exercise condition, following the rules used in normal bowling or basketball shooting games, participants were asked to either roll a bowling ball to knock over pins, or shoot a basketball into a basket. Figures 5.3 and 5.4 illustrate the balls and scenario of two ball games in traditional exercise conditions.

Figure 5.3. Balls (left) and scenario (right) of indoor bowling game.

Figure 5.4. Balls (left) and scenario (right) of basketball shooting game.

Participants were assigned to one of two exercise conditions and performed only one exercise form from that condition. Given the limitations of available facilities (such as TV set, Wii set and rooms), participants from each condition were divided into small groups consisting of four to six older adults. The participants in the same group took turns to perform only one intervention based on the availability of facilities in their centres. The duration of each group was approximately one hour for one exercise session. Based on the recommended elderly exercise time from the American College of Sports Medicine (Mazzeo, 1998) and from previous exergame studies (Cheng et al., 2014; Rendon et al., 2012; Rosenberg et al., 2010), participants in both exercise conditions were asked to perform one session per week for a total of six consecutive weeks. To ensure similar physical environment across the two conditions, all interventions were conducted in the centre activity rooms or foyers with minimal distractions and noise.

5.1.3 Procedures

Figure 5.5 illustrates the flow chart of the study participants. Ninety-three older adults participated in the screening process. Based on the screening process, twenty-eight older adults were excluded because they were identified to have non-depression (scored 0-4 in PHQ-9), while six older adults were excluded because they have major depression (scored 15 and above in PHQ-9). Two participants were excluded because of poor physical mobility (high risk of frailty), and two were further excluded due to the language problems (they can only speak dialects that the research team could not understand). As a result, only 55 participants met the inclusive criteria and were involved in the final study. The depression score of the included participants had a mean of 6.64 (*SD*

= 2.53), and followed a normal distribution (Skewness = 1.09, $SE = .337$; Kurtosis = -0.99, $SE = .664$). Given the limitations in facilities and manpower, random allocation was applied in only two centres, Gek Poh Ville Community Club and Asian Women's Welfare Association. Participants from the other two centres (Care Corner Seniors Activity Centre and Care Corner Special Day Care for the Elderly) only attended either one of the two experimental conditions based on the facilities and preferences of the centres hosting the study. Table 5.1 describes the assignment of participants in the two conditions. At the end of the study, five participants who were absent in more than two exercise sessions were excluded in the study. They were dropped out because of the reasons such as health-related problems, scheduling conflicts, or loss of interest in the study.

Figure 5.5. Flow chart of study participation.

Table 5.1

Distribution of Participants in Two Conditions at the Pre-Study Period

Centres	Exergame	Traditional Exercise	Total
GPVCC	8 (WG)	8 (IB)	16
CCSDC-E	11 (WB)	-	11
CCSAC	-	10 (BS)	10
AWWA	8 (WB)	8 (IB)	16
Total	29	26	55

Note. AWWA, Asian Women's Welfare Association; BS, Basketball Shooting game; CCSAC, Care Corner Seniors Activity Centre; CCSDC-E, Care Corner Special Day Care for the Elderly; GPVCC, Gek Poh Ville Community Club; IB, Indoor Bowling; WB, Wii Bowling; WG, Wii Golf.

5.1.4 Measures

For older adults who fulfilled the admission criteria, their basic demographic data were collected during the pre-study session, including age, gender, education level, living conditions and physical health conditions. The main variables of depression, positive affect, and self-efficacy were also collected at the pre-study and post-study periods. Considering the ageing-related literate and visual problems, participants were assisted by trained student assistants from the research team in filling in the questionnaires. Considering the cultural backgrounds of Singapore, English and Chinese versions of questionnaire were used in the study. A total of forty-seven participants used the Chinese versions while only three participants used English versions. Appendix C shows the survey questionnaires used in the pre-study and post-study periods.

Subthreshold Depression. The Patient Health Questionnaire -9 (PHQ-9; Spitzer et al., 1994) is a self-administrated depression scale under the Primary Care Evaluation of Mental Disorders (PRIME-MD), which is a widely used

diagnostic screening instrument in primary care. In addition to recognising major depression, PHQ-9 is also a useful tool for detecting subthreshold depression in the general population (Martin et al., 2006). The validity and reliability as diagnostic and assessing measurements are well-established in previous studies (Kroenke et al., 2001; Löwe, Unützer, Callahan, Perkins, & Kroenke, 2004). More importantly, PHQ-9 has demonstrated ability in detecting depression change over time and monitoring treatment response (Huang, Chung, Kroenke, Delucchi, & Spitzer, 2006). Therefore, the instrument fits well with the research aims of the current study. The tool uses a four-point Likert scale (from 0 'Not at all' to 3 'Nearly every day') to measure items, such as 'Little interest or pleasure in doing things?' or 'Feeling down, depressed or hopeless?' The total score reflects depression severity, with a higher score indicating higher severity of depression. The Chinese version of PHQ-9 was adapted directly from the PHQ website (www.phqscreeners.com) organised by Pfizer Inc.

Positive Affect. The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) is one of the most widely used scales to measure mood or emotion. The original scale contains 20 items assessing positive and negative affects in different timeframes (e.g., present moment, today, last week). The instrument demonstrated excellent psychometric properties and has been proven to be a valid measure of emotions in previous studies (Carvalho et al., 2013). The current study applied the 10-item positive affect measure from PANAS (PANAS-PA) to evaluate the positive affect that participants experienced when they completed exercise conditions. The measure uses five-point Likert scale (from 1 'Very slightly or not at all' to 5

‘Extremely’) to measure how participants feel at the moment, such as ‘Interested’ or ‘Excited.’ A higher sum score indicates higher level of positive affect. The Chinese version of PANAS-PA was developed using back-translation.

Self-efficacy. The General Self-Efficacy (GSE) Scale is the most widely used scale to assess this general attitude. The GSE scale was originally developed by Jerusalem and Schwarzer in 1979, and later revised and adapted to 26 other languages (Schwarzer & Jerusalem, 1995). The scale has shown high internal consistencies and retest-reliability in general and clinical populations (Luszczynska, Scholz, & Schwarzer, 2005; Scholz, Gutiérrez-Doña, Sud, & Schwarzer, 2002). To reduce the burden for older participants, the current study adapted a short form of GSE consisting of six items (GSE-6). The GSE-6 has been tested to be a reliable and valid instrument in Romppel et al.’s study (2013). The tool uses a four-point Likert scale (from 1 ‘Not at all true’ to 4 ‘Exactly true’) to measure items such as ‘If someone opposes me, I can find the means and ways to get what I want’ or ‘It is easy for me to stick to my aims and accomplish my goals.’ Higher scores indicate greater degree of self-efficacy. The Chinese version of GSE-6 was adapted from Zhang and Schwarzer (1995).

5.1.5 Statistical Analysis

Data were analysed using SPSS 21.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics was conducted to calculate the means or percentages of demographic variables across two conditions. The between-group difference of all demographic variables at pre-study was tested for significance by using t-

test or Chi-square test. A p value of less than .05 in t-test or Chi-square test indicates significant group difference among the conditions. Bivariate associations among subthreshold depression, positive affect and self-efficacy at post-study period were tested using Pearson's r correlation. A series of two-way mixed-design Analysis of Covariance (ANCOVA) was applied to test the hypotheses of H1, H2 and H3 indicating in Section 4.3. The exercise platform (exergames versus traditional exercise) was the between-subject factor, and time (pre- and post-study) was the within-subject factor. Demographic variables were used as covariates in the analysis if they have significant (or approaching significant) difference across the two conditions. ANCOVAs tested the effects between exergames and traditional exercise on each of the three key psychosocial variables over a six-week intervention period. Greenhouse-Geisser correlations were applied in the univariate tests of ANCOVAs.

5.2 Results

5.2.1 Descriptive Statistics

Among the fifty-five participants at the pre-study period, fifty successfully completed all sessions and were measured at the post-study period. The average age was 72.90 ($SD = 7.73$), and the majority of the participants were female ($N = 32, 64.0\%$) and Chinese ($N = 46, 92.0\%$). Twenty-five participants were in exergame condition, while the other twenty-five were in traditional exercise conditions. Exergame condition had more younger participants (aged 55 to 64 years) but less older participants (aged 75 years and above) rather than traditional exercise. Table 5.2 shows further descriptions of the participants in the two conditions at pre-study period. The results of the t-test and Chi-square

test indicated the absence of significant difference in demographic characteristics across two conditions. The results indicated that participants from the two conditions did not have systematic differences in terms of age, gender, ethnicity, education, living conditions, mobility, physical, and cognitive status.

Table 5.2

Demographic Characteristics of Participants across Two Conditions (N = 50)

	Traditional exercise (N = 25)	Exergames (N = 25)	Difference across conditions
Demographics			
Age*	74.60 (6.10)	71.20 (8.86)	$t(48) = 1.58, p = .121$
55 – 64 years	2 (8.0%)	5 (20.0%)	-
65 – 74 years	12 (48.0%)	12 (48.0%)	-
75 years and above	11 (44.0%)	8 (32.0%)	-
Gender (Female)	18 (72.0%)	14 (56.0%)	$\chi^2(1) = 1.39, p = .377$
Race (Chinese)	24 (96.0%)	22 (88.0%)	$\chi^2(1) = 1.07, p = .609$
Education (≤ Secondary school)	21 (84.0%)	21 (84.0%)	$\chi^2(1) = 0.00, p = 1.000$
Living condition (Alone)	9 (36.0%)	9 (36.0%)	$\chi^2(1) = 0.00, p = 1.000$
Physical Health			
Eye sight*	2.36 (1.08)	2.88 (0.73)	$t(48) = -2.00, p = .051$
Hearing*	2.48 (1.16)	2.96 (0.89)	$t(48) = -1.64, p = .107$
Mobility status*	2.36 (0.99)	2.84 (0.75)	$t(48) = -1.93, p = .060$
Cognitive status*	3.48 (1.29)	3.60 (0.82)	$t(48) = -0.39, p = .697$

Note. *Data presented as Mean (Standard Deviation).

Table 5.3 and Table 5.4 show the descriptions of the key psychological outcomes across different conditions at pre-study and post-study period. Results from bivariate correlations indicated a significant correlation between subthreshold depression and positive affect at both pre-study and post-study period. However, self-efficacy was not significantly correlated with subthreshold depression or positive affect after the six-week intervention. Table

5.3 and Table 5.4 also indicate the changes in the means of three psychosocial variables in the two conditions during the intervention period.

Table 5.3

Description of Subthreshold Depression, Positive Affect, and Self-Efficacy at Pre-Study Period (N = 50)

	1	2	3	Cronbach's Alpha α	Total (N = 50)	Exergame (N = 25)	Traditional Exercise (N = 25)
1. Subthreshold Depression (PHQ-9)	-			0.60	6.64 (2.53)	6.88 (2.47)	6.40 (2.61)
2. Positive Affect (PANAS)	-.39**	-		0.75	26.34 (4.78)	26.72 (3.92)	25.96 (5.56)
3. Self-Efficacy (GSE)	-.20	.35*	-	0.51	14.50 (2.76)	14.60 (2.43)	14.40 (3.10)

Note. ^aData are presented as Mean (Standard Deviation).

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5.4

Description of Subthreshold Depression, Positive Affect, and Self-Efficacy at Post-Study Period (N = 50)

	1	2	3	Cronbach's Alpha α	Total (N = 50)	Exergame (N = 25)	Traditional Exercise (N = 25)
1. Subthreshold Depression (PHQ-9)	-			0.70	4.08 (2.32)	2.88 (1.56)	5.28 (2.35)
2. Positive Affect (PANAS)	-.38**	-		0.85	38.94 (5.87)	42.64 (4.54)	35.24 (4.60)
3. Self-Efficacy (GSE)	-.03	.14	-	0.65	19.04 (3.72)	18.84 (1.75)	18.94 (2.88)

Note. ^aData are presented as Mean (Standard Deviation).

* $p < .05$, ** $p < .01$, *** $p < .001$.

5.2.2 Effects of Exercise Platforms

A series of two-way mixed-design ANCOVAs was finally carried out to address the main objective of Study One. Two demographic variables, eye sight and mobility status, were controlled in the ANCOVAs because their differences were approaching significant level across the two conditions.

Findings from the two-way mixed-design ANCOVAs reveal the interaction effects between exercise platform and time on psychosocial variables. These results were used to test the hypotheses in the study. Table 5.5 describes the outcomes of the two-way mixed-design ANCOVAs. First of all, there was a significant exercise platform effect on subthreshold depression over the six-week period, $F(1,46) = 14.13, p < .001$, partial $\eta^2 = 0.24$. This significant interaction effect indicated that the improvements of subthreshold depression across the two conditions were significantly different from each other after the six-week intervention. Figure 5.6 further illustrates the plot for Platform $\times$ Time interaction on subthreshold depression. In this plot, it is clear that although older adults in both conditions had improvements on subthreshold depression, those in the exergame condition had greater reduction. The findings from univariate tests and interaction plot clearly supported H3, and demonstrated that exergames led to lower subthreshold depression among older adults rather than traditional exercise.

Positive affect was another psychosocial parameter that exhibited a significant difference across two conditions over time, $F(1, 46) = 9.86, p = .003$, partial $\eta^2 = 0.18$ (Refer to Table 5.5). This result indicated that the two conditions (exergame versus traditional exercise) led to different levels of

positive affect among older adults. The interaction effect plot shown in Figure 5.7 clearly demonstrated that although older adults in both conditions had improvements on positive affect, those in exergame condition had greater increase. The findings from univariate tests and interaction plot clearly supported H1, and indicated that exergames elicited more positive affect among older adults when compared to traditional exercise.

Table 5.5

Outcomes of Two-Way Mixed-Design ANCOVA (Interaction Effects of Platform X Time)

	<i>F</i>	<i>p</i>	Partial η^2
Subthreshold Depression	14.13	< .001	0.24
Positive Affect	9.86	.003	0.18
Self-Efficacy	0.12	.643	< .01

However, no significant interaction effects were observed in the self-efficacy between two exercise conditions over six weeks, $F(1, 46) = 0.22$, $p = .643$, partial $\eta^2 < 0.01$ (Refer to Table 5.5). Consequently, different from subthreshold depression and positive affect, self-efficacy did not have greater improvement among older adults in exergame conditions rather than among those in traditional exercise condition. This result from two-way ANCOVA did not support H2, and indicated that exergames did not lead to higher self-efficacy among older adults when compared to traditional exercise.

Figure 5.6. Interaction effects between platform and time on subthreshold depression. *Note.* Covariates appearing in the model are evaluated at the following values: eye sight = 2.62, mobility status = 2.60.

Figure 5.7. Interaction effects between platform and time on positive affect. *Note.* Covariates appearing in the model are evaluated at the following values: eye sight = 2.62, mobility status = 2.60.

5.3 Discussion

Study One investigated the anti-depressive effects of exergames on Singaporean older adults with subthreshold depression over a six-week period, by comparing the results to traditional exercise programmes. Overall, findings from this study confirmed the positive effects of exergames on subthreshold depression among older adults. The study also extended the mental benefits of exergames, indicating improvements on positive emotions and self-efficacy on older adults.

5.3.1 *Difference in Anti-depressive Effects*

Several recent studies have applied exergames into the healthcare domain of gerontology and geriatrics, and investigated their anti-depressive effects among older adults (Chao et al., 2015a; Wollersheim et al., 2010). A pilot study from Rosenberg and colleagues (2010) further supported the short-term efficacy of exergames on subthreshold depression ($t(21) = 3.24, p = .004$) among nineteen community-dwelling older adults after twelve-week period. However, these early attempts either applied pre-post study design or used non-exercise conditions as control group. This study is the first to compare the effects between exergames and traditional exercise on older adults with subthreshold depression.

The findings of two-way mixed-design ANCOVAs show that exergames have significant higher anti-depressive effects than traditional exercise over time. An inspection through the interaction effect plot shows that although traditional exercise reduces subthreshold depression, exergames have stronger effects on alleviating subthreshold depression among older adults over

the entire six-week period. The superior anti-depressive effects were possibly caused by the use of different types of motivational features in exergames, which led to more enjoyable and fun experience in exercise performance (Chao et al., 2015b). Recurrent experiences of fun and enjoyment may have long-term effects on depressive symptoms.

5.3.2 Related Psychosocial Effects

In addition to reducing depression, Study One provides promising evidence that exergame playing has significant superior effects in increasing positive affect among older adults with subthreshold depression over traditional exercise programmes. The current study extends the findings of previous studies (Chao et al., 2015b; Rosenberg et al., 2010; Wollersheim et al., 2010) by confirming various psychosocial benefits of exergames for older adults. Although a majority of previous studies have investigated the relation between exergames and mood improvements among young population (Biddiss & Irwin, 2010; Naugle, Naugle, & Wikstrom, 2014), findings from Study One further confirmed the positive effects of exergames on the positive affect among older adults. The high level of positive affect observed in exergames conditions may provide a possible explanation for the low level of depression in this condition.

Self-efficacy was not found to be significantly different among older adults across the two exercise conditions. The relation between self-efficacy and novel digital application was investigated in recent studies (Hill, Smith, & Mann, 1987; Schreder, Smuc, Siebenhandl, & Mayr, 2013). Hill et al. (1987) found that the use of a variety of technologically advanced products increased perceived efficacy beliefs. Nevertheless, inconsistent with previous studies,

self-efficacy was not found to be higher in exergames than in non-digital exercise programmes. Older adults generally suffer from age-related changes, including decline in sensory-perceptual processes (e.g., loss in visual and auditory acuity), motor abilities, response speed, and cognitive processes (Czaja & Lee, 2003; Fisk et al., 2004). These adults may have difficulties in the use of digital technologies (Artinian, Harden, & Kronenberg, 2003; Jimison et al., 2008). These difficulties and barriers in exergame playing are likely to affect their perception of self-efficacy. Relatively low reliability in self-efficacy scale might also contribute to the non-significant effect, which indicating the need to adopt other suitable measurement of self-efficacy among older adults in Singapore. The short intervention period (six weeks) in Study One was another possible explanation that accounts for the failure to detect significant effects on this long-term attribute of self-efficacy.

5.4 Summary

Study One aimed to examine the psychosocial effects of exergames on older adults with subthreshold depression, with comparison to traditional exercise. Fifty community-dwelling Singaporean older adults diagnosed with subthreshold depression were assigned to perform either Wii Sports exergames (Wii bowling and Wii golf) or traditional exercise (indoor bowling and basketball shooting) and completed the six-week study. Subthreshold depression, positive affect, and self-efficacy were assessed at the pre- and post-test periods. The results from two-way mixed-design ANCOVAs indicated that participants in exergames had significantly lower subthreshold depression (supporting H3) and higher positive affect (supporting H1) over the

intervention period than those in traditional exercise. No significant exercise platform effects were reported on self-efficacy over time (not supporting H2).

This study demonstrates the benefits of exergames on psychosocial well-being in older adults with subthreshold depression and provides important guidance for health professionals and game designers. Because exergames were confirmed to have better effects over traditional exercise in Study One, taking a further step to explore the possible influencing factors that may affect the effects of exergames on subthreshold depression is both essential and worthwhile.

In the next chapter, Study Two is presented to explore one of the potential influencing factors, which is the play mode of exergames. The two empirical studies are parts of the entire research that investigates the overall research question of using exergames as an intervention for subthreshold depression among older adults.

CHAPTER SIX

STUDY TWO: EFFECTS OF PLAY MODE

Findings from Study One have indicated the superior effects of exergames over traditional exercise on older adults with subthreshold depression. However, the lack of depth of study in this area calls for further research that explores the influential factors that may affect their anti-depressive effects. Study Two in this chapter⁷ is a pilot study that attempted to contribute to this very new research topic. Inspired from the findings of partner interaction in systematic review (Chapter Three), the study in this Chapter focuses on one factor that may have the strongest link to depression, which is the play mode of exergames. Findings from previous studies have indicated that different player modes (single-player versus multiple-player) may affect a player's psychosocial attributes in real life, such as social support (de Kort & Ijsselstein, 2008; Uz & Cagiltay, 2015) and loneliness (Kahlbaugh et al., 2011). Social support and loneliness are common depression predictors supported by previous literature (Ingram, Jones, Fass, Neidig, & Song, 1999; Nezlek, Imbrie, & Shean, 1994b; Singh & Misra, 2009). Hence, play mode in exergames may affect depression through the mediation effects of social support and loneliness.

A between-group study was conducted in Study Two to test this assumption, by examining the influence of play mode on depression in the

⁷ The content of this chapter has been presented at the workshop of Social Theory in Ageing Informatics 2016, Singapore.

exergame setting. The next section explains why play mode is worth exploring and how this factor may be strongly linked with depression.

6.1 Conceptual Model

Section 4.2 has provided the theoretical underpinning and developed hypotheses for the play mode effect on depression. Multiple-player games lead to more social interactions and communication between players compared with single-player games (Li & Counts, 2007). Multiple-player games can strengthen interdependent bonds between teammates (Banks, 2012; Isbister, 2010) and foster strong feelings of virtual support (Smyth, 2007) and connection (Lazzaro, 2004; Pagulyan et al., 2003). The support and connections gained in multiple-player games may increase players' social support and reduce loneliness in real life. Social support and loneliness were commonly identified as the main psychosocial factors associated with depression among older adults (Lee et al., 2012; Singh & Misra, 2009; Su et al., 2012). As a result, it is reasonable to assume that multiple-player exergames lead to higher social support and lower loneliness than single-player exergames and further reduce depression.

The literature provided above led to important implications for the development of Study Two. Study Two targets testing the influence of play mode on the effects of exergames on subthreshold depression among older adults. It applied a between-group study to compare the effects of exergames with two play modes (single-player versus multiple-player modes) on older adults with subthreshold depression. In game literature, multiple-play mode is further categorised into two patterns, collaborative and competitive modes (Deutsch, 1949a, 1949b). Different from collaborative games with the shared

objective, competitive mode with the personal objective may elicit anxiety and fear of failure (Wu et al., 2015). These emotions elicited in competitive games may have negative effects on depression. Since Study Two was conducted to address subthreshold depression, only the collaborative mode was applied in the multiple-player condition.

Based on the hypotheses developed in Section 4.2, a conceptual model was established based on these hypotheses. The model proposed that both social support and loneliness would mediate the relationship between play mode and depression in exergame playing. Figure 6.1 shows the proposed mediation model used in this study.

Figure 6.1. Conceptual model of Study Two.

6.2 Study Design

A between-group controlled study was carried out between September and November in 2015 among older adults in Singapore (IRB-2014-07-039, see Appendix A).

6.2.1 Stimulus Selection

To manipulate play mode, two different exergame conditions, single-player and multiple-player, were involved in Study Two. Nintendo Wii Tennis was chosen as the exergame for both conditions because of two reasons. First, the tennis game requires small to moderate body movements, which fulfils safety criteria for older adults. Second, the tennis game contains both single-player and multiple-player modes, which could ensure equal comparison between two conditions.

In the *single-player* mode condition, participants formed a group of around fifteen people and took turns playing the exergames. The team played against a virtual player individually. The total time for a group was three hours in one session. Figure 6.2 illustrates the single-player scenario in Wii Tennis. In the *multiple-player* mode condition, two participants formed a team and cooperated in the same game to play against two virtual players. Seven to eight pairs of participants performed the exergames in one session. To balance the performance time with the single-player condition, the total time for multiple-player condition was 1.5 hours for each session. Figure 6.3 illustrates a multiple-player scenario in Wii Tennis.

Participants from both conditions performed the corresponding exergame interventions once a week for six consecutive weeks.

Figure 6.2. Scenario of single-player mode Wii tennis.

Figure 6.3. Scenario of multiple-player mode Wii tennis.

6.2.2 Participants

Study Two had the same target population as Study One. Therefore, participants in Study Two had similar inclusive and exclusive criteria as that described in Chapter Five. Generally, older adults were included in the study if they were aged fifty-five and above and have a PHQ-9 score of 5–14 in the screening process. Given that the interventions were exergames, participants were expected to have little (less than eight hours of total experience) to no experience with the exergaming system. The participants should have no serious cognitive disorders, intellectual disability and physical limitations or have received antidepressant medications within the last three months.

Participants were recruited from two centres, namely, the Gek Poh Ville Community Club and Asian Women's Welfare Association. These centres are located in the western and northern parts of Singapore, respectively. Similar to Study One, participation in this study was voluntary, and informed consent (Appendix B) was obtained for all participants before the study. Each participant was awarded SGD\$15 equivalent of shopping voucher after having completed all sessions.

Figure 6.4. Flow chart of participants in Study Two.

Eighty-eight older adults were recruited and took part in the screening process. Based on the screening process, twenty older adults were excluded because they were identified to have non-depression (scored 0-4 in PHQ-9), while eight older adults were excluded because they have major depression (scored 15 and above in PHQ-9). Two participant were further excluded due to the poor physical (frailty) or cognitive conditions (dementia). At the end, fifty-eight participants met the inclusive criteria and were involved in the final study. The depression score of the included participants had a mean of 6.63 ($SD = 2.42$), and followed a normal distribution (Skewness = 1.03, $SE = .330$; Kurtosis = 0.19, $SE = .650$). In each centre, participants were randomly assigned into one of two experimental conditions. Six participants dropped out during the six-week intervention period due to absences in one or more sessions. Figure 6.4 illustrates the flow chart of the participants in Study Two.

6.2.3 Measures

Similar to measures of Study One presented in Chapter Five, the basic demographic information of participants was collected before the experiment, including their age, gender, education level, living conditions, and physical health conditions. The key variable, subthreshold depression, was also collected at both pre-study and post-study period. However, Study Two involved new measures that are different from Study One. The first empirical study (Chapter Five) investigated the effects between different exercise platforms (exergame and traditional exercise). Identified from the literature (Section 4.1), positive emotion and self-efficacy are the most important factors that lead to this platform effect on subthreshold depression. But for Study Two, play mode effect is more likely to be associated with social variables, i.e. social support and loneliness identified in the previous literature (Section 4.2). In order to have a deep understanding of how play mode affects subthreshold depression, new measures of social support and loneliness were conducted both before and after the intervention period.

Trained student assistants from the research team assisted participants who had literacy and visual problems in filling the questionnaires. Both English and Chinese versions of questionnaire were used in the study. A total of fifty participants used the Chinese versions while only two participants used English versions. Appendix D shows the detailed measurement instruments used in the pre- and post-study periods.

Subthreshold Depression. Similar to Study One, Study Two used the same depression scale, the Patient Health Questionnaire -9 (PHQ-9; Spitzer et

al., 1994) to measure depression. As described in Section 5.1.3, this tool is a widely used depression instrument with high validity and reliability (Huang et al., 2006; Kroenke et al., 2001; Martin et al., 2006). A higher PHQ-9 score reflects higher severity of depression. The Chinese version was adapted directly from the PHQ website (www.phqscreeners.com).

Social support. Social support was measured by the perceived social support subscale from Berlin Social-Support Scales (BSSS; Schulz & Schwarzer, 2003). BSSS was originally developed for cancer patients and their partners, but the scale is used across different clinical and healthy adult populations. The validity of the scale has been demonstrated in several studies (Schulz & Schwarzer, 2003, 2004). The BSSS subscale comprises eight items assessing emotional and instrumental aspects of social support. Participants indicate their agreement with the statements like ‘I know some people upon whom I can always rely’ on a four-point Likert scale. Higher add-up scores indicate higher levels of perceived social support. The Chinese version of BSSS was developed through back translations conducted by three Chinese doctoral students majored in communication studies.

Loneliness. The University of California Los Angeles (UCLA) Loneliness Scale (Russell, 1996) was applied to assess the degree of the loneliness of the participants in the present study. The scale is commonly used for measuring loneliness of respondents, including older adults. The scale also offers a more complete measurement of loneliness because it measures both emotional and social loneliness (Adams, Sanders, & Auth, 2004). Given that the initial 20-item scale is too long and too complex, Hays and DiMatteo (1987) developed a short form of UCLA Loneliness Scale (ULS-8). ULS-8 consists of

eight items selected according to the results of an exploratory factor analysis. The scale has high internal consistency and high correlation with the original scale and other related measures (Hays & DiMatteo, 1987). The ULS-8 was revised to suit elderly participants. The scale employs a four-point Likert scale with values ranging from 'never' to 'always'. The total score of ULS-8 ranges from 8 to 32. No cut-off score was identified to define loneliness, but a higher score on this scale indicates more intense feelings of loneliness. The Chinese version of the ULS-8 was developed for use in the present study based on previous works (Chou, Jun, & Chi, 2005; Zhou, Li, Hu, & Xiao, 2012).

6.2.4 Statistical Analysis

Path analysis was applied to test the conceptual model proposed for the influencing mechanism of play mode on depression. Path analysis is one of the most common techniques used in structural equation modelling (SEM). SEM is a family of statistical methods with a special aim to develop and test theoretical models. SEM evaluates the relationships between observed and latent variables (Hoyle, 1995). In path analysis, goodness-of-fit was first evaluated, followed by the estimation of path coefficients. Path coefficients, also known as standardised regression coefficients, determine the effects of exogenous (predictor) variables on endogenous (predicted) variables.

No strict and clear criteria are required in the sample size of SEM studies. Many researchers in the field recommend using more than 200 subjects (Kline, 2011; Tabachnick & Fidell, 2013). However, the decision of the sample size depends on model complexity and many other factors, such as normality of data or missing patterns. Several recent simulation studies recommended that

small sample sizes would be enough. For instance, Wolf and colleagues (2013) argued that sample size could be as low as 30 for a simple confirmatory factor analysis. Sideridis et al. (2014) found that a sample size of 50–70 would be enough for a model involving four latent variables. Given that no latent variables are involved in path analysis, the sample size requirement for path analysis may even be lower than common SEM analysis. Therefore, although the current study has a relatively small sample size, the number is still acceptable and reasonable for applying path analysis in testing the simple conceptual model that involves only four variables.

Different from common SEM in cross-sectional designs, the conceptual model in the current study involved a categorical exogenous variable (play mode). Bollen (1989) clarified that the inclusion of categorical exogenous variables did not violate the assumption of multivariate normality underlying the commonly used maximum likelihood method of estimation. MacCallum and Austin (2000) further indicated that one can use SEM to model the relationships of experimentally manipulated independent variables (such as dummy variables), to other variables, including covariates, mediators, and outcomes. All path analyses were conducted in Mplus version 6.0 (Muthén & Muthén, 1998-2011).

6.3 Results

6.3.1 Descriptive Statistics

Fifty-two participants completed both pre- and post-study measurements. Similar to Study One, the mean age of included participants was 72.12 (SD = 8.65), and 39 (75%) of them were female participants. Descriptive analysis was

conducted across the two conditions on demographic characteristics and key psychosocial variables at pre-study period. Table 6.1 further illustrates the detailed results. In terms of age groups, the two conditions have the same number of participants aged fifty-five to sixty-four and participants aged seventy-five years and above. Findings from t-and Chi-square tests indicated that participants from the two conditions did not have significant differences in demographic characteristics (except for mobility status), as well as physical and cognitive status. Furthermore, no significant group difference emerged during the pre-study period in depression ($t(50) = 0.56, p = .582$), social support ($t(50) = 1.24, p = .221$), and loneliness ($t(50) = 1.62, p = .111$). As a result, participants in single-player and multiple-player group can be considered as equal in demographic, physical, and psychosocial conditions.

Table 6.1

Descriptive Analysis across Two Conditions in Study Two (N = 52)

	Single-player (N = 27)	Multiple-player (N = 25)	Difference across conditions
Demographics			
Age*	70.78 (8.37)	73.56 (8.88)	$t(50) = -1.16, p = .250$
55 – 64 years	5 (18.5%)	5 (20.0%)	-
65 – 74 years	14 (51.9%)	11 (44.0%)	-
75 years and above	8 (29.6%)	9 (36.0%)	-
Gender (Female)	20 (74.1%)	19 (76.0%)	$\chi^2(1) = 0.03, p = 1.000$
Education (≤ Primary school)	19 (70.4%)	22 (88.0%)	$\chi^2(1) = 2.42, p = .177$
Living condition (Alone)	3 (11.1%)	8 (32.0%)	$\chi^2(1) = 3.40, p = .093$
Exercise frequency (≤ Once per week)	9 (33.3%)	14 (56.0%)	$\chi^2(1) = 2.70, p = .162$
Physical Health			
Eye sight*	2.37 (0.63)	2.52 (0.77)	$t(50) = -0.77, p = .445$
Hearing*	2.93 (1.14)	2.92 (0.86)	$t(50) = 0.02, p = .983$
Mobility status*	3.04 (1.09)	2.40 (0.76)	$t(50) = 2.42, p < .05$
Cognitive status*	3.11 (1.01)	2.64 (0.64)	$t(50) = 1.99, p = .052$

Note. *Data presented as Mean (Standard Deviation).

Table 6.2 and Table 6.3 indicates key psychological outcomes across two conditions at both pre-study and post-study period. Findings indicated significant bivariate correlations among subthreshold depression, social support and loneliness after the intervention period.

Table 6.2

Description of Depression, Social Support, and Loneliness at Pre-Study Period

(*N* = 52)

	1	2	3	Cronbach's Alpha α	Total	Single-player (<i>N</i> = 27)	Multiple-player (<i>N</i> = 25)
1. Depression (PHQ-9)	-			0.57	6.63 (2.42)	6.81 (2.35)	6.44 (2.52)
2. Social support (BSSS)	-.73**	-		0.87	39.48 (7.21)	40.67 (6.53)	38.20 (7.82)
3. Loneliness (ULS-8)	.26	-.09	-	0.64	13.31 (3.25)	14.00 (3.66)	12.56 (2.60)

Note. Data are presented as Mean (Standard Deviation).

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 6.3

Description of Depression, Social Support, and Loneliness at Post-Study Period

(*N* = 52)

	1	2	3	Cronbach's Alpha α	Total	Single-player (<i>N</i> = 27)	Multiple-player (<i>N</i> = 25)
1. Depression (PHQ-9)	-			0.70	2.73 (1.95)	3.22 (1.95)	2.20 (1.85)
2. Social support (BSSS)	-.41**	-		0.82	44.54 (5.11)	44.07 (5.19)	45.04 (5.09)
3. Loneliness (ULS-8)	.69**	-.34*	-	0.73	11.12 (2.49)	11.78 (2.26)	10.40 (2.57)

Note. Data are presented as Mean (Standard Deviation).

* $p < .05$, ** $p < .01$, *** $p < .001$.

6.3.2 Model Examination

In path analysis, goodness-of-fit was first assessed through multiple fit statistics, including Chi-square test, Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Standardised Root Mean Square Residual (SRMR). Chi-square test (χ^2) is the most basic fit statistic that compares the observed variance-covariance matrix to the predicted variance-covariance matrix (Bentler, 2004), theoretically ranges from 0 (perfect fit) to $+\infty$ (poor fit), considered satisfactory when it is non-significant ($p > .05$).

However, a significant value in the Chi-square test does not necessarily indicate a poor model fit because this test is very sensitive to sample size (Gerbing & Anderson, 1992). To reduce the effects of sample size, normed Chi-square (χ^2/df) was calculated. Schermelleh-Engel, Moosbrugger, & Müller (2003) stated that this ratio indicates good fit when it produces 2 or a smaller value while it indicates an acceptable value when it produces a value of 3. A value of normed Chi-square smaller than 3 indicated an acceptable fit. The RMSEA calculates the size of the standardized residual correlations, theoretically ranges from 0 (perfect fit) to 1 (poor fit), with a value less or equal to 0.05 considered as good fit and 0.05 – 0.08 as fair fit (Steiger & Lind, 1980). CFI assesses the extent to which the tested model is superior to the alternative model established with manifest covariance matrix is evaluated (Hu & Bentler, 1990). The CFI produces values between 0–1 and high values are the indicators of good fit. When CFI value is 0.97, it means that the fit in question is better compared to the independence model. An acceptable fit is in question provided that CFI value is larger than 0.95 (Schermelleh-Engel et al., 2003). SRMR is an index of the average of standardized residuals between the observed and the

hypothesized covariance matrices (Chen, 2007). It can be interpreted as the indicator of good fit when it produces a value lower than 0.05 (Hu & Bentler, 1990; Kline, 2011).

Since mobility status was found to be significantly different among participants across the two conditions, it was input into the path analysis model as a control variable. Results from the conceptual model demonstrated poor model fit. An inspection of the modification indices recommended the inclusion of the path from social support to loneliness. Based on the revision recommendation, the final revised model resulted in good fit to data. Table 6.4 shows the goodness-of-fit indices and model fit results.

Table 6.4

Goodness-of-Fit Indices and Model Fits

	χ^2	<i>df</i>	<i>p</i>	χ^2/df	CFI	RMSEA	SRMR
Recommended values	N/A	N/A	> .05	< 2.0	> 0.97	< 0.050	< 0.050
Initial model	7.563	2	0.0228	3.781	0.875	0.231	0.092
Final model (revised)	0.110	1	0.7403	0.110	1.000	< 0.001	0.006

Note. *df*, degree of freedom.

Estimations of path coefficient and hypotheses testing were conducted after determining the final model. Figure 6.5 shows the results of the path analysis in the final model. During the hypotheses testing, significant negative effects of exergame play mode were observed on loneliness among older adults ($\beta = -0.33$, $SE = 0.12$, $p = 0.009$), thereby supporting H5. However, H4 was not supported with no significant play mode effects on social support ($\beta = 0.05$, $SE = 0.14$, $p = 0.737$). Consequently, compared to single-player exergames, multiple-player exergames led to an increased reduction in loneliness among older adults, but not in social support. Strong and significant predictive effects

from loneliness were also observed on subthreshold depression among older adults ($\beta = 0.64$, $SE = 0.09$, $p < .001$). Subthreshold depression was not significantly affected by social support in the model, with $\beta = -0.18$, $SE = 0.10$, $p = 0.090$. Thus, H7 was supported but H6 was not.

Figure 6.5. Results of path analysis in the final model. Path coefficients are standardised. The solid line indicates a significant path with * $p < .05$, ** $p < .01$, *** $p < .001$. The dashed line indicates non-significant path with $p > .05$.

The results from the model examination suggested that play mode in exergames influenced subthreshold depression via mediation of loneliness. Nevertheless, the mediation role of social support was not supported in the relationship between play mode and subthreshold depression. Lastly, an additional significant path was identified from social support to loneliness ($\beta = -0.35$, $SE = 0.12$, $p = .003$). This result highlighted the potential effects of social support on loneliness during exergame playing.

A significant large R^2 of 0.52 ($p < .001$) in subthreshold depression was reported during the post-study period. This result demonstrated that 52% of the unique variance of subthreshold depression was explained by independent and

mediating variables mentioned above. Generally, the findings from path analysis support the final model in which three out of the five path coefficients are statistically significant.

6.4 Discussion

Over the past few decades, play mode has become an important research theme for game studies. The current study extended the discussion of play mode from in-game experience to mental health improvements. The study also introduced this important theme into the new domain of exergames for health. The study investigated the possible effects of play mode (single-player versus multiple-player) on subthreshold depression among older adults through a between-group controlled study. More importantly, the research serves as a pilot study to examine the factors that mediate anti-depressive effects of play mode in exergames. Overall, the proposed mediation model was generally supported by the path analysis conducted in the study. Good model fit and high R^2 of dependent variable further confirmed the robustness of the final model.

In this model, play mode was revealed to have indirect effects on subthreshold depression among older adults, which was mediated by loneliness. Accordingly, older adults who performed multiple-player exergames experienced lower levels of loneliness, and further have more improvement on subthreshold depression, when compared to participants who performed single-player exergames. The significant mediation link found in the study has further deepened the research domain of exergames and literature concerning psychosocial benefits. Several previous studies have indicated that exergames led to less loneliness and depression (Kahlbaugh et al., 2011; Rosenberg et al.,

2010). The current study extended the findings by emphasising the possible influencing role of play mode, that is, multiple-player exergames have better effects over single-player ones on alleviating loneliness and subthreshold depression.

By allowing different players to interact in a team, multiple-player exergames could foster both virtual and real social interactions among players, thereby reducing the risk of social isolation and loneliness (Mueller, Agamanolis, & Picard, 2003; Staiano & Calvert, 2011). In a narrative review, Brox et al. (2011) further highlighted the importance of using multiple-player exergames among older adults. They believed that multiple-player exergames increased social interaction between older adults, reduced their social isolation and prevented loneliness and subthreshold depression. Study Two provided important evidence to support the assumption from previous research, and confirmed the strong effects of play mode on loneliness and subthreshold depression among older adults.

However, the mediating role of social support was not supported in the study, which differed from expectation given. Social support was not significantly affected by the play mode. Although multiple-player exergames increased social interaction among players (Mueller et al., 2003; Staiano & Calvert, 2011), in Study Two they did not lead to higher social support than those in single-player mode. Social support refers to various types of support (i.e., assistance/help) that people receive from others. Social support generally consists of two major categories, namely emotional and instrumental support (Langford, Bowsher, Maloney, & Lillis, 1997; Wills, 1985). In the context of exergaming, different play modes are unlikely to affect instrumental support. In

other words, multiple-player mode simply cannot provide better tangible support or real assistance in daily life over the single-player mode. The increased social bonding and communication in multiple-player exergaming context may not guarantee the rise in emotional support in real life within only six weeks. As a result, the findings from the current study call for further investigation and understanding of the ‘unclear’ association between social support and virtual gaming factors.

Nevertheless, the final model supported the effects of social support on loneliness in exergames. It showed that social support might have indirect effects via loneliness. Despite social support not being affected by play mode, its variances, which were probably affected by other external factors, assumed a significant role in the effects of play mode on subthreshold depression. These findings imply that social support may act as a moderator in the relationship between play mode and subthreshold depression. Future studies are needed to examine this assumption.

Lastly, the proposed model in this study only involved two possible mediators. This condition was not sufficient to draw a more complete picture on the effects of play mode on subthreshold depression among older adults. Future research may explore more related variables to understand the complicated and intertwined associations within the influencing factors.

6.5 Summary

While the meta-analysis (Chapter Three) and Study One (Chapter Five) confirmed the effects of exergames on subthreshold depression, Study Two took a further step to explore play mode, which is an important factor in

exergaming that may affect the anti-depressive effects for older adults. Study Two compared the results of single-player and multiple-player exergames of fifty-two Singaporean older adults with subthreshold depression. The findings suggested that multiple-player exergames could reduce subthreshold depression by affecting loneliness (supporting H5 and H7). Although social support was not found to be a significant mediator of play mode (not supporting H4), it may affect subthreshold depression as a moderator (supporting H6).

In summary, the model examination in Study Two presented a novel understanding of the effects and mechanism of play mode on subthreshold depression. Play mode is an important research theme for game studies. While previous studies only investigated the play mode effects in motivation and game performance (Chen et al., 2015; Peng & Hsieh, 2012; Wu et al., 2015), Study Two extended the discussion to mental health improvements in the context of exergames. Study Two also provided additional insights into a possible causal association linking play mode and subthreshold depression, as well as opened up the discussion on optimising the anti-depressive effects of exergames for older adults.

CHAPTER SEVEN

DISCUSSION AND CONCLUSIONS

This chapter provides the general discussion that combines all studies conducted in this research. The current research aimed to examine the effects of using a simple and convenient intervention, exergames, to address subthreshold depression among older adults. The involved systematic review and empirical studies had covered relevant research topics from the examination of the effects of exergames to possible influencing factors. The summary of the thesis and main conclusions are highlighted in this chapter. The theoretical and practical implications of the thesis are described further by highlighting the initial contributions to the new field of exergames for mental health.

7.1 General Discussion

Population ageing is one of greatest challenges in current society. As we enter the 21st century, global ageing will put increased social and economic demands on all countries. Besides physical health, maintaining psychosocial well-being among the ageing population becomes an important topic for health professionals and researchers.

Subthreshold depression, although not often highlighted in gerontology, is a highly prevalent mental disorder among older adults that causes negative outcomes similar to major depression (Wagner et al., 2000). Compared to major depression, few geriatric studies have focused on the interventions of subthreshold depression (Oxman & Sengupta, 2002). In a meta-analysis

(Cuijpers, Smit, & van Straten, 2007) that targets psychological treatments for subthreshold depression, only seven RCTs were identified from 1966 to 2006. Among them, only two studies examined the treatment effects on older adults (Haringsma, Engels, Cuijpers, & Spinhoven, 2006; Mossey et al., 1996). Realising the limited scope of previous studies, this research has a particular aim of extending the literature on suitable interventions for late-life subthreshold depression.

The present thesis targeted on the context of older adults with subthreshold depression, and described three studies concerning the usage of exergames as treatment interventions for this particular ageing group. Before focusing on older adult participants, the existing studies of exergame and depression were reviewed and analysed in a systematic review and meta-analysis. Despite the effectiveness varied in ten included studies, an overall positive effect of exergames was found on alleviating depression. Particularly, exergames were supported to be particularly effective on those who are older adults, with depression symptoms, and having social interaction with other partners. The findings implied the need to conduct empirical studies to determine effects between exergames and traditional exercise among older adults with depression, and explore the effect of player interaction on the depression in the exergame setting.

A between-group study (Study One) was first conducted on fifty Singaporean older, to examine the effects between exergames and traditional exercise on subthreshold depression. The results demonstrated that older adults in exergame group had better improvements of subthreshold depression and higher level of positive affect than those in traditional exercise over a six-week

intervention period. To further explore the player interaction effect of exergames on subthreshold depression, a second empirical study (Study Two) compared the results of single-player and multiple-player exergames of fifty-two Singaporean older adults with subthreshold depression. The findings suggested that multiple-player exergames could lead to more improvement on subthreshold depression via reducing loneliness, when comparing to single-player exergames. The results from these two studies provided important practical implications in the promotion of healthy and active ageing by using emerging exergame technologies. They also contributed to the theoretical development in research field of exergames for mental health. Both the practical and theoretical implications are elaborated in the following sections.

7.1.1 Applying Exergames in Later Life

Although not initially designed for ageing population, the application of exergames have been investigated in the healthcare domain for older adults (Chao et al., 2015b; Uzor & Baillie, 2014; Yu & Kim, 2015). An old person tends to become less active in daily activities. Studies with objective measurements have found that 67% of older adults were sedentary for at least 8.5 hours a day (Harvey, Chastin, & Skelton, 2013). Older adults were often reported to have low adherence in exercise and physical activity (Cameron et al., 2012; Phillips, Schneider, & Mercer, 2004). The situation becomes even worse with increasing age, and the problem has not improved in decades despite multiple public health efforts. One important contributing factor to poor participation of exercise in older adults may be the repetitive nature of many traditional exercise programmes, which are often perceived as boring and not motivating (Studenski et al., 2010). By combining exercise with video gaming,

exergames were found to increase exercise enjoyment and motivation among users, including older adults (Uzor & Baillie, 2014; Yu & Kim, 2015).

Exergames have the potential to lead to a healthier lifestyle in late life.

Although this research field is still small and developing, previous exergames studies have indicated both physiological and psychosocial benefits for older adults (Chao et al., 2015b; Verheijden Klompstra, Jaarsma, & Strömberg, 2014). Particularly, the anti-depressive effect have been drew a lot of recent attentions (Meldrum et al., 2015; Mhatre et al., 2013; Rendon et al., 2012). Findings from the systematic review and meta-analysis (Chapter Three) have indicated an increasing research interest in the recent years on studying the potential impact of exergames on depression among older adults, with six out of eleven identified studies targeting on ageing population. In the study of Chao et al. (2017), for instance, tested the efficacy of an exergaming program among twelve older female African American. There was a reduce of depression (GDS mean score from 3.50 to 2.75) over fourteen weeks, although it was not statistically significant ($p = .135$). Rendon et al. (2012) applied a 6-week randomised controlled trial to test the effect of Nintendo Wii Fit balance exergames among forty older participants. Depression was reduced in exergame condition, with a GDS median score changing from 6.50 (pre-study period) to 4.00 (post-study period). Similarly to these previous studies, Study One also indicated a reduction of depression (PHQ-9 mean score from 6.88 to 2.88) among Singaporean older adults who performed Nintendo Wii exergames for 6 weeks. The findings have supported the positive anti-depressive effect of exergames on ageing population with subthreshold depression. They implied that exergame platform might be a potentially effective alternative to facilitate

depression therapy for use in older adults who suffer from mild depressive symptoms.

Meanwhile, results from Study One also suggested an increase of positive affect (PANAS score from 26.72 to 42.64) and self-efficacy (GSE score from 14.60 to 18.84) on older adults in exergame condition. Study Two reported improvements on social support and loneliness in both two exergame conditions (single-player and multiple-player mode) among older adults. The findings were consistent with previous exergaming studies on older adults, which indicated the positive impacts on loneliness and mood (Kahlbaugh et al., 2011; Wollersheim et al., 2010) as well as positive affect and self-esteem (Jung et al., 2009). Putting all the evidences together, the psychosocial benefits would become an important aspect of introducing and applying exergaming to older adults.

7.1.2 Comparing Exergames and Traditional Exercise

Although initially designed for entertainment, exergames now are increasingly used in healthcare research and practice. They are often implemented in communities and even rehabilitation settings to promote healthy lifestyle. By adopting video games into physical exercise, exergames were found to be an attractive alternative to increase motivation for traditional exercises (Chao et al., 2015b; Sun, 2013). Compared to traditional exercise, exergames may help older adults become more active, enjoy exercise and stay that way. Study from Robinson et al. (2015) found that Wii Fit exergames were comparable to traditional balance training in terms of physical improvements (bipedal postural sway and grip). They suggested the use of exergames as an effective means of

balance and gait training for people with multiple sclerosis. In a three-month study on 102 older adults in retirement community (Anderson-Hanley et al., 2012), the findings further showed that cybercycling exergame yielded a medium effect on cognitive functions over traditional exercise ($d = 0.50$).

While many studies highlighted the effects on physical and cognitive functions, several recent studies compared the anti-depressive effects of exergames and traditional exercise programmes (Meldrum et al., 2015; Yu & Kim, 2015). Nevertheless, these studies compared exergames to traditional exercise with different exercise nature. For example, Yu & Kim (2015) tested the effects on depression between Xbox Kinect Adventures (e.g., River Rush and Rally Ball games) and Qi-Gong. Their findings cannot distinguish the platform effect from exercise nature effect. To reduce the confounding effect of exercise nature, Study One in current thesis compared the anti-depressive effects between exergames and their ‘simulated’ traditional exercise (with similar exercise nature) in centre-based context. The results supported exergames to be more effective in reducing subthreshold depression and increasing positive affect among Singaporean older adults, when compared to simulated traditional exercise. Meanwhile, although limited by its short duration, the significant Platform $\times$ Time interaction effects in Study One further implied that there may be more improvement of subthreshold depression if older adults play exergames for a longer time. The better simulated exercise experience in exergames might account for their superior effects on positive affect and subthreshold depression. By using video game technology, exergame condition in Study One might create a better simulated exercise environment than traditional exercise condition in an indoor environment (e.g., providing a

virtual ball alley, lighting and score board). These findings together supported exergame to be an effective alternative to traditional exercise in community settings.

However, it is important to note that Study One did not compare the effects of exergames to their ‘real-world’ counterparts. It only compared exergames with simplified ones in centre-based which were designed to meet the physical limitations and safety requirements of older population. For example, Wii Bowling exergame was compared with simulated indoor bowling (but not real bowling on a bowling alley), because it is difficulty for an older person to hold a heavy bowling ball. Given this special condition, the superior effects of exergames in Study One only limited to the comparison with simulated traditional exercise (e.g. indoor bowling game), but not the authentic counterparts in traditional settings (e.g. real bowling game).

Although the findings of Study One did not suggest to replace all traditional exercise with exergames, it would be wise for health professionals and policy makers to pay more attention on psychosocial benefits of exergames, and include this new game technology in the healthcare programmes for older adults. Traditional exercise are widely implemented in the current elderly healthcare programmes. However, these traditional exercise programs are often considered tedious and boring. Older adults were reported to have low motivation and exercise adherence in these exercise programmes (Cameron et al., 2012; Phillips et al., 2004). Healthcare providers, such as centre manager and nursing staff, are encouraged to apply new strategy and use exergames as an alternative activities in healthcare programme to increase the motivation and

exercise adherence among older adults. This programme could reduce subthreshold depression and maintain overall psychosocial well-being.

7.1.3 Encouraging Multiple-Player in Exergames

The research took a further step to investigate the potential influencing factors that may optimise the effects of exergames on subthreshold depression among Singaporean older adults. Study Two compared the effects of single-player and multiple-player exergames, and supported that play mode was important in affecting the anti-depressive effects of exergames. Specifically, findings demonstrated that multiple-player exergames promoted better improvements on subthreshold depression and loneliness among older adults, when compared to single-player exergames.

Older adults often experience social isolation because of age-related changes, such as physical disability or reduction of social relationships (Dean, Kolody, Wood, & Matt, 1992). The lack of social interactions becomes a key cause for subthreshold depression in late life. Study Two supported the view that collaborative multiple-player in exergames reduced loneliness and further subthreshold depression among older adults. Several recent studies in exergaming have highlighted the need to encourage multiple-player pattern for older adults (Brox et al., 2011; Planinc et al., 2013). Harley et al. (2010) indicated that communication and social interactions increased within game events and spread into the daily living of older adults. For example, playing experience becomes a topic of conversation with their family members or friends. Schutter and Abee (2008) conducted a participatory design study among ten Flemish senior citizens, and their findings suggested that older

adults preferred multiple-player games when they were involved in the design process of digital games. The increased social interaction from multiple-player made older adults feel connected to society (Schutter & Abeelee, 2008).

Evidence from previous studies and current research emphasises the importance of designing multiple-player exergames for older adults in healthcare practice.

To maximise psychosocial effects, exergames should be designed with a preference of multiple-player mode for older players, and involve more elements to increase social interactions and support.

It is worthwhile to discuss further on the two sub-modes in multiple-player exergames, collaborative and competitive mode. Considering negative emotions (fear and anxiety of losing) that may be elicited by competitive exergames (Wu, 2012), Study Two only used collaborative mode in multiple-player condition for older adults with subthreshold-depression. Therefore, the results may be limited to the conclusion that collaborative multiple-player exergames have better anti-depressive effects than single-player exergames.

However, gaming literature has discussed the psychosocial effects between the two multiple-player modes (Kort & Ijsselstein, 2008; Peng & Hsieh, 2012;

Wu, 2012). Differing from competitive mode, the shared objective in collaborative games may promote more communication and interaction among players. Nevertheless, the conclusion here does not imply that competitive elements should be totally avoided in exergames with mental health purpose.

Malhotra (2010) emphasised that competition promotes high motivation and performance in games. Consequently, the ideal situation is to design exergames that use competition to improve collaborative skills. Taking account of

therapeutic purpose, competitive elements should be set carefully to avoid aggravating depression or other negative emotions.

7.1.4 Expanding Theoretical Research in Exergaming Domain

The current thesis have made several contributions to expanding the theoretical research in exergaming field, particularly in the new domain of exergames for depression.

Firstly, Subgroup analysis results in meta-analysis have added valuable perspectives in exergaming literature by identifying potential moderators for the effects on depression. Various factors such as age, gender, culture, physical mobility, number of sessions, depression severity, and player interaction were found to moderate the effects of exergames on depression. For example, exergames were supported to be more effective on those who are older adults, female, from non-Caucasian culture, with depression symptoms and good physical mobility, and having social interaction with other partners. Since depression is a very new research topic in the exergaming research, identifying these potential moderators may contribute to the theoretical understanding of this topic, and inspired research trends for future studies in related fields.

Secondly, the examination of play mode effects in Study Two has particularly provided important theoretical implications in exergaming research. Most of the game studies examined the effects of play mode in the behaviours and perceptions, such as motivation, gaming performance and experience (Chen et al., 2015; Peng & Hsieh, 2012; Smyth, 2007). And none of these studies were tested in exergaming context. Only one study (O'Donovan et al., 2012) explored the play mode effects on physical conditions during exergaming

playing. The current thesis extended and tested its possible link to mental health improvements. Findings from Study Two by showing that multiple-player exergames have better effects over single-player ones on alleviating loneliness and subthreshold depression. The result inspires the theoretical discussion of play mode factor in future studies under a broader domain of exergames for mental health. People in late life also suffer from other mental disorders that have similar signs and symptoms to depression, such as anxiety and dementia (Jorm, 2000; Klerman, 2013). It would be worthwhile to investigate whether play mode have similar effects on these mental disorders, and whether the influences follow the same mechanism suggested in Study Two.

Thirdly, the thesis has reviewed and adopted relevant theories from other fields to build the theoretical framework for the effects of platform and play mode. In the highly application-focused domain of exergaming, many hypotheses and studies were established based on previous empirical conclusions. Few studies have paid attention to the theoretical concepts and links. The introduction and adoption of theories such as *Theory of Flow* and *Social Cognitive Theory* have not only strengthened the rationale for hypotheses used in the two empirical studies, but also provided useful knowledge and theoretical underpinnings for future exergame studies focusing on psychosocial well-beings. For instance, the *Theory of Flow* (Csikszentmihalyi, 1990) was adopted in Study One to explain the theoretical links between exercise platform and positive affect. Findings in the study have supported that older adults achieved higher positive affect in playing exergame rather than traditional exercise. The high level of positive affect were likely caused by the high level of ‘flow’ older adults experienced in exergames. This

cognitive stimulation was similar to the young population reported in previous studies (Barry et al., 2016; Vaghetti, Duarte, Ribeiro, & Botelho, 2012).

Nevertheless, *Theory of Flow* also suggested several essential components of flow (Csikszentmihalyi, 1993), such as focused concentration and sense of potential control, which were not measured in Study One. Future exergaming studies need to test this theory among older adults with a completed measure of flow.

Lastly, the two empirical studies were undertaken in the context of Singapore, their results may inspire similar research in other Asian countries and regions who have similar cultural background, such as China, Hong Kong, Taiwan, South Korea, and Japan. These countries and regions are all experiencing rapid population ageing (Joseph & Phillips, 1999; Tamiya et al.; Woo, Kwok, Sze, & Yuan, 2002) and high prevalence of geriatric depression (Wada et al., 2004; Woo et al., 1994). Despite the facts, only two studies in systematic review (Chapter Three) examined the anti-depressive effects of exergames on Asian older adults (Shin et al., 2015; Yu & Kim, 2015). This situation reflects the inadequacy in studies on the novel depression intervention for older adults in Asia. The current research may encourage more Asian-focused studies in the domain of novel depression interventions, particularly in exergames for depression.

7.2 Limitations of Research

This research has several limitations that should be noted. These limitations also lead to several future directions that worth further investigation.

Systematic review and meta-analysis. The limited number of identified studies and moderate heterogeneity may suggest cautious interpretation of key conclusions. Because the use of terms varies greatly in the exergame and depression area, the key word search in the review might limit the complete inclusion of all existing studies. Furthermore, a publication bias, particularly language bias, might have occurred because we restricted the search to English language publications. However, the searching limitation was tried to be addressed by screening the reference list of reviews and relevant articles.

Profile of participants. Both two empirical studies have unbalanced gender distribution, in which more female participants were involved. It might be caused by the fact that female are often more active than male in participating in social science research projects. The gender bias was reported in previous exergaming studies reviewed in systematic review (Chapter Three), in which seven out of eleven trials were female-dominant (female participants took up more than 60% of the whole participants). This phenomenon was also highlighted in many other digital intervention studies involving older adults (Kelley, Morrell, Park, & Mayhorn, 1999; Lee, Yip, Yu, & Man, 2013; McMurchie, Macleod, Power, Laidlaw, & Prentice, 2013). Nevertheless, Except for the gender distribution, the ratios of ethnicity, education level and living conditions approximate those released by a government report on elderly status in 2009 (Ministry of Social and Family Development, 2009). It is still reasonable to consider the sample of two studies to be representative of ageing population in Singapore. Furthermore, participation in both empirical studies was voluntary and thus, the assumption is that most of the included participants have a relatively high motivation to perform exercise or exergames. Further

studies should involve a large sample of participants with balanced exercise motivation and related attitudes (for instance, including those who are inactive and stay at home most of the time). Meanwhile, the thesis only tested the effects of exergames on participants with relatively healthy physical conditions. A scoping review (Verheijden Klompstra et al., 2014) indicated that exergame platforms appear to be safe and feasible for older adults with heart failure, including stroke patients. None of the involved studies reported adverse events for this group of patients. Their results call for more explorations on the anti-depressive effects of exergames for older adults who have certain physical disorders, but can still use exergames.

Interventions. In Study One, exergames were compared to simulated traditional exercise in a centre-based setting, but not authentic counterparts in real world. The simplified features and ‘fake’ environment of the simulated traditional exercise might limit the effects on positive affect and subthreshold depression. Therefore the superior effects of exergames on psychosocial well-being were not confirmed over authentic traditional exercise. More studies need to be conducted before applying the conclusions into the real context. What’s more, the key conclusions in Study One were also drawn based on the comparisons of limited types of exergames and traditional exercises. Although these interventions were selected according to the special requirements of older adults, the results were not applicable to all other exergames and traditional exercises. Therefore, the conclusions should be examined in future studies with diverse exergames and traditional exercises. Study Two has the same limitation of interventions. Only Wii Tennis was found to be suitable for use in both single-player and multiple-player conditions because of the lack of available

exergames in the current market. The intervention limitation in exergames highlighted the need to design specific exergames for older adults with subthreshold depression. There were some pilot studies conducted recently to explore the long-term use of tailored exergames for older adults. Uzor & Baillie (2014) applied exergames designed in close collaboration with elderly users in UK via a twelve-week study for falls rehabilitation in the home. Alankus et al. (2010) designed and user tested stroke rehabilitation games with both stroke patients and therapists in the United States. Findings from these pilot studies have important implications for the design of future exergames that used as long-term therapy for older adults with subthreshold depression. However, the lessons learned from these studies were based on Western population. The variances in socio-cultural background would result in different perceptions and needs towards digital technologies between Western and Asian older adults. As a result, future work might consider developing appropriate exergames for long term use among Asian older adults. The key conclusions from Study One and Study Two should be also confirmed in future studies involving specific exergames designed for Asian older adults.

Study Design. Given the limitations in manpower and time for doctoral research, the two empirical studies were conducted with a small sample size over a short intervention time. The small sample size may lead to weak statistical power, which limited generalisability of the findings. Meanwhile, the two empirical study did not involve a control group (treat-as-usual) due to the difficulties in recruitment and administration of this particular population. With poor physical conditions and mobility, older adults were found to be generally less active in participating activities (including research projects), and had less

commitment in performing interventions regularly. Nevertheless, a more elaborated experimental design with a control group should be used in future to test and control the sensitization effect in the repeated measurements. The six-week intervention time may not be able to detect the effects of exergames as a long-term health intervention. There might be a threshold for duration, beyond which, older adults may get sick of it with negative outcomes. Study Two includes several different measurements from Study One because it was testing different mechanism. Nevertheless, it will be worthwhile to include both positive emotions and self-efficacy in the future play mode study that investigates play mode effect. It may provide additional meaningful findings on whether and how these two variables will be affected by play mode. Moreover, the measurements of self-efficacy and social support might be too general to target on the exercise contexts in the two studies. This could be another possible reason for the non-significant effects of these two variables. Future studies may consider to use exercise-specific measurements for these two concepts. Lastly, although the comparison conditions in the two studies were under similar organisations, participants across different centres may still have different activity programmes (like watching TV and performing other social events). The failure to control these external activities may affect the results.

Overall, the limitations of the current research suggest more robust and comprehensive future research on this new field of using exergames as a form of intervention for depression.

7.3 Future Directions

However, the findings of the thesis also implied several future directions in the research field of exergames and depression. Gender is one of the critical issues. The meta-analysis in Chapter Three pointed out that females achieved better improvement on depression when playing exergames. In both empirical studies, there are more female participants involved than males. It is possible to assume that the female may contribute more on the positive effects of exergames on subthreshold depression. Males and females are often found to have different experiences and preferences in gaming studies (Graves et al., 2007; Sun, 2013). Future relevant studies will help in understanding the effects of gender on anti-depressive effects, thereby creating knowledge for better adoption of this intervention for different genders.

Age may become another issue that requires further exploration. The two empirical studies in Chapter Five and Chapter Six included older adult participants (aged 65 and above) and pre-older adult participants (aged 55 to 64), to get insights into the needs of future older adults. Nevertheless, due to the small sample size, the effects of exergame on different age groups were not examined in the current thesis. Recent geriatric studies have assessed age-related differences between pre-older adults and older adults (Beni et al., 2013; Zavagnin, Borella, & De Beni, 2014). The differences may lead to variations in the levels of social connection and interaction (Carstensen, 1993; Field & Minkler, 1988; Palmore, 1981) which may further affect the way that exergames influence their depression and even psychosocial well-being. More studies should be conducted to test the age differences in the effects of exergames on depression.

Following the discussion of multiple-player mode in exergames, it may be interesting in the future study to further explore who to play with. In Study Two, participants in multiple-player condition played exergames with their peers. Some exergaming studies indicated that exergames could bridge the gap between old and young people and foster communication between these two age groups (Chua, Jung, Lwin, & Theng, 2013; Theng et al., 2012). However, previous literature also indicated that many older adults feel patronised or even prejudiced by ageist bias when they communicate with the youth (Giles & Gasiorek, 2010; Giles, Ryan, & Anas, 2008). Such bias may increase social anxiousness and depression among older adults if they play exergames with youths. Taken together, the effects of playing with the youth or other age groups on the change in the depression state of older adults were not a priori obvious in the exergame domain, and thus needs to be addressed in the future research.

The importance of cultural effect should be also emphasised when studying exergames. The cultural context in which we live affects many aspects of our life. It has an important impact on the development and treatment of depression (Kleinman, 2004; Patel, 2001). As a result, the discussion of potential cultural effect should be extended to the field of exergaming studies on depression. For instance, interdependence on family is an integral part of the Confucian philosophy embedded in the Asian culture, particularly in Chinese culture (Marcella, DeVos, & Hsu, 1985). While Chinese older adults are more likely to rely on social support gained from family (spouses or children and/or grandchildren) to reduce depression (Chi & Chou, 2001), support from friends were reported to be main influential factor in Western elderly samples (Dean,

Kolody, & Wood, 1990). The cultural nuance may lead to different strategies in the implements of multiple-players exergames as a depression interventions for older adults with Asian and Western cultures. Future studies need to further test the assumptions with a particular focus on cultural effect.

7.4 Closing Remarks

The rapid expansion of ageing population has cause wide public concerns for their psychosocial well-being, particularly on the issue of subthreshold depression. Finding suitable and effective treatments for older adults has become an important research topic for both academic and political professionals. The current research contributes to the understanding of using emerging technologies to address this concern. It examined the effects of a simple yet convenient intervention, exergames, on subthreshold depression among Singaporean older adults. In the preliminary work, a systematic review was conducted to identify the overall anti-depressive effect of exergames from existing literature. Based on findings and implications from the review, two main empirical studies were conducted in the centre-based setting. Study One compared the differences between the anti-depressive effects of exergames and traditional exercise, while Study Two investigated whether play mode affected subthreshold depression among older adults. The results from these studies provide important knowledge for addressing depression problems in this special group of people.

Although exploring the novel domain of exergames for subthreshold depression among older adults, the research highlighted some theoretical and practical implications applicable for mental health research and game design.

Future studies are necessary to move further into obtaining a more complete and clearer picture of exergames and subthreshold depression. They could test the effects of other influencing factors (such as gender effects, age cohorts difference, and the people to play with) within different socio-cultural contexts (such as other Asian countries).

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APPENDICES

Appendix A

IRB Approval for Empirical Studies

Research Support Office

Reg. No. 200604393R

IRB-2014-07-039

25 November 2014

Professor Theng Yin Leng
Wee Kim Wee School of Communication and Information

NTU INSTITUTIONAL REVIEW BOARD APPROVAL

Project Title: Examining the Impact of Game Interventions on Depression Among Older Adults
(Amount Pending: SGD\$8,000; to be funded by NTU SUG)

I refer to your application for ethics approval with respect to the above project.

The Board has deliberated on your application and noted from your application that your research involves collecting behavioral data from participants through gaming.

You have also confirmed that informed consent will be obtained from the participants and you have guaranteed the confidentiality of your participants' biodata obtained from them.

The documents reviewed are:

- a) NTU IRB application form dated **31 July 2014**
- b) Participant information sheet and consent form: version 1 dated **31 July 2014**
- c) Data collection form: version 1 dated **31 July 2014**

The Board is therefore satisfied with the bioethical consideration for the project and approves the ethics application under **Expedited** review. The approval period is from **25 November 2014 to 30 April 2016**. The NTU IRB reference number for this study is **IRB-2014-07-039**. Please use this reference number for all future correspondence.

The following protocol and compliances are to be observed upon NTU IRB approval

1. All research involving procedures greater than minimal risk on minors (individuals who are less than the legal age of 21 years old) requires IRB approved written Parental Consent and assent from the participant to be obtained before any research protocols can be administered. Minimal risk refers to an anticipated level of harm and discomfort that is no greater than that ordinarily encountered in daily life, or during the performance of routine educational, physical, or psychological examination.
2. Only the approved Participants Information Sheet and Consent Form should be used. It must be signed by each subject prior to initiation of any protocol procedures. In addition, each subject should be given a copy of the signed consent form.

Research Support Office

3. Consent forms are important documents therefore they should be stored in the strictest arrangement. Loss of consent form would result in disciplinary action.
4. No deviation from, or changes of, the protocol should be initiated without prior written NTU IRB approval of an appropriate amendment.
5. The Principal Investigator should report promptly to NTU IRB regarding:
 - a. Deviation from, or changes to the protocol.
 - b. Changes increasing the risk to the subjects and/or affecting significantly the conduct of the trial
 - c. All serious adverse events (SAEs) which are both serious and unexpected.
 - d. New information that may affect adversely the safety of the subjects of the conduct of the trial.
 - e. Completion of the study.
6. Continuing Review Request/ Notice of Study completion form should be submitted to NTU IRB for the following:
 - a. Annual review: Status of the study should be reported to the NTU IRB at least annually using the Continuing Review Request/ Notice of Study completion form.
 - b. Study completion or termination: Continuing Review Request/ Notice of Study completion form is to be submitted within 4 to 6 weeks of study completion or termination.

A handwritten signature in black ink, appearing to read "Lee Sing Kong", is positioned above the printed name.

Professor Lee Sing Kong,
Chair, NTU Institutional Review Board
encl.

cc Chair, Wee Kim Wee School of Communication and Information
 Members, NTU Institutional Review Board

Appendix B

Participant Information Sheet and Consent Form for Empirical Studies

Participant Information Sheet

Please read this carefully before you participate in the study

Dear Participant,

You are invited to participate in a research which aims to examine the effects of exercise on older adults' mental well-being. This study is part of the research undertaken by Li Jinhui, PhD candidate, in the Wee Kim Wee School of Communication & Information (WKWSCI), NTU, Singapore. The Principal Investigator for this project is Dr. Theng Yin Leng from the Division of Information Studies, School of Communication & Information, Nanyang Technological University.

What you will do in this study:

You will be randomly assigned into one of several conditions. These conditions may involve different types of exercise activities. You will be asked to form a small group and perform the activity assigned to you for one to three hours per session, one session per week, for 6 weeks. You will be given a paper questionnaire at the start and end points of the study.

Risks:

The activity you will perform does not have severe anticipated risks. During activity session you can expect to sweat, become fatigued and experience mild to moderate muscular discomfort may occur as a result of exercise. If you become tired during any point of the session, please stop playing the activity and rest for as long as you need. The risk of injury when playing the activity is minimal and not greater than those that may occur in daily life. We will also have the professional staff from your center to accompany with you during the whole session.

Compensation:

You will receive a total of **S\$15** voucher upon completion of all the sessions (including the questionnaires).

Voluntary Withdrawal:

Your participation in this study is completely voluntary, and you may withdraw from the study at any time without penalty.

Confidentiality:

Your personal identifiers, such as your name and NRIC will be collected, according to the university's policy of reimbursement. However, to protect your confidentiality, this information will not be presented to a third party, including future publications. Photographs may be taken during the study for documentation, but we will not publish photographs containing your face if you disapprove. Finally, your survey response will be used for research purposes only.

Further Information:

If you have questions about the study or your rights as a participant in this study, please contact Dr. Theng Yin-Leng, Division of Information Studies, Wee Kim Wee School of Communication & Information, Nanyang Technological University, Email: TYLTHENG@ntu.edu.sg

If you have any concerns about this study or your experience as a participant, you may contact the Institutional Review Board (IRB) at NTU at 65-65922495 (collect calls will be accepted if you state you are a study participant); email: irb@ntu.edu.sg

参与者信息表

请在参与研究前仔细阅读本文

尊敬的参与者，

您被邀请参加一项研究，其目的是研究运动对新加坡老年人精神心理的影响。本研究是南洋理工大学黄金辉信息与传播学院的博士研究生李锦辉的博士论文中的一部分。研究项目的主负责人是南洋理工大学信息学系的邓燕玲博士。

在本研究里你需要做什么？

您将被随机分配到某个研究情景下。这些研究情景可能涉及不同类型的锻炼活动。您会被要求和几个你的同伴组成一个小组，每周执行一次分配给您的活动，每次大约 1 至 3 小时，为期 6 周。在研究开始和结束的时候您被要求完成一份问卷调。

参加研究的风险

要求您完成的锻炼活动基本不会导致严重的身体伤害。在活动过程中，你可能会出汗，感到疲惫，因为运动的原因可能会感觉轻度到中度的肌肉不舒服。如果你在活动过程中觉得累了，请停止活动并做适当休息。当你运动的时候，受伤的可能性很小，不会大于你在平常生活中可能受伤的机率。您所在的活动中心的护理人员也会陪同着你完成这些活动。

奖励

如果您完成了这两个月内所有要求的活动（包括问卷），您将会得到一共 **15 新**币的购物卷。

自愿参加

您的参与是完全自愿的，你可以随时退出。

资料保密

根据南洋理工大学的研究项目补偿规定，我们需要收集您的个人信息，例如您的姓名和身份证号。为了保护您的隐私，这些信息将不会提供给任何第三方，也不会出现在以后出版的论文里。在活动过程中，一些照片将会被拍摄下来作为资料而收集。但是，如果您不同意，我们是不会发布包含您正面或者侧面的照片的。最后，您的问卷答案只会被用于研究目的。

联系

如果您有任何关于本研究和你权利的问题，可以联系南洋理工大学黄金辉传播与信息学院的邓燕玲博士，电邮：TYLTHENG@ntu.edu.sg。如果您有任何关于作

为参与者的疑虑，可以联系南洋理工大学的机构审查委员会，电话65-65922495，
电邮： irb@ntu.edu.sg

Informed Consent Form

Please read this consent agreement carefully.

参与调查研究同意书

请仔细阅读本文

Agreement:

I have understood all the information mentioned in "Participant Information Sheet". I do hereby declare that I voluntarily participate in the activity mentioned in above on my own accord and that I shall not hold the organizer responsible for any loss of life or injury which may be sustained by me arising from the activity.

同意参与

我理解了在《参与者信息表》里的提及的所有信息，并自愿同意参加本次调查。在参加事项活动期间，若本人有遭受任何意外或伤亡，都与主办当局无关。

Name 姓名: _____

(Center 活动中心: _____ Condition 研究情景: _____)

Signature 签名: _____

Date 日期: _____

Appendix C

Measurement Instruments for Study One

Condition: _____ Center: _____
ID: _____

Baseline measure (T0) for Study 1

(This section will be assessed only in the pre-test measurement)

PH_T0 PHQ-9

Over the last 2 weeks, how often have you been bothered by any of the following problems? 在过去两个星期内，你多经常会被以下的问题困扰：		Not at all 几乎没有	Some days only 大概几天 而已	More than 7 days 多于 7 天	Nearly every day 几乎每天
PH1_T0	Little interest or pleasure in doing things? 做任何事都觉得沉闷或者根本□ 想做任何事	0	1	2	3
PH2_T0	Feeling down, depressed, or hopeless? 情绪低□ 、抑郁或绝望	0	1	2	3
PH3_T0	Trouble falling or staying asleep, or sleeping too much? 难于入睡；半夜会醒或相反地睡觉时间过多	0	1	2	3
PH4_T0	Feeling tired or having little energy? 觉得疲倦或活□ □ 足	0	1	2	3
PH5_T0	Poor appetite or overeating? 胃口极差或进食过□	0	1	2	3
PH6_T0	Feeling bad about yourself—or that you are a failure or have let yourself or your family down? □ 喜欢自己——觉得自己做得□ 好、对自己失望或有负家人期望	0	1	2	3
PH7_T0	Trouble concentrating on things, such as reading the newspaper or watching television? 难于集中精神做事，□ 如看报纸或看电视	0	1	2	3
PH8_T0	Moving or speaking so slowly that other people could have noticed? Or the opposite—being so fidgety or restless that you have been moving around a lot more than usual? 其他人反映你□ 动或□ 话迟缓；或者相反地，你比平常活动□ 多——坐□ □ 安、停□ 下□	0	1	2	3
PH9_T0	Thoughts that you would be better off dead or of hurting yourself in some way? 想到自己最好去死或者自残	0	1	2	3

Patient Health Questionnaire (PHQ-9): Adopted from Spitzer et al. (1994). Scores of 5, 10, 15, and 20 represent cut-points for mild, moderate, moderately severe and severe depression, respectively.

PE_T0 PANAS-PA

Please rate how you feel at this moment 下列各项描述分别在多大程度上符合你现在的实际感受						
		Very slightly or not at all 很少或者几乎没有	A little 有一点	Moderately 中等程度	Quite a bit 很多	Extremely 非常多

PE1_ T0	Interested 感兴趣的	1	2	3	4	5
PE2_ T0	Excited 兴奋的	1	2	3	4	5
PE3_ T0	Strong 坚强的	1	2	3	4	5
PE4_ T0	Enthusiastic 热情的	1	2	3	4	5
PE5_ T0	Proud 自豪的	1	2	3	4	5
PE6_ T0	Alert 警醒的	1	2	3	4	5
PE7_ T0	Inspired 受鼓舞的	1	2	3	4	5
PE8_ T0	Determined 坚决的	1	2	3	4	5
PE9_ T0	Attentive 注意力集中的	1	2	3	4	5
PE10_ T0	Active 积极的	1	2	3	4	5

Positive affect scale from The Positive and Negative Affect Schedule (PANAS-PA): Adopted from Watson, Clark, & Tellegen (1988). Higher sum score of the 10 items indicates higher level of positive emotions.

SE_T0 SES-6

Please indicate to what extent each statement applies to you 以下描述你的同意程度是		Not at all true 完全不正确	Hardly true 多数不正 确	Moderatel y true 多数正确	Exactly true 完全正确
SE1_ T0	If someone opposes me, I can find the means and ways to get what I want. 即使别人反对我，我仍有办法取得我所要的	1	2	3	4
SE2_ T0	It is easy for me to stick to my aims and accomplish my goals. 对我来说，坚持理想和达成目标是很容易的	1	2	3	4
SE3_ T0	I am confident that I could deal efficiently with unexpected events. 我自信能有效地应对任何突如其来的事情	1	2	3	4
SE4_ T0	Thanks to my resourcefulness, I know how to handle unforeseen situations. 以我的才智，我可以应付意料之外的情况	1	2	3	4
SE5_ T0	I can remain calm when facing difficulties because I can rely on my coping abilities. 我能冷静地面对困难，因为我可信赖自己处理问题的能力	1	2	3	4
SE6_ T0	I can usually handle whatever comes my way. 无论什么事在我身上发生，我都能应付自如	1	2	3	4

The short form of General Self-Efficacy Scale (GSE-6): Adopted from Romppel et al.'s (2013). Higher scores indicate greater degree of self-efficacy.

Demographic information

age	Age 年龄	
gend	Gender 性别	☐ 0. Female 女 ☐ 1. Male 男
race	Race 种族	☐ 0. Chinese 华族 ☐ 1. Malay 马来族 ☐ 2. Indian 印度 ☐ 3. Others 其他
edu	Education level 教育程度	☐ 0. No formal school education 没上过学 ☐ 1. Primary school 小学 ☐ 2. Secondly school 中学 ☐ 3. Junior College/ Polytechnic/ Pre-university 初级学院、理工学院、大学预科 ☐ 4. University or above 大学学历及以上
live	Current living arrangement 生活状况	☐ 0. Alone 独住 ☐ 1. Family 与家庭一起 ☐ 2. Others 其他 _____
fina	Percived financial status 自我感觉财务状况	☐ 0. Extremely inadequate 非常不足 ☐ 1. Inadequate 不足 ☐ 2. Adequate 足够 ☐ 3. Extremely adequate and can save money 非常足够并可以存钱
exer	In the past 3 months, How often you participate in exercise, e.g., jogging, ball activities, Taijiquan, yoga, or dancing? (≥ 30 min per time) 在最近的 3 个月内，你经常做运动吗,例如慢跑，球类运动，太极，瑜伽和跳舞？（每次 30 分钟以上才算）	☐ 0. Never 基本没有 ☐ 1. Less than once per month 低于一个月一次 ☐ 2. Around twice per month 一个月两次左右 ☐ 3. Around once per week 一周一次左右 ☐ 4. 2-3 times per week 一周两三次 ☐ 5. Almost everyday 几乎每天一次

Physcial conditions 身体状况		Poor 差	Fair 一般	Good 好	Very good 很好	Excellent 极好
eye	Eye sight 视力	1	2	3	4	5
hear	Hearing 听力	1	2	3	4	5
mob	Mobility status 肢体状况	1	2	3	4	5
cogn	Cognitive status 思维状况	1	2	3	4	5

=====End of the questionnaire Thank you 问卷结束 谢谢参与=====

Condition: _____ Center: _____
ID: _____

Final measure (T1) for Study 1
(This section will be assessed after the 6 weeks)

PH PHQ-9

Over the last 2 weeks, how often have you been bothered by any of the following problems? 在过去两个星期内，你多经常会被以下的问题困扰：		Not at all 几乎没有	Some days only 大概几天而已	More than 7 days 多于 7 天	Nearly every day 几乎每天
PH1	Little interest or pleasure in doing things? 做任何事都觉得沉闷或者根本□ 想做任何事	0	1	2	3
PH2	Feeling down, depressed, or hopeless? 情绪低□ 、抑郁或绝望	0	1	2	3
PH3	Trouble falling or staying asleep, or sleeping too much? 难于入睡；半夜会醒或相反地睡觉时间过多	0	1	2	3
PH4	Feeling tired or having little energy? 觉得疲倦或活□ □ 足	0	1	2	3
PH5_T3	Poor appetite or overeating? 胃口极差或进食过□	0	1	2	3
PH6_T3	Feeling bad about yourself—or that you are a failure or have let yourself or your family down? □ 喜欢自己——觉得自己做得□ 好、对自己失望或有负家人期望	0	1	2	3
PH7_T3	Trouble concentrating on things, such as reading the newspaper or watching television? 难于集中精神做事，□ 如看报纸或看电视	0	1	2	3
PH8_T3	Moving or speaking so slowly that other people could have noticed? Or the opposite—being so fidgety or restless that you have been moving around a lot more than usual? 其他人反映你□ 动或□ 话迟缓;或者相反地,你比平常活动□ 多——坐□ □ 安、停□ 下□	0	1	2	3
PH9_T3	Thoughts that you would be better off dead or of hurting yourself in some way? 想到自己最好去死或者自残	0	1	2	3

Patient Health Questionnaire (PHQ-9): Adopted from Spitzer et al. (1994). Scores of 5, 10, 15, and 20 represent cutpoints for mild, moderate, moderately severe and severe depression, respectively.

PE_T3 PANAS-PA

Please rate how you feel at this moment 下列各项描述分别在多大程度上符合你现在的实际感受						
		Very slightly or not at all 很少或者几乎没有	A little 有一点	Moderately 中等程度	Quite a bit 很多	Extremely 非常多

PE1_ T3	Interested 感兴趣的	1	2	3	4	5
PE2_ T3	Excited 兴奋的	1	2	3	4	5
PE3_ T3	Strong 坚强的	1	2	3	4	5
PE4_ T3	Enthusiastic 热情的	1	2	3	4	5
PE5_ T3	Proud 自豪的	1	2	3	4	5
PE6_ T3	Alert 警醒的	1	2	3	4	5
PE7_ T3	Inspired 受鼓舞的	1	2	3	4	5
PE8_ T3	Determined 坚决的	1	2	3	4	5
PE9_ T3	Attentive 注意力集中的	1	2	3	4	5
PE10_ T3	Active 积极的	1	2	3	4	5

Positive affect scale from The Positive and Negative Affect Schedule (PANAS-PA): Adopted from Watson, Clark, & Tellegen (1988). Higher sum score of the 10 items indicates higher level of positive emotions.

SE_T3 SES-6

Please indicate to what extent each statement applies to you 以下描述你的同意程度是		Not at all true 完全不正确	Hardly true 多数不正 确	Moderatel y true 多数正确	Exactly true 完全正确
SE1_ T3	If someone opposes me, I can find the means and ways to get what I want. 即使别人反对我，我仍有办法取得我所要的	1	2	3	4
SE2_ T3	It is easy for me to stick to my aims and accomplish my goals. 对我来说，坚持理想和达成目标是很容易的	1	2	3	4
SE3_ T3	I am confident that I could deal efficiently with unexpected events. 我自信能有效地应对任何突如其来的事情	1	2	3	4
SE4_ T3	Thanks to my resourcefulness, I know how to handle unforeseen situations. 以我的才智，我可以应付意料之外的情况	1	2	3	4
SE5_ T3	I can remain calm when facing difficulties because I can rely on my coping abilities. 我能冷静地面对困难，因为我可信赖自己处理问题的能力	1	2	3	4
SE6_ T3	I can usually handle whatever comes my way. 无论什么事在我身上发生，我都能应付自如	1	2	3	4

The short form of General Self-Efficacy Scale (GSE-6): Adopted from Romppel et al.'s (2013). Higher scores indicate greater degree of self-efficacy.

=====End of the questionnaire Thank you 问卷结束 谢谢参与=====

Appendix D

Measurement Instruments for Study Two

No: _____ - _____ - _____ - _____
Time Center Condition Participant

Baseline measure (T0) for Study 2

(This section will be assessed only in the pre-test measurement)

PH_T0 PHQ-9

Over the last 2 weeks, how often have you been bothered by any of the following problems? 在过去两个星期内，你多经常会被以下的问题困扰：		Not at all 几乎没有	Some days only 大概几天而已	More than 7 days 多于 7 天	Nearly every day 几乎每天
PH1_T0	Little interest or pleasure in doing things? 做任何事都觉得沉闷或者根本□ 想做任何事	0	1	2	3
PH2_T0	Feeling down, depressed, or hopeless? 情绪低□、抑郁或绝望	0	1	2	3
PH3_T0	Trouble falling or staying asleep, or sleeping too much? 难于入睡；半夜会醒或相反地睡觉时间过多	0	1	2	3
PH4_T0	Feeling tired or having little energy? 觉得疲倦或活□ □ 足	0	1	2	3
PH5_T0	Poor appetite or overeating? 胃口极差或进食过□	0	1	2	3
PH6_T0	Feeling bad about yourself—or that you are a failure or have let yourself or your family down? □ 喜欢自己——觉得自己做得□ 好、对自己失望或有负家人期望	0	1	2	3
PH7_T0	Trouble concentrating on things, such as reading the newspaper or watching television? 难于集中精神做事，□ 如看报纸或看电视	0	1	2	3
PH8_T0	Moving or speaking so slowly that other people could have noticed? Or the opposite—being so fidgety or restless that you have been moving around a lot more than usual? 其他人反映你□ 动或□ 话迟缓；或者相反地，你比平常活动□ 多——坐□ □ 安、停□ 下□	0	1	2	3
PH9_T0	Thoughts that you would be better off dead or of hurting yourself in some way? 想到自己最好去死或者自残	0	1	2	3

Patient Health Questionnaire (PHQ-9): Adopted from Spitzer et al. (1994). Scores of 5, 10, 15, and 20 represent cutpoints for mild, moderate, moderately severe and severe depression, respectively.

BS_T0 BSSS

Indicate how you feel about each statement. 你对以下的描述		Very strongly disagree 非常强烈不同意	Strongly disagree 强烈不同意	Mild disagree 部分不同意	Neutral 中立	Mild agree 部分同意	Strongly agree 强烈同意	Very strongly agree 非常强烈同意
BS1_T0	There are some people who truly like me. 有人是真的很喜欢我	1	2	3	4	5	6	7
BS2_T0	Whenever I am not feeling well, other people show me that they are fond of me.	1	2	3	4	5	6	7

	每当我觉得不太舒服的时候，有人让我觉得他们很关心我							
BS3_T0	Whenever I am sad, there are people who cheer me up. 每当我伤心的时候，有人会鼓励我	1	2	3	4	5	6	7
BS4_T0	There is always someone there for me when I need comforting. 当我需要安慰的时候总能找到人	1	2	3	4	5	6	7
BS5_T0	I know some people upon whom I can always rely. 我知道有些人我可以一直依靠	1	2	3	4	5	6	7
BS6_T0	When I am worried, there is someone who helps me. 当我担心的时候，就会有人来帮助我	1	2	3	4	5	6	7
BS7_T0	There are people who offer me help when I need it. 每当我需要帮助的时候就会有人帮助我	1	2	3	4	5	6	7
BS8_T0	When everything becomes too much for me to handle, others are there to help me. 当我没有能力处理事情的时候，有人会来帮助我	1	2	3	4	5	6	7

Berlin Social-Support Scales (BSSS): Adapted from Schulz & Schwarzer (2003). Higher scores indicate higher perceived social support. Emotional support includes items 1,2,3,4; Instrumental support includes items 5,6,7,8.

LS_T0 ULS-8

How often do you feel like the following statements? 你是否时常会有以下的感觉？		Never 从不	Rarely 很少	Sometimes 有时	Always 一直
LS1_T0	I lack companionship 我缺少别人的陪伴	1	2	3	4
LS2_T0	There is no one I can turn to 没有人可以寻求帮助	1	2	3	4
LS3_T0	I am an out-going person 我是一个愿意交朋友的人	1	2	3	4
LS4_T0	I feel left out 我感到被冷落	1	2	3	4
LS5_T0	I feel isolated from others 我感到和其他人疏远了	1	2	3	4
LS6_T0	I can find companionship when you want it? 当我想要的时候，我能找到人陪我	1	2	3	4
LS7_T0	I am unhappy by being so withdrawn 我因为很少与别人来往而感到伤心	1	2	3	4
LS8_T0	People are around me but not with me 虽然身边有人陪，但没人关心我	1	2	3	4

ULCA Loneliness Scale: Adopted from Hays & DiMatteo (1987). Items of 3 and 6 should be reversed in scoring (i.e. 1=4, 2=3, 3=2, 4=1). Higher scores indicate greater degree of loneliness.

Demographic information

age	Age 年龄	
gend	Gender 性别	☐ 0. Female 女 ☐ 1. Male 男
edu	Education level 教育程度	☐ 0. No formal school education 没上过学 ☐ 1. Primary school 小学 ☐ 2. Secondly school 中学 ☐ 3. Junior College/ Polytechnic/ Pre-university 初级学院、理工学院、大学预科 ☐ 4. University or above 大学学历及以上
live	Current living arrangement 生活状况	☐ 0. Alone 独住 ☐ 1. Spouse 与配偶一起 ☐ 2. Family 与家庭（有孩子）一起 ☐ 3. Friend(s) 与朋友一起 ☐ 4. Relatives 与亲戚一起 ☐ 5. Others 其他 _____
fina	Percived financial status 自我感觉财务状况	☐ 0. Extremely inadequate 非常不足 ☐ 1. Inadequate 不足 ☐ 2. Adequate 足够 ☐ 3. Extremely adequate and can save money 非常足够并可以存钱
exer	In the past 3 months, How often you participate in exercise, e.g., jogging, ball activities, Taiji Quan, yoga, or dancing? (≥ 30 min per time) 在最近的 3 个月内，你经常做运动吗,例如慢跑，球类运动，太极，瑜伽和跳舞？（每次 30 分钟以上才算）	☐ 0. Never 基本没有 ☐ 1. Less than once per month 低于一个月一次 ☐ 2. Around twice per month 一个月两次左右 ☐ 3. Around once per week 一周一次左右 ☐ 4. 2-3 times per week 一周两三次 ☐ 5. Almost everyday 几乎每天一次

		Poor 差	Fair 一般	Good 好	Very good 很好	Excellent 极好
eye	Eye sight 视力	1	2	3	4	5
hear	Hearing 听力	1	2	3	4	5
mob	Mobility status 肢体状况	1	2	3	4	5
cong	Cognitive status 思维状况	1	2	3	4	5

=====End of the questionnaire Thank you 问卷结束 谢谢参与=====

No: _____ - _____ - _____ - _____
Time Center Condition Participant

Final measure (T1) for Study 2

(This section will be assessed only in the completion of the intervention)

PH_T1 PHQ-9

Over the last 2 weeks, how often have you been bothered by any of the following problems? 在过去两个星期内，你多经常会被以下的问题困扰：		Not at all 几乎没有	Some days only 大概几天而已	More than 7 days 多于 7 天	Nearly every day 几乎每天
PH1_T1	Little interest or pleasure in doing things? 做任何事都觉得沉闷或者根本□ 想做任何事	0	1	2	3
PH2_T1	Feeling down, depressed, or hopeless? 情绪低□ 、抑郁或绝望	0	1	2	3
PH3_T1	Trouble falling or staying asleep, or sleeping too much? 难于入睡；半夜会醒或相反地睡觉时间过多	0	1	2	3
PH4_T1	Feeling tired or having little energy? 觉得疲倦或活□ □ 足	0	1	2	3
PH5_T1	Poor appetite or overeating? 胃口极差或进食过□	0	1	2	3
PH6_T1	Feeling bad about yourself—or that you are a failure or have let yourself or your family down? □ 喜欢自己——觉得自己做得□ 好、对自己失望或有负家人期望	0	1	2	3
PH7_T1	Trouble concentrating on things, such as reading the newspaper or watching television? 难于集中精神做事，□ 如看报纸或看电视	0	1	2	3
PH8_T1	Moving or speaking so slowly that other people could have noticed? Or the opposite—being so fidgety or restless that you have been moving around a lot more than usual? 其他人反映你□ 动或□ 话迟缓；或者相反地，你比平常活动□ 多——坐□ □ 安、停□ 下□	0	1	2	3
PH9_T1	Thoughts that you would be better off dead or of hurting yourself in some way? 想到自己最好去死或者自残	0	1	2	3

Patient Health Questionnaire (PHQ-9): Adopted from Spitzer et al. (1994). Scores of 5, 10, 15, and 20 represent cutpoints for mild, moderate, moderately severe and severe depression, respectively.

BS_T1 BSSS

Indicate how you feel about each statement. 你对以下的描述		Very strongly disagree 非常强烈不同意	Strongly disagree 强烈不同意	Mild disagree 部分不同意	Neutral 中立	Mild agree 部分同意	Strongly agree 强烈同意	Very strongly agree 非常强烈同意
BS1_T1	There are some people who truly like me. 有人是真的很喜欢我	1	2	3	4	5	6	7
BS2_T1	Whenever I am not feeling well, other	1	2	3	4	5	6	7

	people show me that they are fond of me. 每当我觉得不太舒服的时候，有人让我觉得他们很关心我							
BS3_T1	Whenever I am sad, there are people who cheer me up. 每当我伤心的时候，有人会鼓励我	1	2	3	4	5	6	7
BS4_T1	There is always someone there for me when I need comforting. 当我需要安慰的时候总能找到人	1	2	3	4	5	6	7
BS5_T1	I know some people upon whom I can always rely. 我知道有些人我可以一直依靠	1	2	3	4	5	6	7
BS6_T1	When I am worried, there is someone who helps me. 当我担心的时候，就会有人来帮助我	1	2	3	4	5	6	7
BS7_T1	There are people who offer me help when I need it. 每当我需要帮助的时候就会有人帮助我	1	2	3	4	5	6	7
BS8_T1	When everything becomes too much for me to handle, others are there to help me. 当我没有能力处理事情的时候，有人会来帮助我	1	2	3	4	5	6	7

Berlin Social-Support Scales (BSSS): Adapted from Schulz & Schwarzer (2003). Higher scores indicate higher perceived social support. Emotional support includes items 1,2,3,4; Instrumental support includes items 5,6,7,8.

LS_T1 ULS-8

How often do you feel like the following statements? 你是否时常会有以下的感觉？		Never 从不	Rarely 很少	Sometimes 有时	Always 一直
LS1_T1	I lack companionship 我缺少别人的陪伴	1	2	3	4
LS2_T1	There is no one I can turn to 没有人可以寻求帮助	1	2	3	4
LS3_T1	I am an out-going person 我是一个愿意交朋友的人	1	2	3	4
LS4_T1	I feel left out 我感到被冷落	1	2	3	4
LS5_T1	I feel isolated from others 我感到和其他人疏远了	1	2	3	4
LS6_T1	I can find companionship when you want it? 当我想要的时候，我能找到人陪我	1	2	3	4
LS7_T1	I am unhappy by being so withdrawn 我因为很少与别人来往而感到伤心	1	2	3	4
LS8_T1	People are around me but not with me 虽然身边有人陪，但没人关心我	1	2	3	4

ULCA Loneliness Scale: Adopted from Hays & DiMatteo (1987). Items of 3 and 6 should be reversed in scoring (i.e. 1=4, 2=3, 3=2, 4=1). Higher scores indicate greater degree of loneliness.

=====End of the questionnaire Thank you 问卷结束 谢谢参与=====

PUBLICATIONS

The following lists the Journal papers and conference papers I have published or presented during the doctoral study:

Relating to Ph.D. Study

Journal articles:

- Li, J.,** Theng, Y.L. and Foo, S. (2016). Effect of exergames on depression: A systematic review and meta-analysis. *Cyberpsychology, Behavior, and Social Networking*, 19(1), 34-42.
- Li, J.,** Theng, Y.L. and Foo, S. (2016). Exergames for older adults with subthreshold depression: Does higher playfulness lead to better improvement in depression? *Games for Health Journal*, 5(3), 175-182.
- Li, J.,** Theng, Y.L. and Foo, S. (2015). Depression and psychosocial risk factors among community-dwelling older adults in Singapore. *Journal of Cross-Cultural Gerontology*, 30(4), 409-422.
- Li, J.,** Theng, Y.L. and Foo, S. (2015). Does psychological resilience mediate the impact of social support on geriatric depression? An exploratory study among Chinese older adults in Singapore. *Asian Journal of Psychiatry*. 14, 22-27.
- Li, J.,** Theng, Y.L. and Foo, S. (2014). Game-based digital interventions for depression therapy: A systematic review and meta-analysis. *Cyberpsychology, Behavior, and Social Networking*, 17(8), 519-527.

Conference papers:

- Li, J.** (2014, October). Examining the impact of game interventions on depression among older adults. Paper presented at Extended abstract of *CHI PLAY '14*, Toronto, ON, Canada.
- Li, J.,** Theng, Y.L., and Foo, S. (2016, June). Examining the Psychosocial Effects between Exergames and Traditional Exercise on Older Adults with Subthreshold Depression. Paper accepted at the International Communication Association Conference (ICA 2016), Fukuoka, Japan.
- Li, J.,** Theng, Y.L., and Foo, S. (2015, August). Exergame for older adults with subthreshold depression: Examining the influences of playfulness on the antidepressant effect of exergames. Paper presented at the 10th Singapore Public Health and Occupational Medicine Conference, Singapore.

Li, J. (2013, November). A baseline study on depression and psychosocial factors among older adults in Singapore. Paper presented at the 4th Honors Symposium for Asian Ph.D. Students in Communication Research, Hong Kong.

Working with other researchers

Journal articles:

- Xu, X., **Li, J.**, Pham, T.P., Salmon, C.T., and Theng, Y.L. (2016). Improving Psychosocial Well-Being of Older Adults through Exergaming: The Moderation Effect of Intergenerational Communication and Age Cohorts. *Games for Health Journal*, 5(6), 389-397.
- Li, J.**, Theng, Y.L., Cheong, W.L., Hoo, Y.F., and Ngo, M.D. (2016). Exergames for the corporate wellness program in Singapore: An investigation of employees' acceptance via watching Kinect video. *Digital Health*, 2.
- Wu, Z., **Li, J.**, and Theng, Y.L. (2015). Examining the influencing factors of exercise intention among older adults: A controlled study between exergame and traditional exercise. *Cyberpsychology, Behavior, and Social Networking*, 18(9), 521-527.
- Li, J.**, Theng, Y.L. and Foo, S. (2015). Predictors of online health information seeking behavior: Changes between 2002 and 2012. *Health Informatics Journal*, 22(4), 804-814.

Conference papers:

- Xu, X., Theng, Y.L., **Li, J.**, and Pham, T.P. (2016, May). Investigating Effects of Exergames on Exercise Intentions among Young-Old and Old-Old. Paper accepted at *ACM CHI 2016*, San Jose, CA, USA.
- Li, J.**, Theng, Y.L., Foo, S., and Fernando, O.N.N. (2013, September). Content analysis on user-focused support features of health support sites for geriatric depression. Proceedings of IEEE International Conference on Healthcare Informatics (ICHI 2013), 367 - 375, Philadelphia, PA, USA.
- Li, J.**, Theng, Y.L., and Foo, S. (2015, March). Predictors of online health information seeking behavior: Changes in the past ten years. Paper presented at the inaugural International Convention of Psychological Science (ICPS), Amsterdam, The Netherlands.
- Xu X., Tan P.P., **Li, J.**, and Theng, Y.L. (2015, March). Examining the influence of exergames on elderly's perceived benefits and barriers to exercise. Paper presented at the inaugural International Convention of Psychological Science (ICPS), Amsterdam, The Netherlands.

Li, J., Theng, Y.L., and Foo, S. (2014, May). Coping appraisal mediates the impact of social support on depression among older adults in Singapore. Paper presented at the Association for Psychology Science 26th Annual Convention (APS 2014), San Francisco, CA, USA.

Dasgupta, P., Chi, J., and **Li, J.** (2013, August). The New Face of Political Engagement? : Factors influencing political activity of users on social networking sites. Paper presented at the annual AEJMC conference, Washington, DC, USA.