RELATIONSHIPS BETWEEN LEISURE ACTIVITY PARTICIPATION, MAHJONG PLAYING AND COGNITIVE, PSYCHOLOGICAL AND DAILY FUNCTIONS IN OLDER INDIVIDUALS

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Relationships Between Leisure Activity Participation, Mahjong Playing and Cognitive, Psychological and Daily Functions in Older Individuals

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CERTIFICATE OF ORIGINALITY

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Abstract

Ageing is a dynamic and modifiable process (Dixon, 2011). As population ageing would lead to significant social and financial burdens, it is important to investigate strategies that may promote functions in older adults. Previous studies have shown that leisure activity participation is one strategy to increase cognitive reserve and promote better functions of ageing. The literature, however, had focused on general cognition and seldom probed into higher-order cognitive (e.g., executive functions [EF]), psychological, and daily functions. Moreover, there is little research examining the benefits of culturally specific activities such as mahjong playing, which is a common and enjoyable leisure activity among Chinese older adults. Therefore, the current PhD project addressed the research gaps and investigated whether leisure activity participation and mahjong playing could help to facilitate better functions of ageing. To achieve this aim, three studies were conducted.

Study 1 was a cross-sectional survey study (*n* = 525) that explored the relationships between leisure activity participation, mahjong playing, and the cognitive, psychological, and daily functions in older adults. Results showed that engaging in leisure activities could significantly predict general cognition, EF, loneliness, levels of depression, anxiety, stress, and functional independence. In addition, participation in a culturally specific leisure activity, mahjong playing, could significantly predict all of the above functions, suggesting that mahjong playing is a potential activity to promote better functions in Hong Kong older adults.

Study 2 was a scoping review that examined the existing literature and synthesised the benefits of mahjong playing on cognitive, psychological, and daily functions in older adults. Fifty-three studies from the Western and Asian literature were included in the review, and the benefits of mahjong playing could be categorised

into five domains: (i) subjective meaning attached to mahjong playing, (ii) short-term benefits, (iii) long-term benefits, (iv) relationship between mahjong playing and disease prevalence, and (v) effectiveness of mahjong interventions. The findings suggested that mahjong playing is beneficial for older adults, improving cognitive, psychological, and daily functions. Nevertheless, the underlying functional and neural mechanisms of how it facilitates better functions remained unclear.

Study 3 used functional near-infrared spectroscopy (fNIRS) to clarify the relationships between mahjong playing and the updating and switching components of EF in younger (n = 36) and older adults (n = 36). Results showed that mahjong playing is closely related to EF, and significant prefrontal activations were observed during the computerised mahjong games designed to assess the two components of EF. More importantly, it was found that although older adults showed comparable behavioural performance to younger adults during the computerised mahjong games; they showed a significantly higher prefrontal activation than younger adults. It suggested that older adults may utilise neural compensation to offset the differences in behavioural performance, further explaining the underlying neural mechanism of the benefits of mahjong playing.

Overall, findings in this thesis have contributed to the ageing literature by providing empirical evidence to support the benefits of leisure activity participation and one culturally specific activity (i.e., mahjong playing) in older adults. The research has also expanded the examination from general cognition to EF, psychological, and daily functions. Finally, this thesis has provided neural evidence to support the involvement of EF during mahjong playing and the reason for its benefits in older adults.

Publications Arising from the Thesis

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Leung, C., Wong, K. C., So, W. W., **Tse, Z. C. K.**, Li, D., Cao, Y., & Shum, D. H. (2022). The application of technology to improve cognition in older adults: A review and suggestions for future directions. *PsyCh Journal*, *11*(4), 583-599. https://doi.org/10.1002/pchj.565

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Yu, M. H. M., Cao, Y., Fung, S. S. Y., Kwan, G. S. Y., **Tse, Z. C. K.**, & Shum, D. H. K. (2025). Intolerance of uncertainty, aging, and anxiety and mental health concerns: A scoping review and meta-analysis. *Journal of Anxiety Disorders*, 102975. https://doi.org/10.1016/j.janxdis.2025.102975

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AD	Alzheimer's disease
ADL	Activities of daily living
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
APOE	Apolipoprotein E
B	Unstandardized regression coefficients
BA	Brodmann areas
BOLD	Blood Oxygenation Level Dependent
CBSI	Correlation-based signal improvement
CDR	Clinical Dementia Rating
CDRS	Chinese version of the Mattis Dementia Rating Scale
CLHLS	Chinese Longitudinal Healthy Longevity Survey
CMMSE	Cantonese-version Mini-Mental State Examination
CNKI	China National Knowledge Infrastructure
COBRA	Cognitive Complaints in Bipolar Disorder Rating Assessment
COBRA-C	Chinese version of the Cognitive Complaints in Bipolar Disorder Rating Assessment
CRUNCH	Compensation-related utilization of neural circuits hypothesis
CSSCI	Chinese Social Sciences Citation Index
CTT	Color Trails Test
DASS-21	Depression Anxiety and Stress Scale-21
deoxy-Hb	Concentration of deoxygenated haemoglobin
DEX	Chinese version of the Dysexecutive Questionnaire
dlPFC	Dorsolateral prefrontal cortex

DV	Dependent variable
EEG	Electroencephalogram
EF	Executive functions
F_{inc}	F for change
fMRI	Functional magnetic resonance imaging
fNIRS	Functional near-infrared spectroscopy
HAROLD	Hemispheric Asymmetry in OLDer adults
HK-MoCA	Hong Kong Montreal Cognitive Assessment
HRF	Hemodynamic response function
IADL	Instrumental activities of daily living
IADL-CV	Chinese Lawton Instrumental Activities of Daily Living Scale
ICC	Intraclass correlation coefficient
IP	Internet Protocol
IVs	Independent variables
M	Mean
MCI	Mild cognitive impairment
MMSE	Mini-Mental State Examination
MNI	Montreal Neurological Institute
MoCA	Montreal Cognitive Assessment
MRI	Magnetic resonance imaging
NIA	National Institute on Aging
NIRS-SPM	Statistical Parametric Mapping for Near-infrared Spectroscopy
OD	Optical density
oxy-Hb	Concentration of oxygenated haemoglobin
PFC	Prefrontal cortex

PHOEBE	Placing Headgear Optodes Efficiently Before Experimentation
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PSP	Power Matrix Threshold
QT-NIRS	Quality Testing of Near Infrared Scans
RCT	Randomised controlled trials
ROI	Region of interest
SCI	Scalp Coupling Index
SD	Standard deviations
SE	Standard error
SPMSQ	Short Portable Mental Status Questionnaire
SPSS	Statistical Package for Social Sciences
sr^2	Semi-partial correlation
STAC	Scaffolding Theory of Cognitive Aging
STAC-r	Revised version of the Scaffolding Theory of Cognitive Aging
TCi-HSS	Taiwan Citation Index-Humanities and Social Sciences
TMT	Trail Making Test
TMT-B	Trail Making Test B
VIF	Variance inflation factor
β	Standardized regression coefficients

Chapter 1

Overview

Population ageing is a significant global challenge, and it poses profound challenges to the healthcare systems, social services and governmental financial load. While ageing is associated with a decline in cognitive, psychological and daily functions (Grünwald et al., 2022; Preston & Biddell, 2021; Rabin et al., 2015), engaging in leisure activities has been found to foster better functions in older adults through the accumulation of cognitive reserve (Park & Reuter-Lorenz, 2009; Stern & Munn, 2010; Stern, 2009; Stern et al., 2023). However, previous research has mainly focused on general cognitive function, and aspects in higher-order cognitive (e.g., executive functions [EF]), psychological, and daily functions have received less attention. Moreover, most of the previous studies were conducted in Western countries and there are very few studies that examined the benefits of culturally specific activities such as mahjong playing.

In light of these research gaps, the current thesis aimed to investigate whether engaging in leisure activities and one culturally specific activity (i.e., mahjong playing) could help to promote better functions of older adults. A comprehensive approach was used to address the gaps, and mahjong playing was selected to examine the benefits of a culturally specific activity. The examination has been expanded from general cognition to EF to enhance the understanding of how the accumulation of cognitive reserve promotes better maintenance of EF in older adults.

The next two chapters will provide a review of the literature relating to ageing, cognitive reserve, leisure activity participation, and mahjong playing. **Chapter 2** summarises the theories of dynamics of ageing, concepts of neural compensation and cognitive reserve. It suggests that accumulating cognitive reserve could better maintain the functions of older adults. **Chapter 3** provides a summary of the current research on participating in (i) leisure activities and (ii) mahjong playing, to enhance cognitive, psychological and daily functions in older adults. It also highlights the limitations of previous studies: (i) limited research on EF, psychological and daily functions, (ii) unclear effectiveness regarding the domains of leisure activities, and (iii) unclear effectiveness regarding the optimal dosage of the participation. It then introduces the aims and hypotheses of the current thesis.

Chapter 4 describes Study 1, a cross-sectional survey study of 525 older adults. The study aimed to examine the relationships between leisure activity participation, mahjong playing, and the cognitive, psychological and daily functions. **Chapter 5** describes Study 2, a scoping review of both Western and Asian journal papers. The study aimed to examine the benefits of mahjong playing in cognitive, psychological, and daily functions in older adults. **Chapter 6** describes Study 3, a neuroimaging experimental study which included 36 young adults and 36 older adults. The study aimed to investigate the relationships between mahjong playing and EF, and the underlying neural mechanisms of mahjong playing. Finally, **Chapter 7** provides a general discussion that synthesises all the findings of the thesis and offers some overarching conclusions.

Chapter 2

Literature Review: Ageing, Neural Compensation and Cognitive Reserve

2.1 Population Ageing and Its Impacts

Population ageing is not only a significant global healthcare challenge but also a focused healthcare issue in Hong Kong. It is anticipated that the world population aged 65 years or over will increase from around 807 million in 2023 to around 1.6 billion in 2050 and then to 2.2 billion by late 2070s (United Nations Department of Economic and Social Affairs, 2023). In Hong Kong, the number of older adults aged 65 years or above is predicted to increase from 1.45 million in 2021 to 2.74 million in 2045 (Census and Statistics Department, Hong Kong Special Administrative Region, 2023). Although Hong Kong citizens enjoy the third-highest life expectancy in the world (United Nations Department of Economic and Social Affairs, 2024), the coming ageing tsunami poses significant pressure and challenges on the healthcare system (Hospital Authority, 2021). Among the total population aged between 65 to 69 years in Hong Kong, 53.9% of them were diagnosed with chronic disease, and this percentage was 78.4% for those aged 70 years or above (Census and Statistics Department Hong Kong Special Administrative Region, 2021). The Government also reported an annual expenditure of about $900 million and $1440 million respectively, for the Community Care Services Voucher and the Residential Care Service Voucher for the Elderly (Chan, 2024). Specifically in 2023-2024, the Hong Kong Government spent a total of HKD 53.03 billion (USD 6.80 billion) on the welfare policy for older adults with lower incomes, including long-term care services and financial support and healthcare protection (Research Office Legislative Council Secretariat, 2024). This amount accounted for 19% of the total health expenditure (Department of Health, the Government of the Hong Kong Special Administrative Region, 2024). In sum, the ageing population is and will continue to be a tremendous social and financial burden for Hong Kong.

2.2 Ageing and Its Associated Changes

The normal ageing process is associated with various physiological, social and psychological changes. Physiologically, older adults face an increased risk of different physical health issues (Preston & Biddell, 2021), such as cardiovascular disease (Kim, 2023), hypertension (Buford, 2016), and cancer (White et al., 2014). These changes are often described through biological theories that focus on fundamental shifts at the molecular and cellular levels (Hayflicks, 1985). In addition to the physiological changes, ageing also brings social changes in social roles after retirement (Grünwald et al., 2022), along with shifts in social connectedness and engagement (Siracusa et al., 2022). These alterations in social roles and responsibilities, social interaction, and societal values are explained by sociological theories (McMullin, 2000). More importantly, older adults also encounter psychological changes, such as the resolution of conflicts between integrity and despair as mentioned in Erikson's Psychosocial development theory (Maree, 2021), cognitive declines and neurodegeneration (Harada et al., 2013), perceived isolation and risk of mental disorders (Santini et al., 2020). These psychological changes are explained by the psychological theories that emphasise aspects of psychological functioning, including personality, memory and learning (Schroots, 1996).

While a holistic approach is essential for understanding the complexities of ageing, this thesis focuses mainly on the psychological perspective due to its relevance to cognitive, psychological and daily functions (Wernher & Lipsky, 2015).

2.2.1 Age-Related Cognitive Declines

Extensive evidence has been accumulated for complaints by older individuals relating to cognitive functions such as memory, EF, attention, and language (Rabin et al., 2015). Salthouse (1996) proposed the processing speed theory, and postulated that ageing is linked to limited cognitive resources, imposing general processing constraints that lead to reduced processing speed when handling complicated cognitive tasks. A review by Light (1987) noted that this theory has guided most research on cognitive ageing, as it could be tested using objective measurements such as the Digit Symbol Substitution Test. Additionally, research has also shown that processing speed could serve as a biomarker of cognitive ageing (Deary et al., 2010), and significantly predict a better ageing process (Ticha et al., 2023), as well as learning and memory (Saikia & Tripathi, 2024).

Beyond behavioural evidence, it is important to note that ageing in healthy older adults is also associated with the shrinkage of brain volumes and structures, which alters brain functions and influences cognitive performance (Fjell & Walhovd, 2010). These age-related cognitive changes have also been supported by neuropsychological and brain imaging studies (Harada et al., 2013). Park and Reuter-Lorenz (2009) summarised that ageing is associated with global thinning and volumetric shrinkage of the brain, white matter hyperintensities, additional bilateral prefrontal activation during cognitive tasks, a decrease of neural specificity (i.e., dedifferentiation) and neural inefficiency. Notably, these age-related cognitive changes were found to be associated with an increased risk of falls (Allali et al., 2017) and worsening functional independence (Lee et al., 2019).

2.3 Dynamics of Ageing: Maintenance and Improvement

Ageing is associated not only with deterioration but also with resilience. Dixon (2011) pointed out that ageing is a dynamic and modifiable process. One enduring theme in the research on theories of psychological ageing refers to the “Balance of

Trajectory", which encompasses the dynamics of ageing, including decline, maintenance and improvement. As mentioned in the *Handbook of Theories of Aging* and the *Strategic Directions of the National Institute on Aging (NIA) for 2020-2025*, the ultimate aim of studying ageing is to acquire a better understanding of the ageing processes, and maintain the health and independence of older adults (Bengtson & Settersten, 2016; Hodes, 2020). Therefore, research should extend beyond the investigation of age-related declines to the maintenance and improvement of abilities in older adults.

The following sections summarise three leading theories on ageing (i.e., Counterpart Theory, Theory of Selection, Optimization and Compensation, and the Scaffolding Theory of Cognitive Aging [STAC]), and explore their viewpoints on the dynamics of ageing (i.e., decline, maintenance and improvement).[1]

2.3.1 Counterpart Theory

The counterpart theory proposed by Birren (1964) accounts for the ageing process as a counterpart of adult development. In other words, similar to an individual developing into an adult, the adult experiences the counterpart process of development (i.e., ageing) and becomes an older adult. It is one of the earliest and most prominent theoretical developments in the field of psychological ageing. The theory highlights that ageing is dynamic (i.e., capable of maintaining, improving, rather than simply declining) and encompasses two characteristics: (i) complexity and adaptive capacity and (ii) subjective interpretation.

First, ageing is a complex and dynamic process, and research should examine ageing from the biological, psychological and social perspectives (Birren et al., 1983).

[1] This is not a comprehensive literature review of all theories of psychological ageing. Instead, the most influential and relevant theories were selected and discussed in this chapter.

The theory also proposed adaptive capacity as a critical dependent variable (DV) in the study of ageing and it refers to the development of self-regulatory adjustments to survive (Birren, 1988). It is suggested that increased experience would foster a better adaptive capacity and result in a better ageing process (Birren, 1988).

Second, it underscored that ageing is more than an objective event; an individual should have a subjective interpretation of ageing events (Birren, 1999). It highlighted the personal experience and awareness of ageing, in which a higher level of awareness would be associated with better functions of ageing (Diehl et al., 2015).

The theory posits that ageing is dynamic and subjective, underscoring the potential of plasticity throughout the ageing process. It is supported by empirical evidence, showing that early-life experiences, such as exercise, new learning and years of education (Birren & Fisher, 1995; Birren & Morrison, 1961), were associated with better functions during the ageing process. An earlier review summarised that the counterpart theory advocates the contribution of favourable late-life characteristics, including intelligence and the potential for a longer lifespan (Schroots, 1996). However, it remains unclear how the experience could facilitate a better adaptive capacity and result in a better ageing process. The evidence should also be considered preliminary, as it primarily involved patients with brain lesions to investigate the brain mechanism of ageing (Hicks & Birren, 1970), rather than employing advanced neuroimaging techniques to measure the neural activation.

2.3.2 Theory of Selection, Optimization and Compensation

Baltes (1987) and Baltes et al. (2005) introduced the theory of selection, optimization and compensation within a lifespan development framework, delving into the dynamics of ageing in terms of gains (growth) and losses (decline). The theory proposed that an older individual experiences more losses than gains during ageing, but older individuals can maintain and improve their abilities by employing selection, optimisation and compensation. It also proposed two other characteristics of ageing: (i) multidimensionality and multidirectionality, and (ii) plasticity.

First, the main proposition of the theory is that it considers ageing as multidimensional and multidirectional (Baltes, 1987). In particular, ageing includes multiple dimensions, such as crystallised and fluid intelligence, and both types of intelligence demonstrate different directions during ageing (i.e., multidirectionality). By definition, fluid intelligence refers to the mechanics of intelligence that deals with basic cognitive operations, while crystallised intelligence refers to the pragmatics of intelligence that concerns the context- and knowledge-related applications. For example, it is noted that fluid intelligence (e.g., information processing and memory) would decline with age while crystallised intelligence (e.g., language and social intelligence) would accumulate and maintain over the course of ageing (Baltes, 1987).

Second, Baltes (1987) also suggested that plasticity could be built via life conditions and experiences, such that an individual has the potential to modify performance within the developmental process. For example, older adults could coordinate the selection, optimization and compensation of behaviours to enhance, maintain and regulate performance, respectively (Baltes et al., 2012). Specifically, older adults select the goals to ensure that sufficient resources are available, and then they optimise their behaviour by engaging in and refining the resources. Lastly, older adults can compensate for the lost behavioural capacities by coordinating the resources to achieve a normal level of functioning.

The theory emphasises that ageing is not only a deterioration but also an adaptive process, highlighting the potential of continued growth. It is supported by empirical evidence that older adults who engage in selective, optimisation and compensatory behaviours show more adaptive outcomes (i.e., plasticity), such as better life satisfaction (Morris-Foster, 2024), well-being (Carpentieri et al., 2016), and self-efficacy (Salminen et al., 2021). This theory underscores a positive view of aging, suggesting that older adults could actively shape the ageing experience through strategies like selection, compensation and optimisation. However, these studies mainly focused on behavioural evidence (Carpentieri et al., 2016; Morris-Foster, 2024; Salminen et al., 2021), leaving a gap in understanding the biological and neural mechanisms of plasticity. Additionally, more research is needed to explore how these strategies can be generalised to different types of intelligence.

2.3.3 Scaffolding Theory of Cognitive Aging (STAC) and the Revised version of the Scaffolding Theory of Cognitive Aging (STAC-r)

With the technological advancement in brain imaging and the increasing amount of brain-based evidence on ageing, Park and Reuter-Lorenz (2009) proposed a brain-based theory related to the cognitive neuroscience of ageing, namely the STAC, which was later revised as STAC-r in 2014 (Reuter-Lorenz & Park, 2014). Overall, the theory and its revised version suggest that the brain and cognitive system are dynamic and adaptive to respond to neural challenges and functional deterioration. Specifically, the brain is capable of maintaining and improving neuronal resources. The theory and its revised version introduce two ideas related to the neural mechanism of dynamics of ageing: (i) compensation scaffolding, and (ii) life-course factors.

First, the dynamics of ageing are characterised by compensatory scaffolding, which is a process that ameliorates the adverse impacts of neural and functional decline. It is the process by which the brain recruits additional circuitry beyond the established pathways acquired during early development (Park & Reuter-Lorenz, 2009). Findings have confirmed that the compensatory scaffolding mainly resides in the prefrontal cortex (PFC; Park & Reuter-Lorenz, 2009). Empirical research supported the idea that once the primary network becomes inefficient, an increment of bilateral prefrontal activation would be observed in older adults compared to younger adults (Cabeza, 2002). This piece of evidence suggested that older adults could employ compensatory scaffolding to offset the neural inefficiency in older adults.

Second, it is also proposed that life-course factors (e.g., life experiences, genetic endowments and environmental influences) may influence the structure and function of the ageing brain (Reuter-Lorenz & Park, 2014). Park and colleagues suggested that engaging in intellectual and social activities may facilitate cognition and enrich cognitive resources. Building on the counterpart theory that “increased experience could facilitate better functions of ageing”, the STAC and STAC-r elaborated on which type of experience could positively or negatively influence neural health.

The STAC and STAC-r address the neurobiological underpinnings and mechanisms of cognitive change, suggesting that cognitive deterioration could be altered via compensatory mechanisms (Reuter-Lorenz & Park, 2024). They are supported by cross-sectional and longitudinal empirical research, indicating that overactivation (Cabeza, 2002) and life-course experiences (Oschwald et al., 2020) were effective in stimulating the compensation for achieving better performance throughout the ageing process. An advantage of the theories is the comprehensive understanding of the neurobiological underpinnings of ageing, emphasising that cognitive resources could be maintained and improved. However, a limitation is that they focus on compensation/neuroplasticity (Goh & Park, 2009; Gutchess, 2014) and do not extend the discussion on cognitive reserve (i.e., the extent of capacity that an individual has to cope with brain pathology; Stern, 2009). Nonetheless, they acknowledged that the scaffolding model is related to cognitive reserve. Specifically, it is suggested that the cognitive reserve may affect the quality, quantity and/or effectiveness of the scaffolding (Park & Reuter-Lorenz, 2009). In other words, it is noted that cognitive resources and performance could be maintained by neural compensation and cognitive reserve. More research is needed to clarify the interaction between compensation and cognitive reserve, and examine how the dynamic brain is affected by engaged and active lifestyles.

2.4 Maintenance: Neural Compensation and Cognitive Reserve

The two main strategies to maintain cognitive performance and foster better functions of ageing are neural compensation and cognitive reserve. The following sections first introduce two influential models/hypotheses related to neural compensation, including the compensation-related utilization of neural circuits hypothesis (CRUNCH), and Hemispheric Asymmetry in OLDer adults (HAROLD); then it reviews the concept of cognitive reserve.

2.4.1 Neural Compensation

2.4.1.1 CRUNCH. The CRUNCH proposed that age-related cognitive declines can be compensated by overactivation in other brain areas (Reuter-Lorenz & Cappell, 2008). The hypothesis is supported by the overactivation observed in older adults even though the behavioural performances are age-equivalent. For example, Cappell et al. (2010) demonstrated that in conditions of lower working memory load, although older and younger adults exhibited comparable behavioural accuracies, older adults showed increased prefrontal activation. It supported the CRUNCH and suggested that the overactivation may help older adults compensate for the age-related loss and facilitate a similar behavioural performance with younger adults. In other words, the overactivation makes up for the decreased neural efficiency and processing deficits in older adults.

2.4.1.2 HAROLD. The HAROLD model adds specificity to the CRUNCH. It further proposed that the pattern of overactivation is less lateralised in older adults than in younger adults, suggesting the bilateral activations for compensation in older adults (Cabeza, 2002). The reduction in neural specialisation could be explained by another concept in the cognitive neuroscience of ageing, namely, dedifferentiation (i.e., a more widespread neural activation during the tasks; Dennis et al., 2020). The reduction in neural specialisation is supported by the literature (Cabeza et al., 1997; Park et al., 2004). For example, older adults exhibited a dedifferentiation of neural response in the ventral visual cortex, a brain area typically responsive to specific visual categories (e.g., faces, places and words; Park et al., 2004). This dedifferentiation is characterised by less category-specific activity and a decrease in selectivity of the neural activity in older adults compared to their younger counterparts.

2.4.2 Cognitive Reserve

Cognitive reserve is a complementary concept to neural compensation; an individual with a greater capacity to cope with brain pathology is described as having better cognitive reserve (Stern, 2009). The accumulated reserve could keep performance at a high level and facilitate better maintenance (i.e., the structural and functional integrity of the brain; R. Cabeza et al., 2018; Stern et al., 2023). The research on reserve has also stimulated discussion on the positive aspects of ageing, including the reversibility of age-related declines and the resilience to maintain the functions before the declines emerge. It highlights the plasticity of the brain and the endurance of preventing age-related cognitive declines in older adults (Reuter-Lorenz & Lustig, 2005).

A meta-analysis by Opdebeeck et al. (2016) operationalised cognitive reserve in terms of three proxy measures, including (i) educational level, (ii) occupational status and (iii) engagement in cognitively stimulating activities, and reported that all three of them have significant positive effects on cognitive functions. Among the three proxy measures of cognitive reserve, engaging in cognitively stimulating activities is the one that has the greatest potential for older adults to accumulate cognitive reserve (Oosterhuis et al., 2023). Education-level attainment and occupational status refer to the demographic background and are not easily modifiable. In this connection, it is valuable to examine if engaging in leisure activities, a type of cognitive stimulating activities, are related to cognitive reserve.

In summary, the ageing process encompasses not just decline but also opportunities for maintenance and improvement. Neural compensation and cognitive reserve are crucial mechanisms for maintaining functions as individuals age. Of these, engaging in leisure activities appears to have the potential for accumulating cognitive reserve. The subsequent chapter will review and discuss the literature regarding leisure activity participation and its relationship with cognitive, psychological and daily functions, with a specific focus on one popular culturally specific activity in Asia, namely, mahjong playing.

Chapter 3

Literature Review: Leisure Activity Participation, Mahjong Playing and Ageing

3.1 Leisure Activity Participation and Cognitive, Psychological and Daily Functions

Leisure activities, such as reading and exercising, are defined as activities that people engage in for enjoyment or well-being instead of work or activities of daily living (ADL; Verghese et al., 2006). After retirement, older adults usually have greater flexibility in utilising their spare time. Spending time on leisure activities is one of the common choices among the older population. Previous studies have generally classified leisure activities into four domains: (i) intellectual/cognitive/mental activities, e.g., reading, and writing; (ii) social activities, e.g., visiting family/friends and attending church; (iii) physical activities, e.g., walking and jogging; and (iv) recreational activities, e.g., watching television and listening to radio (G. T. Y. Leung, K. F. Leung, et al., 2011; Stern & Munn, 2010; Wenzel et al., 2024).

Theories and empirical studies have supported the benefits of leisure activity participation on the grounds of active engagement, healthy lifestyle, and accumulation of cognitive reserve. First, the Activity Theory proposed by Havighurst (1948) postulated that active engagement in leisure activity would help promote better functions during ageing. Similarly, the STAC-r proposed that lifestyle factors, such as engaging in physical and intellectually stimulating activities, may contribute to enriching and maintaining neural resources during the ageing process (Daffner, 2010; Reuter-Lorenz & Park, 2014). Both theories suggest that leisure activity participation is positively related to better functions of ageing. Previous empirical studies have also shown that engaging in intellectual, physical, and social activities helped to maintain cognitive performance (Hertzog et al., 2008; Valenzuela & Sachdev, 2007) and accumulate cognitive reserve (Cappa, 2017). A review by Daffner (2010) has illustrated that engaging in physical and intellectually stimulating activities are the two major lifestyle factors in maintaining information processing capacity and enhancing cognitive reserve. Later, an updated review also addressed the importance of regular social engagement in enhancing cognitive reserve (Krivanek et al., 2021). J. Wang et al. (2020) also provided evidence to support that a higher frequency and longer duration of intellectual activities participation were associated with better global cognitive function. Findings of these empirical studies suggested that leisure activity participation plays a significant role in accumulating cognitive reserve. However, previous studies have primarily concentrated on a limited range of activities, and it remains unclear which domains and dosages of leisure activities yield the most significant effect in facilitating the cognitive, psychological, and daily functions. The following section reviews the literature related to the domains and dosages of leisure activity participation and cognitive, psychological and daily functions in older adults.

3.1.1 Cognitive Functions

3.1.1.1 Domains of Leisure Activity and Cognitive Functions. Evidence has shown that leisure activity participation could help to prevent the risk of cognitive decline, dementia and Alzheimer's disease (AD; Krueger et al., 2023; Scarmeas et al., 2001; Verghese et al., 2003; Zhu et al., 2017). A highly cited meta-analysis (i.e., 300 times in Scopus) reported that engaging in cognitively stimulating activities helps to accumulate cognitive reserve and, thus, prevents age-related declines in memory, EF, visuospatial ability, and language (Opdebeeck et al., 2016). Following this line of research, there is ample evidence which supports the positive relationship between intellectual leisure activity participation and the cognitive performance of older adults, as summarised in two systematic reviews (Iizuka et al., 2019; Stern & Munn, 2010).

In addition to intellectual activities, engaging in social and physical activities have also been found to help mitigate age-related cognitive decline or prevent the risk of cognitive impairment (Hammond & Stinchcombe, 2022; Hertzog et al., 2008; Muiños & Ballesteros, 2021). Recreational activities received the least attention in research, yet Gavett et al. (2024) reported that recreational activity engagement was associated with the maintenance of cognitive performance in older adults. These behavioural enrichment effects were further supported by a systematic review and meta-analysis of structural magnetic resonance imaging (MRI), in which increased cognitive and social activity levels were also associated with greater whole-brain white matter volume, greater regional grey matter volume, and fewer white matter lesions in older adults (Anatürk et al., 2018). Physical activity has also been found to positively associated with grey matter volume and mitigated the relationship between age and fractional anisotropy (Casaletto et al., 2020). Taken together, the evidence reviewed so far suggests that leisure activity, regardless of which domain, could promote cognitive health in older adults as measured not only behaviourally, but also using neural parameters.

3.1.1.1 Dosage of Participation and Cognitive Functions. A recent review explored the optimal dosage of participation, including frequency, intensity, duration and variety/diversity of activities (Wenzel et al., 2024). According to the results of the review, all studies included reported a significant positive association between the dosage of intensity, duration, and diversity of activities and cognitive performance in older adults. However, only 13 of the 15 studies reported a significant positive association between the dosage of frequency and cognitive performance; the remaining two studies found no significant relationship (Wenzel et al., 2024). This suggests that more research is needed to clarify the optimal dosage of the activity.

3.1.2 Psychological Functions

3.1.2.1 Domains of Leisure Activity and Psychological Functions. Research on the relationship between leisure activity participation and psychological functions remains limited compared to studies on cognitive functions. Despite this scarcity, previous studies have highlighted the potential of leisure activities to enhance psychological functioning such as reducing feelings of loneliness, improving life satisfaction, and promoting mental health including alleviation of depression, anxiety and stress (Leung et al., 2010; Teh & Tey, 2019; Tymoszuk et al., 2020; Wang et al., 2019; Xiaoyi et al., 2024; Yen et al., 2024). Studies also reported the positive influences of leisure activity participation on well-being (Adams et al., 2011; Lampinen et al., 2006) and quality of life (Gabriel & Bowling, 2004) in older adults.

Research in this area did not put a heavy emphasis on investigating which domain of the activity was associated with the greatest effect on psychological functioning. Instead, a scoping review showed that engaging in social, physical, cognitive, and recreational activities could all help to promote the mental health and well-being of older adults (Rivera-Torres et al., 2021). Previous studies also showed that participating in social activities such as volunteering and cultural activities would result in a positive impact on mental health, life satisfaction and help to reduce feelings of loneliness (Ma et al., 2020; Ryu & Heo, 2018; Teh & Tey, 2019). Moreover, previous studies tended to group the leisure activities as one unitary variable to examine its advantages in promoting psychological functioning in older adults, such as reducing loneliness (Wang et al., 2024), fostering life satisfaction, and alleviating stress and depression levels (Çol et al., 2022). For studies that examined leisure activities separately, some studies revealed that social and physical activity positively predicted life satisfaction and happiness but negatively predicted the level of loneliness and depression in older adults (Luo & Waite, 2014; Yen et al., 2024). Interestingly, Fingerman et al. (2022) investigated television watching, one of the recreational activities, and found that the positive association between watching television and loneliness was only significant in older adults who lived alone instead of older adults who lived with others. This finding prompted an examination of the demographics alongside the association between leisure activity and psychological functioning. In sum, the evidence reviewed so far suggests that leisure activity participation has the potential to promote better psychological functioning in older adults.

3.1.2.1 Dosage of Participation and Psychological Functions. Despite these advantages, there were very few studies that investigated the dosage of participation. Frequent and diverse social leisure activity participation has been found to be associated with a decline in depressive symptoms (Wang et al., 2019). One study reported that an increased frequency and intensity of physical leisure activity helped to improve life satisfaction in older adults (Skałacka & Błońska, 2023). Additionally, another study reported that moderate and frequent physical activity could reduce the odds of depression, while vigorous physical activity could increase the odds of depression (Meng et al., 2021). In the same study, no significant relationship was found between the duration of physical activity and the risk of depression (Meng et al., 2021). Nonetheless, Chen et al. (2012) showed that only the intensity of physical activity, instead of the duration and frequency, was significantly associated with depressive symptoms. In this area of literature that focused on the dosage of participation, it is clear that the research has placed a strong emphasis on physical activity, and the findings were mixed. More research is, therefore, needed to clarify the benefits of other domains, such as intellectual and social activities, on the psychological functions of older adults, along with the dosage effect.

3.1.3 Daily Functions

3.1.3.1 Domains of Leisure Activity and Daily Functions. Studies examining the relationship between leisure activity participation and daily functions are also limited in comparison to research on cognitive functions. Nevertheless, existing literature reported that leisure activity participation could promote the maintenance of functional ability in older adults. It included lower risk of poor self-rated health (Stalling et al., 2020), reduced risk of frailty (Zhao et al., 2022), and fewer limitations in ADL (Falk et al., 2014; Gu et al., 2023; Ukawa et al., 2022). Similar to the literature that reported benefits in psychological functioning, this body of literature on functional abilities also did not clarify which domain of activities contributed the most. Literature either focused on a few domains (D'Orsi et al., 2014; Gao et al., 2018; Gu et al., 2023) or grouped the activities as one unitary variable (Chen & Chippendale, 2017; Zhao et al., 2022). Taken as a whole, the literature seems to suggest that all four domains, including intellectual, social, physical and recreational activities, were helpful in reducing the risk of functional disability (D'Orsi et al., 2014; Fujiwara et al., 2009; Gao et al., 2018; Gu et al., 2023).

3.1.3.2 Dosage of Participation and Daily Functions. There were not many studies that investigated the effects of frequency, duration, intensity and diversity of activities on daily functions. Most studies measure the frequency of the activity, and a higher frequency was found to be associated with better daily functions (Gao et al., 2018; Wang et al., 2021; Zhao et al., 2022). Ukawa et al. (2022) found that the diversity of activities was positively associated with the maintenance of functional independence. The remaining studies used a dichotomous classification of the participation (i.e., yes or no), which did not clarify the dosage effect (D'Orsi et al., 2014; Falk et al., 2014; Gu et al., 2023).

3.1.4 Limitations of the Previous Research Studies

In light of the abovementioned evidence, three research gaps could be identified, namely (i) limited research on EF, psychological and daily functions, (ii) unclear effectiveness regarding the domains of activities, and (iii) unclear effectiveness regarding the optimal dosage of participation.

3.1.4.1 Limited Research on EF, Psychological and Daily Functions. First, the majority of the literature concentrated on the cognitive benefits of leisure activities, and there is a paucity of literature addressing the benefits of EF, psychological and daily functions.

EF refers to a broad range of cognitive abilities that help to organise, monitor and pursue goal-directed behaviours (Diamond, 2013). Specifically, it is a complex and important function for planning and executing tasks and managing daily independent activities (Vaughan & Giovanello, 2010). EF is closely related to the functions of the PFC, and the frontal lobe hypothesis of cognitive ageing also suggests that the prefrontal lobe is the first area to show malfunction in normal ageing (West, 1996). Miyake et al. (2000) have suggested that EF has three major components, including (i) inhibition, (ii) shifting (or task switching, hereafter referred to as switching throughout this thesis and in the subsequent sections), and (iii) updating and monitoring in working memory representations (hereafter referred to as working memory or updating throughout this thesis and in the subsequent sections).[2] Later,

[2] The terms, working memory and updating, referred to the same concept and were used interchangeably in the thesis.

Miyake and Friedman (2012) proposed a unity/diversity framework of EF and found that EF could be presented by a "common EF" at the unity level and two particular abilities, namely updating-specific (referred to as a working memory-specific factor) and shifting-specific factors (referred to as a switching-specific factor), at the diversity level. The absence of an inhibition-specific factor is because of the perfect correlation between the common EF and inhibition factor.

Many systematic reviews and meta-analyses have summarised the cognitive benefits of leisure activity participation (Iizuka et al., 2019; Opdebeeck et al., 2016; Stern & Munn, 2010). However, there are only a few studies that investigated the benefits of leisure activities on EF (Blasko et al., 2014; Park et al., 2014). Different from general cognitive functions, Blasko et al. (2014) reported that passive activity, such as watching television, showed the opposite effect on EF in older adults. Another empirical study conducted by Park et al. (2014) also found that engaging in intellectual or social activities may bring limited benefits to EF in older adults. Nevertheless, a study by Reas et al. (2019) reported that engaging in lifetime and late-life physical activity was found to be associated with better EF.

In addition to the limited evidence on EF, only a few reviews were conducted to examine psychological and daily functions (Rivera-Torres et al., 2021). Although some studies included more than one type of functions (Langlois et al., 2012; Ren et al., 2023; Simone & Haas, 2013), a comprehensive picture is lacking in the existing literature. For example, Ren et al. (2023) examined the benefits of cognitive and daily functions, while Langlois et al. (2012) investigated the benefits of cognitive performance and quality of life in older adults. Simone and Haas (2013) focused on the functional status and subjective well-being of older adults. To date, no study has included all the three categories of functions as measures and provided a thorough understanding of the benefits of leisure activity participation on the grounds of cognitive, psychological, and daily functions.

3.1.4.2 Unclear Effectiveness Regarding the Domains of Activities. Second, it remains unclear which domain(s) of activities (intellectual/social/recreational/physical), is/are most effective in promoting cognitive, psychological, and daily functions. Most previous studies included only one or two domains of leisure activity and did not systematically measure the extent and level of participation using different indices or measures. For example, some studies only focused on physical activity (Ahn et al., 2024; Lopez-Bueno et al., 2023), while others only focused on intellectual activity (Liu et al., 2021; Qiu et al., 2019). As such, very few studies have used a comprehensive approach to examine leisure activity participation and its relationship with variables. In light of the complexity of ageing and the importance to fully understand the beneficial effects of leisure activity participation on older adults, it is essential to comprehensively and systematically assess all four domains.

3.1.4.3 Unclear Effectiveness Regarding the Optimal Dosage of Participation. Third, although some recent findings have been reported regarding the dosage effect of activity participation, more research is needed to clarify the optimal dosage, including the frequency, intensity, duration, and diversity of the activities. The dosage was often found to be positively associated with cognitive performance (Wenzel et al., 2024), but mixed findings have been reported on the psychological and daily functions. For psychological functions, only intensity and frequency were positively associated with the odds of depression, while duration of the activity was not found to have a significant association (Meng et al., 2021). For daily functions, studies often measured frequency or a dichotomous classification of the participation, resulting in inconclusive findings (D'Orsi et al., 2014; Falk et al., 2014; Gao et al., 2018; Gu et al., 2023; Wang et al., 2021; Zhao et al., 2022). Therefore, more studies are needed to clarify the dosage effect on cognitive, psychological and daily functions.

3.2 Leisure Activity Participation in Hong Kong Older Adults

Despite the ample evidence on the benefits of leisure activity participation in Western countries (i.e., cognitive: Scarmeas et al., 2001; psychological: Gabriel & Bowling, 2004; functional: Everard et al., 2000), there are only a handful of studies that examined the benefits of leisure activity participation of older adults in Hong Kong. It should be noted that older adults in Asian societies may have a different pattern of lifestyle and a different preference for leisure activity participation, which could potentially lead to cultural differences in research findings. For example, some culturally specific activities such as mahjong playing, calligraphy, Tai Chi, and Qigong were common among older adults in Asian societies. Preliminary evidence has found that these culturally specific activities, such as Tai Chi and Qigong, are beneficial to the cognitive and physical functions of older adults (Park et al., 2023). An intervention study also revealed that mahjong playing, a popular intellectual and social activity, was beneficial in attenuating the progression of cognitive decline in older adults with dementia (Cheng, Chow, Song, Yu, & Lam, 2014). In light of the promising effect of physical and intellectual activities on age-related declines, it is reasonable to suggest that these activities may also play a role in facilitating better cognitive, psychological and daily functions. However, as limited research has been conducted, more studies are needed to update the nature and extent of leisure activity participation and its relationships with cognitive, psychological and daily functions among Hong Kong older adults.

3.2.1 Nature and Extent of Leisure Activity Participation among Hong Kong Older Adults

The earliest review that summarised leisure activity participation of Hong Kong older adults was conducted by Kwan (1990). It included 17 studies from 1972 to 1990 and synthesised the prevalence of participation to understand how older adults (aged 60 years or older) spent their leisure time.[3] Note that it was an exploratory study that aimed to summarise the available evidence regarding how older adults spent their leisure time, and it was neither a systematic review nor a meta-analysis. Nonetheless, it was an initial attempt that aimed to address the issue of the ageing population via understanding the patterns of activities and time spent among older adults. Kwan (1990) presented the background statistics of leisure activity participation and concluded that the most popular leisure activities among older adults in Hong Kong included watching television or movies, morning walking or Tai Chi exercise, social gatherings and mahjong or chess playing. One distinctive difference between the studies reviewed by Kwan and Western studies is the participation in activities related to the Chinese culture, such as taking part in the Chinese fitness exercise Tai Chi, listening to Chinese opera and playing mahjong. Kwan's review supported the claim that older adults in Asian societies may have a different preference for leisure activity participation. Therefore, it is important to investigate how leisure activities benefit Hong Kong older adults and how these Chinese cultural activities contribute to better functions of ageing.

One major limitation of Kwan's review is the absence of analysis of functional measures in terms of cognitive, psychological and daily functions. To address this gap, Chou et al. (2004) provided an update on the participation statistics among 2,180

[3] Number of participants in each included study ranged from $N = 19$ to $N = 1,172$.

Hong Kong older adults (aged 60 years or older) as well as correlation statistics between participation and cognitive, physical and daily functions and socioeconomic and health characteristics. The study used the data from the General Household Survey collected by the Department of Census and Statistics in Hong Kong since 1981 and documented that most of the older adults (93.9%) reported watching television or listening to the radio as an everyday leisure activity among the seven specified leisure activities, including (i) watching television/listening to radio, (ii) reading newspaper/books/magazines, (iii) socialising with relatives and friends, (iv) playing mahjong or cards, (v) exercising in the morning/strolling in the park, (vi) going out for breakfast, and (vii) strolling on the street/shopping (Chou et al., 2004). Results indicated that frequent engagement in reading was associated with better cognitive abilities, while frequent engagement in social and physical activities was associated with better functional independence (Chou et al., 2004). Although the study examined the association between leisure activity participation and cognitive and daily functions, one limitation was the small number of leisure activities included. With only seven specific activities included, the research provided limited insights regarding the benefits of the diversity of activities on cognitive and daily functions. Including a greater diversity of activities may help to increase the explained variance in the regression model and enhance the comprehensiveness of findings regarding the benefits of leisure activity participation. Moreover, the frequency measured by Chou et al. (2004) was rated on a 5-point scale, ranging from 0 (*not at all*) to 4 (*every day*). A score of one on the scale indicates a frequency of less than once a week. Given that the study assessed the times of engagement during an average week, it is unclear that the frequency of biweekly, monthly, and yearly participation was coded as 0 (no participation) or 1 (less than once a week; Chou et al., 2004). In this case, the results may not accurately capture some activities with lower participation frequencies. For example, older adults may report a lower frequency of playing mahjong or cards since the activities require multiple players (Tian et al., 2022). Given that retrospective data were used by Chou et al. (2004), it is understandable that the design and measures were difficult to modify. In any case, the study provided valuable insight and preliminary evidence to support the association between leisure activity participation and cognitive and daily functions. Nevertheless, more studies, with a comprehensive design and functional measures, are needed.

Cheung et al. (2009) conducted another cross-section study and included 269 older adults (aged 65 years or above) to understand the relationship between leisure activity participation and health-related quality of life. The study included a greater diversity of activities, in which it categorised 18 leisure activities into four domains, namely: recreational, cognitive, social and productive activities. The frequency of participation was rated on a 6-point scale, ranging from 0 (*never*) to 6 (*daily*). In contrast to Chou et al. (2004), frequency of "one to three days per month" and "less than once per month or occasionally" were included in the scale. Results showed that the common everyday leisure activities included watching television (98.9%), listening to music/radio (57.2%), reading books/newspapers/magazines (57%), caring for pets/plants (38%) and gathering with people for meal/shopping (32%). The study also reported that engagement in cognitive and social activities was positively associated with quality of life, as measured by the Short Form-12 version 2. However, unexpectedly, engaging in more productive activities, such as volunteering and caring for pets/plants were associated with poor quality of life. Engaging in recreational activities was also found to have a marginally negative association with the quality of life. Similar to Chou et al. (2004) and Kwan (1990), Cheung et al. (2009) also included some activities related to Chinese culture, such as mahjong playing and gathering with people for meals. The study suggested that leisure activity may help to provide sources of relief from stressful life events for older adults, including companionship developed during the engagement in social activity and the self-determination developed during leisure activity participation (Cheung et al., 2009). The study offered a systematic approach to investigate the relationship between leisure activity participation and quality of life in older adults. Nonetheless, as stated in the study, only the frequency and types of leisure participation were measured, and the sample size was relatively small. A more holistic approach is needed to understand how leisure activity participation influences the cognitive, psychological and daily functions of older adults.

An update regarding leisure activity participation among Hong Kong older adults was conducted by Zhao and Chen (2013). It aimed to examine the nature and extent of leisure activity participation in Hong Kong older adults. It included 130 older adults (aged 65 years or above) and measured the demographics and leisure activity participation pattern, motivation, benefits and constraints. Sixteen leisure activities were categorised into four domains, namely: physical, recreational, social, and intellectual. Frequency of participation was measured on a 5-point scale, ranging from 0 (*none*) to 5 (*everyday*). Frequency less than weekly participation, such as biweekly and monthly, was rated as “occasionally” in this study. Similar to the findings of previous studies (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990), the most common leisure activities were watching television (97.2%), reading books/newspaper (43.4%), slow walking (32.1%) and listening to the radio/music (30.2%). Conversely, different from the three previous studies (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990), this study included fewer activities related to Chinese culture. Only Tai Chi/ Qigong was included in the Leisure Activity Participation Questionnaire. Similar to Kwan's review, this study did not include a more comprehensive analysis of measures of cognitive, psychological, and daily functions. Alternatively, it collected the motivation, perceived benefits, and constraints of the engagement. Regarding motivation, it was reported that enjoyable experiences, improving health conditions, and enriching life were the three important motivation sources of participation. Older adults also showed that participating in leisure activities has brought them enjoyable experiences and relaxation. More importantly, the study also pointed out that ageing and poor health conditions were the two crucial constraints for restraining participation in leisure activities. On the one hand, given that the sample size is limited, the research encouraged large-scale studies to understand the comprehensive nature of the issue. On the other hand, research also highlighted that the preference for the choice of activities among older adults was mainly determined by the perceived meaningfulness towards the activity. Therefore, it is important for future research to consider the meaningfulness and the enjoyment of the activity while promoting leisure activity engagement among Hong Kong older adults. In this case, activities related to the Chinese culture would show great potential to increase the motivation for engagement and pleasurable experiences of older adults. Mahjong playing, as mentioned by Cheung et al. (2009), is "the most culturally relevant cognitive activity in the Chinese community and can be played by those who are illiterate". The features of complexity, variation, and excitement may attract older adults, and it seems to be a potential activity to facilitate active engagement in leisure activities in older adults (Cheung et al., 2009).

3.2.2 State of Research: Leisure Activity Participation and Cognitive, Psychological and Daily Functions in Hong Kong Older Adults

Before describing and reviewing the current literature on mahjong playing, the following section summarises the state of research regarding leisure activity participation and the cognitive, psychological and daily functions. Instead of investigating each specific activity, this body of research categorised similar activities into one domain and studied the association between the domain of the activity and the targeted outcomes, such as cognitive and psychological health. There is a paucity of studies in the field of leisure activity participation and its benefits for older adults. In light of the limited evidence, six studies regarding the development of a standardised leisure activity scale and its application are summarised in the following paragraphs.

Regarding the limited diversity of the activities in the previous literature, G. T. Y. Leung, K. F. Leung, et al. (2011) developed a classification scale with 33 leisure activities, which included 13 intellectual, 8 social, 9 recreational, and 3 physical activities.[4] The domains of the 33 activities were firstly classified by a focus group that comprised of professionals, which included psychogeriatricians, social worker, clinical psychologist, occupational therapists and physiotherapists. Seventy-five older adults were then recruited to assign the 33 activities into four domains (i.e., intellectual, social, recreational and physical) and evaluate the helpfulness of the activity in training the relevant ability. For example, the helpfulness of the intellectual activity in training memory and thinking. After that, an expert panel validated the classification of the 33 leisure activities with respect to the opinions of the older

[4] The three physical activities refer to three groups of exercise, which are mind-body exercise, strenuous aerobic exercise and stretching and toning exercise. Within each group of exercise, there are more specific activities such as Tai Chi and Qigong under the mind-body exercise, and swimming and dancing under strenuous aerobic exercise. In total, there are 18 physical activities.

adults. Importantly, the scale included plenty of activities related to Chinese culture, such as mahjong playing, calligraphy, watching Chinese opera performances, Tai Chi, Qigong, Chinese martial arts and pebble trail walking. The scale also contributes to a systematic classification of the activities, thus helping to improve the quality and comprehensiveness of the subsequent research. Yet, more clinical trials with larger sample sizes are needed to examine the benefits of leisure activity participation.

Leung et al. (2010) also used the earlier version of the leisure activity scale and assessed 512 older adults (aged 61-100 years) to examine the relationship between leisure activity participation and cognitive functions. Many cognitive and neuropsychological assessments were administered, such as the Digit Span Test, Category Verbal Fluency Test, Word List Learning, Cantonese-version Mini-Mental State Examination (CMMSE) and the Cantonese version of the Alzheimer's Disease Assessment Scale-cognitive subscale. Results showed that engaging in intellectual activities was associated with better cognitive functions. The study found that the diversity of intellectual activities may be more important than the frequency and duration of the activities, in which a greater diversity of activity was often significantly associated with cognitive functions.

Apart from cognitive functions, G. T. Y. Leung, A. W. T. Fung, et al. (2011) also analysed 505 older adults (aged 61-100 years) and aimed to examine the association between leisure activity participation and the incidence of global cognitive decline in older adults. This study used the same classification system of leisure activity (i.e., G. T. Y. Leung, K. F. Leung, et al., 2011) and measured three types of dosage of participation (i.e., total number of subtypes, total frequency and total hours per week). The incidence of cognitive decline was measured by a one-point decrease in z-score in the CMMSE. Results showed that a greater total number of subtypes and greater total hours per week of intellectual activities were associated with a lower incidence of global cognitive decline. Besides, a greater number of subtypes of physical activity was found to predict a higher incidence of global cognitive decline. However, the association became non-significant when non-aerobic exercise was excluded from the analysis. The study also found no significant relationships between recreational, social and overall activity participation and the incidence of global cognitive decline.

Apart from merely understanding the relationship between leisure activity participation and the performance and decline of cognitive function, Fung et al. (2011) further examined the factors that may modulate the cognitive function of older adults. They classified 476 older adults (aged 60-92 years) into four groups according to their cognitive performances at the 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles, which represented cognitive functions at very low, low, high and very high levels, respectively. Two comparisons were made, particularly between the 25^{th} and 75^{th} percentiles and between the 10^{th} and 90th percentiles. Both comparisons showed that cognitive function was positively associated with the frequency of intellectual activities performed. The frequency of physical activities was only negatively associated with cognitive function in the comparison between the 10^{th} and 90^{th} percentiles. Given that the sample size of this group of comparison is small (i.e., 43 and 66 older adults in the 10^{th} and 90^{th} percentiles, respectively), it is suggested that more studies are needed to clarify the relationships, especially the relationship between physical activities and cognitive functions. Nevertheless, the research highlighted the importance of the frequency of intellectual activities on cognitive functions.

There is another piece of research which focused on the association between leisure activities, cognitive functions and purpose in life (i.e., a psychological outcome). Apart from the four domains of activities (i.e., intellectual, social, recreational and physical), Fung and Lam (2013) revised the scale developed by G. T. Y. Leung, K. F. Leung, et al. (2011) and included two additional domains of activities, including spiritual and prosocial activities. The study recruited 380 older adults (aged 60-97 years) and found that cognitive function was positively correlated with frequencies of aerobic exercise, intellectual activity, and spiritual activity. However, it was reported that cognitive function was negatively correlated with the frequency of stretching and toning exercises. A follow-up linear regression analysis revealed that only the frequencies of intellectual and spiritual activity could significantly predict the cognitive performance of older adults. This study also investigated the relationship between leisure activity participation and purpose in life. Results found that purpose in life was positively correlated with spiritual, intellectual, and social activities. Linear regression also showed that the frequencies of spiritual, social and intellectual activities could predict a better purpose in life. More importantly, only spiritual activity was a significant predictor when the results were controlled for the effect of loneliness, age and years of education.

Su et al. (2018) conducted a study with older adults in Hong Kong and Guangzhou and aimed to examine the relationship between social activity and cognitive functions in older adults. The study included 557 older adults aged 60 years and above, with 297 older adults from Guangzhou and 260 older adults from Hong Kong. Social activity participation was measured by the total number and the total hours per week of social activities in the social domain of the validated checklist (i.e., G. T. Y. Leung, K. F. Leung, et al., 2011). After controlling for the demographics and the engagement in the other three domains of activities, only the total number of social activities could significantly predict cognitive performance as measured by the

Digit Vigilance test. While a greater number of social activities could predict better cognitive performance, the study also explored the relationships between individual social activities and the cognitive performances from each neuropsychological test. For example, attending an interest class consistently predicts better performance in the CMMSE, the Word List Learning test, the Delayed Recall Test, and the Trail Making Test (TMT). Religious activity was also found to have a significant positive association with the Word List Learning Test and the Digit Vigilance Test. Singing was also found to significantly predict better performance in the Category Verbal Fluency Test and the TMT. Although some of the older adults were from Guangzhou instead of Hong Kong, this study highlighted that some social activities, such as attending an interest class, could serve as a form of training for older adults. This is because some social activities may have overlapping components with intellectual activities such as attending an interest class or mahjong playing. In that case, older adults who have received little education may receive educational opportunities, social interaction and cognitive stimulation during their participation in social activities. The study also suggested that the quality of social activity should be examined in future studies, such as the satisfaction and burdens of engagement.

3.2.3 Limitations of the Previous Research Studies in Hong Kong Older Adults

Similar to Western studies, the research conducted in Hong Kong also shared similar research gaps, including (i) limited evidence on EF, psychological and daily functions, and (ii) uncertain effectiveness regarding the domains of activities and optimal dosage of participation.

3.2.3.1 Limited Evidence on EF, Psychological and Daily Functions. Almost all of the previous studies conducted in Hong Kong focused primarily on general cognitive benefits, such as associating with better cognitive ability (Fung & Lam, 2013; Fung et al., 2011; Leung et al., 2010; Su et al., 2018), preventing cognitive declines (G. T. Y. Leung, A. W. T. Fung, et al., 2011) and reducing the risk of dementia (Wong et al., 2016). There are very few studies that focus on EF, psychological and daily functions.

Although some studies have included EF tests (Fung & Lam, 2013; Fung et al., 2011; Leung et al., 2010; Su et al., 2018), only two studies have separated the analyses of general cognitive function and EF (Leung et al., 2010; Su et al., 2018). Particularly, Su et al. (2018) investigated switching and inhibition with the Category Verbal Fluency Test, TMT, and Stroop Colour Word Interference Test. Leung et al. (2010) also investigated switching and working memory with the Category Verbal Fluency Test and Backward Digit Span Test, respectively. The remaining two studies analysed cognitive function as a composite variable and did not separate the general cognitive function and EF (Fung & Lam, 2013; Fung et al., 2011). Results from the two studies regarding EF were promising. They found that engaging in leisure activities was positively associated with working memory (Leung et al., 2010) instead of inhibition (Su et al., 2018). Moreover, the two studies reported mixed findings regarding switching (Leung et al., 2010; Su et al., 2018). On the one hand, Leung et al. (2010) showed that engaging in a higher level of intellectual and social activities was associated with better switching as measured by the Category Verbal Fluency Test. On the other hand, Su et al. (2018) reported that engaging in higher levels of intellectual activities and lower levels of recreational activities were associated with better switching as measured by the TMT. No significant findings were reported from the Category Verbal Fluency Test in Su et al. (2018). Given the small number of studies conducted and the mixed findings, more studies are needed to provide conclusive results.

Only a few studies have explored the benefits of leisure activities on psychological and daily functions. Fung et al. (2011) showed that a higher level of loneliness was associated with worse cognitive performance in older adults, but it did not discuss the relationship between activity participation and loneliness. In another study, Fung and Lam (2013) reported that participating in a higher frequency of spiritual activity would help to predict a better purpose in life (i.e., a psychological outcome) in older adults, after controlling for loneliness, age and years of education. In these studies, psychological health and daily functions were mainly measured as a potential confounding or demographic variable instead of an criterion variable (Fung & Lam, 2013; Fung et al., 2011; Leung et al., 2010; G. T. Y. Leung, A. W. T. Fung, et al., 2011; Su et al., 2018). Some other studies did not use the classification scale developed by G. T. Y. Leung, K. F. Leung, et al. (2011) also reported some positive impacts of engaging in leisure activities on quality of life (Cheung et al., 2009) and mental health (Liu et al., 2023). Therefore, the impact of leisure activity participation on psychological and daily functions should not be overlooked. However, there were very few studies had been conducted. Thus, more studies are needed to clarify the benefits of leisure activity participation in psychological and daily functions in older adults.

3.2.3.2 Uncertain Effectiveness Regarding the Domains of Activities and Optimal Dosage of Participation. The studies carried out in Hong Kong also lack a comprehensive understanding of how the domains and dosages of leisure activity participation are related to outcomes. Regarding domains, Fung et al. (2011) focused on cognitive activities and revealed that a higher level of cognitive activity participation was associated with better cognitive performance in older adults. Additionally, Fung and Lam (2013) found that engaging in cognitive and spiritual activities made a significant contribution to the prediction of cognitive functions in older adults. Regular participation in intellectual, stretching and toning physical exercises was also significantly associated with a reduced risk of poststroke dementia (Wong et al., 2016). Some specific social activities, such as attending an interest class, religious activity, and singing, were associated with better cognitive functions in older adults (Su et al., 2018).

Regarding optimal dosage, two studies have divided the dosage into three dimensions, including diversity, frequency and duration (Leung et al., 2010; G. T. Y. Leung, A. W. T. Fung, et al., 2011). The main results from Leung et al. (2010) indicated that an increased diversity, frequency, and duration of intellectual leisure activity and an increased diversity of social leisure activity were associated with better cognitive functions. However, G. T. Y. Leung, A. W. T. Fung, et al. (2011) reported that an increased diversity and duration of intellectual activity and a decreased diversity of physical activity predicted a lower incidence of global cognitive decline. In light of the mixed findings, it is important to conduct a comprehensive study to investigate how different domains and dosages contribute to cognitive, psychological and daily functions.

Compared with Western studies, one characteristic of the studies conducted in Hong Kong relates to the inclusion of culturally specific activities such as Tai Chi, Qigong, mahjong playing and calligraphy. It supplemented the prevalence and effectiveness of these Chinese cultural leisure activities in older Asian adults. Although age-related differences across cultures have been more often observed in social and personality research domains (Fung, 2013, 2024), it is believed that these culturally specific activities may promote an active engagement among the Chinese older adults, which may help to facilitate an active lifestyle and promote better functions of ageing (Havighurst, 1948). According to Fung (2013, 2024), ageing is a meaning-making process, and individuals from different cultures may engage in some culturally specific leisure activities. The socioemotional selectivity theory also proposes that older adults would shift their goals of living from knowledge goals (e.g., acquire new skills) to emotional goals (e.g., enjoying positive emotions; Cartensen et al., 2003). It is believed that these culturally specific activities may be culturally meaningful, which may help to fulfil emotional goals, facilitate an active lifestyle (Havighurst, 1948), and promote better functions among Chinese older adults. Therefore, this thesis selected one popular cultural-specific activity, mahjong playing, among Asian countries as a medium to better understand how leisure activity promotes better functions of ageing.

3.3 Mahjong Playing as a Specific Leisure Activity in the Asian Context

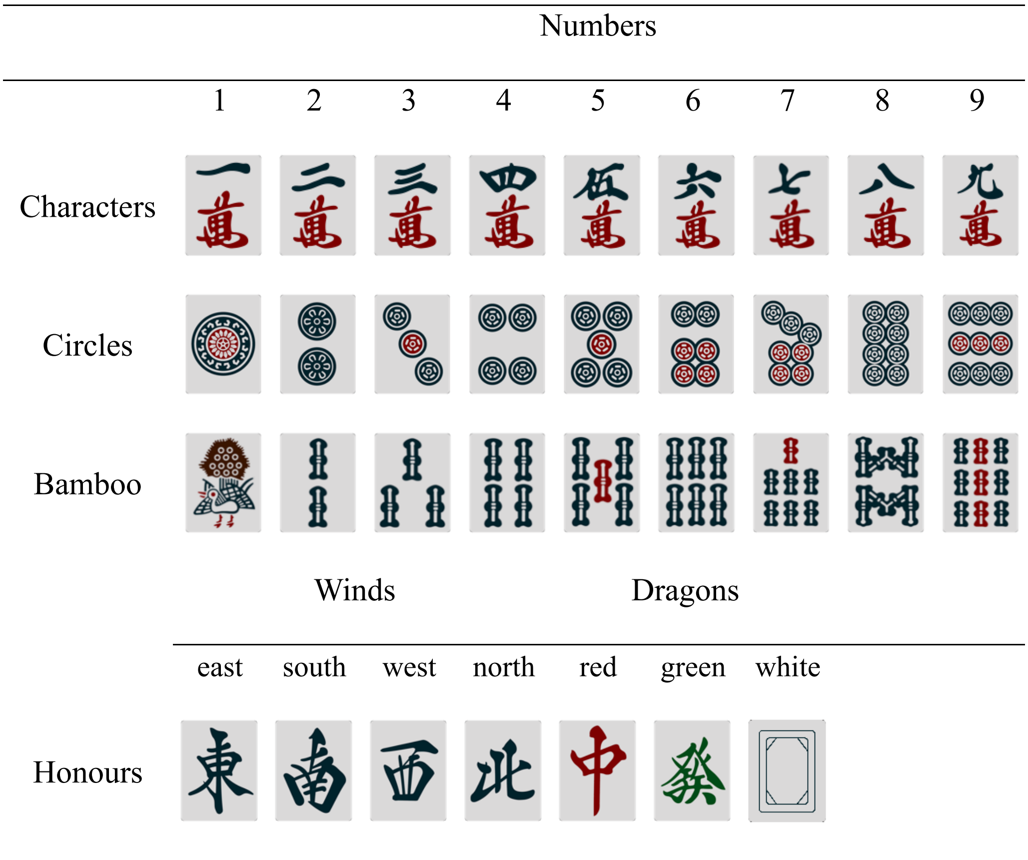
Mahjong is a popular intellectual and social leisure activity in Asian societies. It is a traditional and popular game regarded as China's national game (Greene, 2015). Older adults often play mahjong during family gatherings and festivals. Therefore, gathering to play mahjong has strengthened the social bonds of older adults with family and friends, symbolising an important life event for them. The game is also widely played in Asian countries, enjoyed by both the wealthy and the poor in rural and urban areas (Greene, 2015; Zhang et al., 2023). Some Asian countries have developed variations of the game, such as Japanese Mahjong and Vietnamese Mahjong.

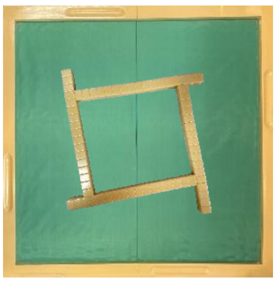
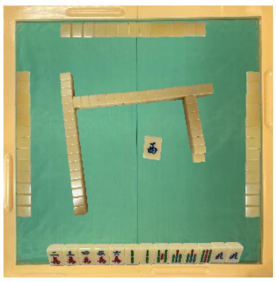
In the most recent study regarding the nature and extent of leisure activity participation in Hong Kong, the average prevalence rate of mahjong playing in older adults was 25.8% among older adults in Hong Kong (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990). Kwan (1990) mentioned that mahjong playing is more than gambling; it is also a social gathering event for older adults to spend their leisure time. Cheung et al. (2009) also emphasised the cognitive complexity nature and the ease of taking part in mahjong game. By definition, mahjong is a multi-player game, and it usually involves 136 to 152 tiles (Cheng et al., 2006). Figure 3.1a displays the 34 base tiles of a 136-tile mahjong set, in which each base tile has four copies in one tile set. Four categories are shown, including characters, circles, bamboo, and honour. The characters, circles, and bamboo tiles consist of numbers one to nine, while the honour tiles consist of four winds and three dragons. Figures 3.1b (i-iii) illustrate the simple process of the game. Players start the game by building the wall with the tiles facing down in the middle of the mahjong table (see Figure 3.1bi). Then, each player will take tiles from the wall, specifically, the first player will receive 14 tiles, while the other players will receive 13 tiles (see Figure 3.1bii). Afterward, the first player will discard one tile from the current hand, and the next player will either take the discarded tile or draw another tile from the wall (see Figure 3.1biii). The game continues as the players keep taking turns to draw and discard tiles until one of the players claims to win by forming a certain set of combinations. Players are only eligible to claim a win by forming a certain grouping such as triplet (three tiles grouped with the same pattern; see Figure 3.1ci), sequence (three tiles grouped with either ascending or descending orders; Figure cii), or pair (two tiles with the same pattern; see Figure 3.1ciii) as fast as possible. A winning hand should consist of one pair and four sets of triplets or sequences. Figure 3.1d shows an example of the winning hand.

Figure 3.1

An Example Set of Mahjong Base Tiles, Basic Groupings, a Simple Illustration of the Game, the Examples of Mahjong Groupings and an Example of Winning Hand

(a)



(bi)  (bii)  (biii) 

(ci)  (cii)  (ciii) 

(d) 

Note. (a) An example set of 136-tile mahjong, showing the 34 base tiles in the character, circles, bamboo and honours categories. (b) A simple illustration of a four-player mahjong game, where players will be seated at each of the four sides of the green mahjong table. (bi) Players start the game by building the wall in the middle of the mahjong table, (bii) then the first player (as indicated by the tiles facing upward) will receive 14 tiles from the wall, and the other three players (as indicated by the tiles facing downward) will receive 13 tiles, (biii) the first player will start the game by discarding one tile from the hand, i.e., west in this case. The next player will either take the discarded tile or draw another tile from the wall. (c) Three common mahjong groupings, including (ci) a triplet (cii) a sequence, and (ciii) a pair. (d) An example of a winning hand consists of 14 tiles in total, it includes at least one pair and four sets of triplet or sequence.

3.3.1 Prevalence Rate of Mahjong Playing in Hong Kong Older Adults

In Hong Kong, it has been reported that 14.2% to 16.7% of older adults played mahjong or cards more than one to two times a week (Cheung et al., 2009; Chou et al., 2004). In Ho and Chan's (2005) study, a 10-point scale ranging from 0 (*never*) to 9 (every day) was used to measure the frequency of mahjong playing, and the results showed a mean frequency of 2.38 among older adults in Hong Kong. Given that 2 (*three to four times a year*) represents yearly participation on the 10-point scale, it may imply that most of the older adults in Hong Kong often engage in mahjong playing yearly instead of weekly.

Given that, only 14.2% to 16.7% of older adults played mahjong weekly (Cheung et al., 2009; Chou et al., 2004), 83.3% to 85.8% of the older adults have never played mahjong or played it on a monthly or yearly basis. It highlighted two groups of older adults: (i) novel players and (ii) infrequent players. Both groups are not experts in mahjong playing, and extensive cognitive efforts may be required during the game. As suggested by Park et al. (2014) and Opdebeeck et al. (2016), engaging in a novel and cognitively demanding activity could help to promote cognitive benefits and accumulate cognitive reserve in older adults. Cheng et al. (2006) further highlighted the novelty of mahjong playing: “Each game is a new one, and therefore presents a completely different combination of stimuli for the player—this is something not always achievable with professional intervention programs” (p. 612). Hence, it is reasonable to suggest that mahjong playing is a potential activity that can help to accumulate cognitive reserve and facilitates better functions of ageing. Nonetheless, it should be noted that the prevalence rate of mahjong playing in Hong Kong older adults has not been updated since Chou et al. (2004) and Cheung et al. (2009). Also, more research is needed to better understand how mahjong playing promotes better functions of ageing.

3.3.2 Limitations of Previous Research Studies and Potential Research Directions

Four research directions are proposed to further explore the benefits of mahjong playing.

3.3.2.1 Mahjong Playing and EF. One limitation of this research area is that the studies have focused on the benefits of mahjong playing for general cognitive function in older adults instead of EF. Current literature often used the Mini-Mental State Examination (MMSE) or Chinese version of the Mattis Dementia Rating Scale (CDRS) to assess global cognitive function (Ho & Chan, 2005; Mai et al., 2023; Mao et al., 2020; Yu et al., 2021; Zhang et al., 2023). Only a small number of studies have assessed the benefits of mahjong playing on EF (Cheng, Chow, Song, Yu, Chan, et al., 2014; Lu et al., 2015; Zhang et al., 2020).

Mahjong is considered to involve not only general cognitive functions but also

EF. In the training studies conducted by Cheng et al. (2006), he suggested that the game requires attentional control and alertness, speed of information processing, and visual-motor coordination. Ho and Chan (2005) further proposed that the game involves memory, conceptualisation, and cognitive flexibility. Noticing that the game is intellectually challenging, it shares characteristics that are highly similar to EF. For example, when the players sort and arrange the sequence of the tiles, it may require the ability to hold and manipulate the information in the mind, which is highly similar to working memory. Thinking of which tile to discard and which tile could increase the winning probability may also require the ability to switch, inhibit, and plan, and these abilities are also highly similar to other sub-components of EF (i.e., switching and inhibition). The similarities between the mahjong game rules and the characteristics of EF prompt further investigation into the relationship between mahjong playing and EF.

3.3.2.2 Mechanisms of Mahjong Playing. Moreover, the underlying mechanisms of how mahjong playing is associated with better functions remain unclear. Mahjong playing is regarded as an intellectual and social leisure activity, yet the majority of the literature considered it as a general leisure activity and did not examine specifically its cognitive or social characteristics in the research questions (Chou et al., 2004; Deng et al., 2018; Lee et al., 2020; Mao et al., 2020; Ren et al., 2023; Sha et al., 2022; Tang et al., 2021; S. Wang et al., 2022; Yu et al., 2021; Zhao et al., 2023). On the one hand, mahjong playing requires cognitive skills to sort, arrange and discard tiles. On the other hand, mahjong playing also requires social skills to interpret the intentions and predict the actions of other players. To further support the strength of studying mahjong playing, it is crucial to elucidate the relationship between the game rules and the cognitive and social functions. Particularly, it would be useful to separate the cognitive and social components and examine how one of them contributed to the benefits of mahjong playing in older adults. For example, future studies should examine whether the cognitive component of mahjong playing could help to mitigate the age-related cognitive decline or accumulate the cognitive reserve of older adults. Considering this approach, it provides a clearer picture and better explanation of how mahjong facilitates cognitive benefits in older adults.

3.3.2.3 Mahjong Playing and Neural Activation. There is also limited evidence on the relationship between mahjong playing and brain activation. To better examine whether mahjong playing could help to accumulate cognitive reserve, it would be valuable to measure brain activation during the game. In light of the CRUNCH, it is expected that older adults who play mahjong regularly would have greater brain activity to compensate for the age-related decline in behavioural performance (Reuter-Lorenz & Cappell, 2008). It is important for future studies to collect behavioural and neural measures concurrently. It helps to facilitate the explanation of how mahjong playing works and promotes positive impacts in older adults. To date, only one study has used functional near-infrared spectroscopy (fNIRS)[5] to measure cortical activation during the mahjong game (Fujimori et al., 2015). The study aimed to compare the brain responses across the virtual world and the real world. Three conditions of the mahjong game were designed, including (i) a solitaire video game (i.e., playing with three virtual players on the computer), (ii) a real-life version with three other players without conversation and (iii) a real-life version with three other players with conversation. The study recruited 14 participants and required them to participate in all three conditions. To accommodate the neural data acquisition, a

[5] The term fNIRS is used interchangeably with NIRS in the field. By definition, NIRS is a non-invasive imaging method, and it is a tool for functional neuroimaging, viz., fNIRS (Cui et al., 2010).

block design with three task periods (i.e., each task period lasted for 300 s) and four rest periods (i.e., rest period lasted for 10 s to 20 s) was implemented in each condition. In data analysis, the hemodynamic responses between the task blocks and the rest periods were first compared, and the resulting *t*-values from the three settings were then analysed using one-way analysis of variance (ANOVA). Results showed that the two real-life conditions both demonstrated significantly greater activation compared to the video game condition, and the two real-life conditions did not show significant differences (Fujimori et al., 2015). These results suggest that playing mahjong in a real-life setting may increase brain activation greater than in a video game setting. However, it should be noted that the solitaire video game is a matching game that uses a set of mahjong tiles, and it does not require the abovementioned cognitive skills. Furthermore, this study did not recruit older adults, which means the findings may not be generalised to the older population. More importantly, the study only collected neural evidence but not behavioural responses. Nevertheless, the results supported the claim that, compared to resting sedentary states, playing mahjong increases brain activation. Regarding this piece of preliminary evidence, it is possible to extend the target population to older adults and examine if playing mahjong could also help to increase the brain activity of older adults.

3.3.2.4 Mixed Findings on the Benefits of Mahjong Playing in Older Adults. Evidence related to mahjong playing is still accumulating, and the findings regarding its benefits in older adults are mixed. On the one hand, literature supported the positive impact of mahjong playing on older adults, such as better prevention of cognitive decline (Zhang et al., 2023), better psychological status as measured by less loneliness (Teh & Tey, 2019) and reduced risk of functional decline (Gao et al., 2018). On the other hand, contradictory results have shown that playing mahjong or cards was negatively correlated with functional independence (Chou et al., 2004). Compared with reading, Ho and Chan (2005) also reported that mahjong playing was not related to general cognition.

Literature did not provide a conclusive finding regarding the optimal frequency of mahjong playing. Only some studies have explored the frequency of mahjong playing, in which the results showed that a higher frequency could predict better functions compared with occasional or no participation at all (Gao et al., 2018; Teh & Tey, 2019; Zhao et al., 2023). Other studies examined the benefits of mahjong playing with a dichotomous classification (i.e., either participated or not), which did not provide sufficient information regarding the optimal dosage (Ren et al., 2023; Zhang et al., 2023).

The implementation of mahjong as a training for older adults who have dementia also reported positive effects on cognitive functions and depressive symptoms (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014; Cheng et al., 2012). It should be noted that the designs of these training studies are mostly randomised controlled trials (RCT), which provide the strongest evidence of the benefits of mahjong playing. Notably, the training studies emphasised clinical populations such as older adults with mild cognitive impairment (MCI; Zhang et al., 2020) or dementia (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014; Cheng et al., 2012) instead of the healthy population. Only Lu et al. (2015) investigated the efficacy of mahjong training on healthy older adults.

Considering the limited number of studies, it is difficult to understand whether and how mahjong playing helps to promote better functions of ageing. The mixed results highlight the need to further clarify the mechanism and effectiveness of mahjong playing. It is critical to explore the optimal frequency of mahjong playing, as well as the effective duration of exposure, to yield significant advantages. In sum, more research is needed regarding how mahjong playing promotes better functions of ageing and accumulates cognitive reserve in healthy older adults.

3.4 Rationale of the Present PhD Study

Chapters 2 and 3 reviewed the theories of dynamics of ageing, the concept of cognitive reserve, and the current literature on leisure activity participation and mahjong playing. Importantly, the review suggested that engaging in leisure activities and mahjong playing would be useful in promoting better functions of ageing. However, studies conducted to date are limited and prevent clear conclusions from being drawn. The current PhD project considered the limitations in the existing literature and devised three studies based on the following three rationales.

3.4.1 Clarify the Effective Domains and Dosages of Leisure Activity Participation and Extend the Scope of Research to EF, Psychological and Daily Functions

Given that the STAC-r model proposed life-course factors such as life experiences and environmental influences may facilitate neural enrichment and further accumulate the cognitive reserve, it would be useful to investigate what type of experiences could strengthen cognitive reserve and result in better functions in older adults. The current literature explored the benefits of engaging in leisure activities to promote better functions of ageing. However, three limitations were identified: (i) limited research on EF, psychological and daily functions, (ii) unclear effectiveness regarding the domains of activities, and (iii) unclear effectiveness regarding the optimal dosage of participation. Therefore, the first study (Study 1) employed a cross-sectional survey design and comprehensively examined the relationship between leisure activity participation, mahjong playing and the cognitive, psychological and daily functions of older adults.

3.4.2 Investigate Mahjong Playing as a Culturally Specific Activity and Clarify Its Benefits in Older Adults

Most of the cognitively stimulating leisure activities in previous studies are either from Western countries or culturally general activities, such as reading, playing bridge, or doing crosswords (Opdebeeck et al., 2016). Considering the cultural context in ageing research (Fung, 2013, 2024), it is important to explore if there are culturally specific activities in Asian countries that could help to promote better functions of ageing. Given that mahjong playing is a popular activity among older adults in Hong Kong, it is selected as the culturally specific leisure activity in this PhD project. However, in the literature, limited evidence and mixed findings were reported. A scoping review (Study 2) was proposed to evaluate the existing evidence across the Western and Asian databases, as well as identify the research gaps for future research.

3.4.3 Examine the Underlying Mechanisms and Neural Basis of Mahjong Playing

The mechanism of how mahjong playing facilitates better functions of ageing remains a major limitation in the current literature. Mahjong playing is considered a general leisure activity with cognitive and social components in the literature, and only one study has probed into the neural activations of mahjong playing. Regarding the complexity of the game rules and the extensive cognitive efforts during the game, it is possible to suggest that mahjong playing is related to EF. An experimental study (Study 3), separating the cognitive component from the social component, and incorporating both behavioural and neural evidence, was conducted to examine the underlying mechanisms and neural basis of mahjong playing.

3.5 Aims and Objectives

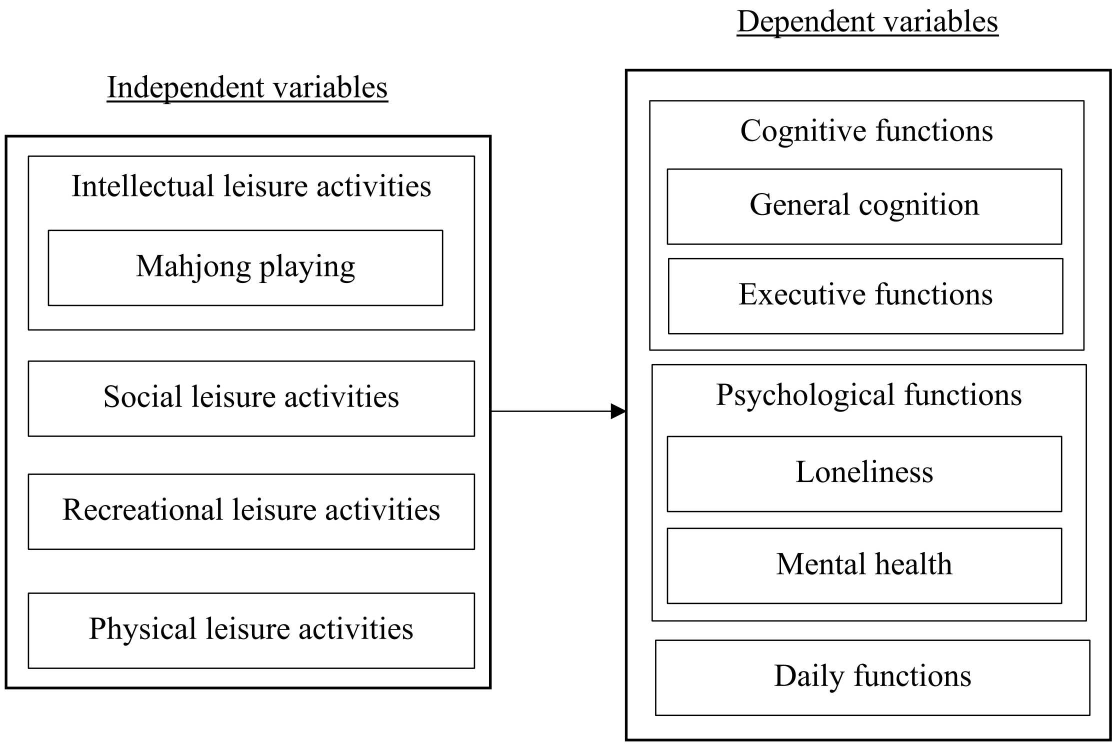
The current PhD project aimed to investigate whether leisure activity participation and one culturally specific activity (i.e., mahjong playing) are associated with better functions in older adults.

Three objectives are proposed. First, this thesis aimed to comprehensively investigate the relationships between leisure activity participation, mahjong playing and the cognitive, psychological, and daily functions in older adults. Second, it aimed to systematically examine and synthesise the existing evidence related to mahjong playing and cognitive, psychological and daily functions in older adults. Third, it aimed to examine the relationship between mahjong playing and EF by evaluating both behavioural and neural evidence. Overall, it was expected that leisure activity participation and mahjong playing are related to better cognitive, psychological and daily functions in older adults. Figure 3.2 shows a theoretical framework for this PhD project.

The present thesis is comprised of three studies (i.e., Chapters 4 to 6), one for each of the above three objectives. Chapter 4 is a comprehensive, cross-sectional survey study examining the nature, extent, and benefits of leisure activity participation in older adults. Chapter 5 is a scoping review that systematically evaluated the relevant studies identified in both Western and Asian literature and their evidence on the benefits of mahjong playing in older adults. Chapter 6 is an experimental study incorporating behavioural and neural data to investigate how mahjong playing is related to EF. Chapter 7 summarises and discusses the findings of all studies.

Figure 3.2

Theoretical Framework of this PhD Project



Chapter 4

Study 1: Leisure Activity Participation (Including Mahjong Playing) and Relationships with Cognitive, Psychological and Daily Functions

4.1 Introduction

In Chapter 3, the literature on leisure activity participation, mahjong playing, and cognitive, psychological, and daily functions in older adults was reviewed. Results from previous studies tended to support that engaging in leisure activities and mahjong playing may be beneficial for older individuals. However, several research gaps were identified that warrant further investigation. A comprehensive cross-sectional survey study (Study 1) was planned to find out whether leisure activity participation and mahjong playing are related to cognitive, psychological, and daily functions in older adults in Hong Kong.

The following sections briefly recapitulate the research gaps that have led to the current study.

4.1.1 Leisure Activity Participation and Cognitive, Psychological and Daily Functions in Older Adults

First and foremost, the nature and extent of leisure activity participation of healthy older adults in Hong Kong have not been updated in recent years. Although some studies have examined the participation in physical activities of older adults in Hong Kong (Lee et al., 2023; Su et al., 2020), they did not provide a comprehensive picture of leisure activity participation. In Chapter 3, it was noted that Kwan (1990) and Chou et al. (2004) provided a comprehensive overview of leisure activity participation in healthy older adults in Hong Kong. Later, Cheung et al. (2009) and Zhao and Chen (2013) updated these previous studies. However, these studies were conducted at least 12 years ago. Therefore, it is necessary to undertake another update.

Second, previous studies tended to focus on the relationship between leisure activity participation and general cognition, but most of them did not examine if participation in such activities was related to higher-level cognitive processes such as EF and with psychological and daily functions (Iizuka et al., 2019; Opdebeeck et al., 2016; Rivera-Torres et al., 2021; Stern & Munn, 2010). EF, as highlighted by Diamond (2013), is an important function for daily activities, such as goal-directed behaviours and planning. Investigation into EF offers a more nuanced understanding of specific cognitive processes and provides valuable insights into how this function is related to leisure activity participation. Examining psychological and daily functions can also contribute to a more comprehensive understanding of how leisure activity participation is related to these functions. Although some reviews have investigated more than one type of functions (Langlois et al., 2012; Ren et al., 2023; Simone & Haas, 2013), only a very small number of studies adopted a holistic approach to understanding the benefits of leisure activity on cognitive, psychological and daily functions within one study. Therefore, it is important to conduct a comprehensive study to examine the benefits of leisure activity participation on cognitive, psychological and daily functions.

The third research gap is concerned with which domain of activities (i.e., intellectual, social, recreational, and physical) and what dosage of participation (e.g., diversity, frequency, and duration) can give rise to the strongest results. Previous literature suggested that not only could the same domain of activities provide benefits for the same domain of functions, but there are also cross-domain benefits. For example, not only could intellectual activity benefit cognitive functions, but social and physical activities could also provide cognitive benefits to older adults

(Hammond & Stinchcombe, 2022; Hertzog et al., 2008; Muiños & Ballesteros, 2021). Likewise, intellectual, physical and recreational activities could provide psychological benefits such as better mental health and well-being to older adults (Rivera-Torres et al., 2021). Therefore, it is important to clarify if cross-domain benefits can result from a study that used all four domains of leisure activities and three types of functions. Furthermore, inconsistencies have been reported in the literature regarding the dosage of participation. For example, a higher frequency of leisure activity participation may not always lead to better cognitive functioning (Wenzel et al., 2024), and the longer duration of participation may not always have a significant impact on reducing the risk of developing depression (Meng et al., 2021). Moreover, in terms of daily functions, most of the studies used a dichotomous classification of participation (i.e., yes or no), which did not allow the examination of the dosage effect (D'Orsi et al., 2014; Falk et al., 2014; Gu et al., 2023). Together, these issues highlight a need to further investigate which domain of activities and what dosage of participation may yield the most advantageous functions of ageing.

4.1.2 Mahjong Playing and Cognitive, Psychological and Daily Functions in Older Adults

Mahjong playing is a specific intellectual and social leisure activity developed in China. In Chapter 3, it was postulated that the game requires extensive cognitive efforts and would be a potential activity to accumulate cognitive reserve in older adults. Results from previous studies also supported the claim that participation in the game was associated with better cognitive, psychological and daily functions in older adults (Shen et al., 2024; Zhao et al., 2023). Thus, it is reasonable to expect that mahjong playing is a potential specific activity for healthy Chinese older adults to promote better functions of ageing. However, as the field is relatively new, not enough research has been conducted to clarify whether and how mahjong playing facilitates better functions of ageing, and there are two research gaps, as discussed in Chapter 3.

First, the prevalence rate of mahjong playing among Hong Kong older adults has not been updated since Cheung et al.'s study (2009). Additionally, most of the studies considered mahjong together with card games and chess, and did not examine the relationships between this group of activities and functions separately. For example, Kwan (1990) summarised 17 studies and classified mahjong playing and chess together as one activity. Chou et al. (2004) reported that 25.1% of the older adults in Hong Kong played mahjong or cards. Cheung et al. (2009) reported that 34.6% of older adults in Hong Kong played mahjong.[6] A later update by Zhao and Chen (2013) did not even include mahjong playing in their study on leisure activity participation among older adults in Hong Kong. Given all these issues, it is difficult to obtain a comprehensive and clear picture of mahjong playing independently.

Second, the dosage effect of mahjong playing in healthy older adults remains unclear and needs further clarification. Some studies used a dichotomous classification (i.e., either participated in mahjong playing or not) to examine the benefits of mahjong playing (Ren et al., 2023; Zhang et al., 2023), which precludes the examination of the dosage effects, such as frequency and duration. The other studies that did look at the dosage effect reported mixed results regarding the optimal participation frequency. For example, some studies showed that an increased frequency of mahjong playing was effective in preventing cognitive decline (Zhang et al., 2023), experiencing less loneliness (Teh & Tey, 2019) and reducing the risk of functional decline (Gao et al., 2018). However, the significant relationship between

[6] It includes the older adults who played mahjong for less than one day per month/occasionally, one to three days per month, one to three days per week, four to six days per week and every day.

the frequency of mahjong playing and the cognitive and daily functions was not supported by the results of some other studies (Chou et al., 2004; Ho & Chan, 2005). Besides, only a very small number of studies had been conducted to investigate the relationships between the duration of mahjong playing and the functions of ageing. For example, studies that implemented mahjong training typically involved three one-hour sessions per week (i.e., three hours per week), and results demonstrated that it was effective in improving cognitive and daily functions, as well as alleviating depressive symptoms (Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014; Cheng et al., 2012; Zhang et al., 2020). Regardless, more studies are needed to clarify the dosage effect of mahjong playing.

4.1.3 Aims and Hypotheses

This study aimed to examine whether different domains and dosages of leisure activities, as well as different dosages of mahjong playing, would predict cognitive, psychological and daily functions in healthy older adults. It tried to address four research questions: (i) What is the nature and extent of leisure activity participation among older adults in Hong Kong? (ii) What are the relationships between different domains (i.e., intellectual, social, recreational and physical) and dosages (i.e., diversity, frequency and duration) of leisure activity participation and the cognitive, psychological, and daily functions in older adults in Hong Kong? (iii) What is the nature and extent of mahjong playing in older adults in Hong Kong? (iv) What is the relationship between mahjong playing and the cognitive, psychological, and daily functions in older adults in Hong Kong?

Four hypotheses were proposed accordingly. Firstly, previous studies (viz., Cheung et al., 2009; Chou et al., 2004; Kwan, 1990; Zhao & Chen, 2013) reported that watching television, slow walking, reading and meeting relatives or friends were common leisure activities for older adults in Hong Kong. Therefore, it was hypothesised that a similar pattern in the rate of participation and frequency would be observed. There was no hypothesis made on the duration of each activity, as previous studies did not measure this aspect. Patterns in the rate of participation, frequency, and duration of each activity would be reported.

Second, in previous literature, engaging in cognitively stimulating, social and physical activities had been found to be associated with better cognitive performance in older adults (Hammond & Stinchcombe, 2022; Hertzog et al., 2008; Muiños & Ballesteros, 2021; Opdebeeck et al., 2016). Moreover, participating in social and intellectual activities had been found to be associated with better mental health (Gao et al., 2024; Zhang et al., 2021). These studies highlighted that the benefits of leisure activity participation were not only limited to the same domain of activities and functions but also extended to cross-domain advantages. Regarding the dosage of participation, Wenzel et al. (2024) reported that an increased diversity, frequency and duration of participation would be associated with better functions of ageing. Therefore, in this study, it was hypothesised that different domains (including cross-domain) of leisure activities (viz., intellectual, social, recreational and physical activities) and an increased dosage of participation (viz., higher diversity, frequency, and duration) would be positively associated with the cognitive, psychological and daily functions of older adults.

Third, the three previous studies from 1990 to 2009 reported an average prevalence rate of 25.8% among older adults in Hong Kong for mahjong playing (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990); and Cheung et al. (2009) reported that the most common frequency of mahjong playing in older adults was one to three days per week (14.5% of 34.6%, among those who played mahjong).

Therefore, it was hypothesised that mahjong playing would exhibit a similar prevalence rate and frequency among the older adults in Hong Kong. There was no hypothesis made on the duration of mahjong playing, as it was not measured by previous studies.

Lastly, an exploratory hypothesis was proposed regarding the relationship between mahjong playing and cognitive, psychological, and daily functions in older adults. In light of the positive relationship between mahjong playing and cognitive, psychological and daily functions reported in the literature (Shen et al., 2024; Zhao et al., 2023), it was hypothesised that an increased frequency and longer duration of mahjong playing would predict better cognitive, psychological and daily functions in older adults.

4.2 Method

4.2.1 Participants

A cross-sectional online survey study was conducted via the service provided by a data collection company, Kantar, from April 2024 to July 2024. Considering the comprehensiveness of the current study and the sample sizes (range = 505 to 512) of previous studies (Leung et al., 2010; G. T. Y. Leung, A. W. T. Fung, et al., 2011), a sample comprising around 500 older adults was planned to be collected to yield reliable results.[7]

Three thousand one hundred and forty-seven potential participants were screened on the data collection platform (i.e., Qualtrics) with the following eligibility criteria:

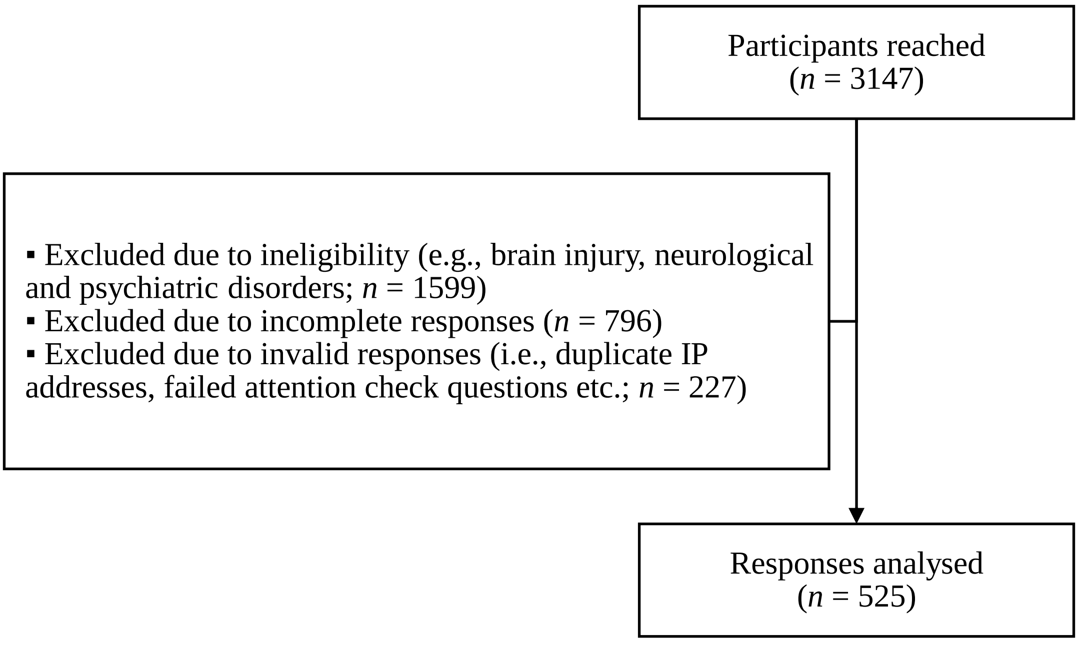
[7] According to Tabachnick et al. (2019), the minimum sample size required to attain sufficient statistical power was suggested to be calculated using the formula of $n \geq 20+5m$, where m denotes the number of predictors. Given that the number of predictors included in a regression model ranged from 12 to 21 in the present study, a sample size of between 80 to 125 participants was required. Considering the average of the required sample size (i.e., 103 participants) and the reported average prevalence rate of 25.8% for playing mahjong or cards in Hong Kong (Chou et al., 2004; Cheung et al., 2009; Kwan, 1990), expanding the sample size to approximately 500 participants would ensure sufficient statistical power (i.e., average required sample size/average mahjong prevalence = 103/25.8% = 400).

(i) age at 60 years or above, (ii) healthy and living in the community, (iii) absence of brain injury, neurological disorders, and psychiatric conditions, (iv) living in Hong Kong. To ensure the validity of the data collected, responses with duplicate Internet Protocol (IP) addresses and those by participants that failed any of the five attention check questions (e.g., “Please select ‘sometimes’ in this question” and “Please select ‘fairly often’ in this question”) were also excluded. Five hundred and twenty-five responses remained after applying the criteria and attention check questions. Participants received reward points from Kantar to compensate for their participation. Figure 4.1 shows the flowchart of the recruitment of the sample in this study.

Ethics approval was obtained from the PolyU Institutional Review Board (HSEARS20210302003-02). The study was pre-registered prior to data collection at the Open Science Framework (https://osf.io/pk6wx).

Figure 4.1

Flowchart of the Recruitment in this Study



4.2.2 Materials and Instrumentations[8]

4.2.2.1 Leisure Activity Participation. Leisure activity participation was measured by the revised version of the Leisure Activity Checklist developed by a group of Hong Kong researchers (G. T. Y. Leung, K. F. Leung, et al., 2011; see Table A4.1 in Appendix A). It categorises activities into four domains (viz., intellectual, social, recreational and physical), with 13 intellectual, 8 social, 9 recreational, and 18 physical activities in total.

To examine the nature and extent of leisure activity participation, the participation rate of each activity (i.e., the percentage of engaged participants relative to the total sample size) was reported. Additionally, the frequency (i.e., times of engagement within one week) and duration (hours of engagement each time) of each activity among the engaged participants were reported.

Within each domain, participation is operationalised in terms of three dosages, including diversity, frequency, and duration.

4.2.2.1.1 Diversity of the Activities Participated in the Four Domains. This was defined by the variety of activities engaged in a specific domain of leisure activities. Following Leung et al. (2010) and G. T. Y. Leung, A. W. T. Fung, et al. (2011), this was measured by the total number of subtypes of activities (V) that the participant engaged in each domain: $V_d = \sum(A_{d,1} \times 1 + A_{d,2} \times 1 + \cdots A_{d,n} \times 1)$, where A_d represented the activities participants reported in the checklist within the domain d and n represented the number of activities engaged in. Four predictors were calculated and included in the prediction: (i) diversity in the intellectual domain ($V_{intellectual}$; range

[8] The survey also collected additional items for another project, including retrospective and prospective memory measured by the Chinese Version of the Prospective and Retrospective Memory Questionnaire, and life satisfaction measured by the 5-item Chinese Version of Satisfaction with Life Scale. The current study focused on general cognition, EF, loneliness, levels of depression, anxiety and stress, and functional independence.

from 0 to 13), (ii) diversity in the social domain (V_{social}; range from 0 to 8), (iii) diversity in the recreational domain ($V_{receraitonal}$; range from 0 to 9), and (iv) diversity in the physical domain ($V_{physical}$; range from 0 to 18).

For the reported activities only, participants were directed to two additional questions asking for the frequency and duration of each engagement.

4.2.2.1.2 Total Frequency of Activities Participated in the Four Domains. This was defined by the total frequency of engaged activities in a specific domain of leisure activities. Two steps were included in the calculation of total frequency.

First, the frequency of each reported activity (*f*) was asked, with the following coding: 0 point for never or participating less than monthly, 0.25 points for monthly participation, 0.5 points for biweekly participation, 0.75 points for three times per month, 1 point for weekly participation, 2 points for two days per week, 3 points for three days per week, 4 points for four days per week, 5 points for five days per week, 6 points for six days per week, and 7 points for daily participation (Leung et al., 2010; G. T. Y. Leung, A. W. T. Fung, et al., 2011).[9] Activities reported with a frequency less than monthly were excluded from the calculation of the total frequency, consistent with the literature that aimed at capturing the regularity of the participation (G. T. Y. Leung, A. W. T. Fung, et al., 2011).

Second, the total frequency in each domain (*F*) was calculated: $F_d = \sum(A_{d,1} \times f_1 + A_{d,2} \times f_2 + \cdots A_{d,n} \times f_n)$, where A_d represented the activities participants reported in the checklist within the domain *d*, *f* represented the frequency

[9] Originally, the coding method used in Leung et al. (2010) and G. T. Y. Leung, A. W. T. Fung, et al. (2011) coded the frequency of each reported activities as follows: 0 point for never or participating less than monthly, 0.25 points for monthly participation, 0.5 points for biweekly participation, 1 point for weekly participation, 4 points for several days per week, and 7 points for daily participation. However, this coding method was not linear, and the point of 0.75 was missing. Therefore, the coding method was revised in this study. Subsequent analyses were also performed using the original coding method, revealing no differences in the overall model significance, except for the scale measuring general cognition reported no significant results (*p* = .055).

of the reported activities, and *n* represented the number of activities engaged in. Four predictors were calculated and included in the prediction: (i) total frequency in the intellectual domain ($F_{intellectual}$; range from 0 to 91), (ii) total frequency in the social domain (F_{social}; range from 0 to 56), (iii) total frequency in the recreational domain ($F_{recerational}$; range from 0 to 63), and (iv) total frequency in the physical domain ($F_{physical}$; range from 0 to 126).

4.2.2.1.3 Duration (Total Hours Per Week) of Activities Participated in the Four Domains. This was defined by the total time spent on engaged activities in a specific domain of leisure activities. Two steps were included in the calculation of total hours per week.

First, the duration of each reported activity (*d*) was asked. Then, the total hours per week (*H*) in each domain was calculated: $H_d = \sum(A_{d,1} \times f_1 \times d_1 + A_{d,2} \times f_2 \times d_2 + \cdots A_{d,n} \times f_n \times d_n)$, where A_d represented the activities participants reported in the checklist within the domain *d*, *f* represented the frequency of the reported activities, *d* represented the duration of the reported activities, and *n* represented the number of activities engaged in. Four predictors were calculated and included in the prediction: (i) total hours per week in the intellectual domain ($H_{intellectual}$; range from 0 to 168), (ii) total hours per week in the social domain (H_{social}; range from 0 to 168), (iii) total hours per week in the recreational domain ($H_{recerational}$; range from 0 to 168), and (iv) total hours per week in the physical domain ($H_{physical}$; range from 0 to 168).

The content validity of the scale was ascertained by discussing with experts from different disciplines, including elderly care professionals, occupational therapists, and community elderly. Its construct validity was supported by the strongly correlated results from the experts and older adults. No reliability was reported by the previous studies.

4.2.2.1.4 Mahjong Playing Information. Data pertaining to the engagement in mahjong playing was extracted from the Leisure Activity Checklist. It included the measurement of a dichotomous classification of participation in mahjong playing (*yes*/*no*), frequency, and duration (i.e., total hours per week).

In addition, to explore the prevalence of occasional and infrequent players, this study also collected a dichotomous classification of basic mahjong knowledge (*yes*/*no*) and time per year.

However, due to the high multicollinearity among the variables (i.e., variance inflation factor [VIF] > 10 and tolerance < 0.1), the two variables representing dichotomous classification of participation (*yes*/*no*) and frequency of mahjong playing ($f_{mahjong\ playing}$) were combined. In total, frequency (*never*/*yearly*/*monthly*/*weekly or above*) and total hours per week of mahjong playing were included in the analyses.

4.2.2.2 Cognitive Functions.

General cognition and EF were measured as cognitive functions.

4.2.2.2.1 General Cognition. The 16-item Chinese version of the Cognitive Complaints in Bipolar Disorder Rating Assessment (COBRA-C) was used to assess general cognition (Xiao et al., 2015). Items were rated on a 4-point Likert scale, ranging from 0 (*never*) to 3 (*always*). The total score ranges from 0 to 48, and a higher score indicates more subjective complaints related to general cognition. The COBRA-C was reported to have high internal consistency (Cronbach's α = .91) and good test-retest reliability (intraclass correlation coefficient [ICC] =.90; Xiao et al., 2015). The scale reported excellent internal consistency in this study (Cronbach's α = 0.90). Content validity of the scale was established by a group of experts assessing the relevance and comprehensiveness of the items, while construct validity (i.e., known-groups difference) was established by successfully classifying the healthy subjects and subjects with bipolar disorder (Xiao et al., 2015). However, concurrent validity was only partially established as Cognitive Complaints in Bipolar Disorder Rating Assessment (COBRA; the patient group) was only significantly associated with the two subscales (i.e., phonemic fluency and verbal memory) in the Montreal Cognitive Assessment (MoCA; Xiao et al., 2015).

4.2.2.2.2 EF. EF was measured by the 20-item Chinese version of the Dysexecutive Questionnaire (DEX; Yang et al., 2018). Items were rated on a 5-point Likert scale, ranging from 0 (*never*) to 4 (*very often*). The total score ranges from 0 to 80, and a higher score represents a higher frequency of EF failures in daily life. The internal consistency of this questionnaire is excellent in the literature (Cronbach's α = .92; Bennett et al., 2005) and in this study (Cronbach's α = 0.93). The construct validity was evaluated by confirmatory factor analysis and as expected a four-factor model (viz., volition, intentionality, inhibition and abstract problem-solving) was reported (Yang et al., 2018). Given that this study aimed to examine the relationship between leisure activity participation and EF from a broad perspective, a unitary EF score, rather than the four factor scores, was used.

4.2.2.3 Psychological Functions.

Loneliness and the levels of depression, anxiety and stress were measured as psychological functions.

4.2.2.3.1 Loneliness. The level of loneliness was measured by the 20-item Chinese version of the UCLA Loneliness Scale (Russell, 1996). Items were rated on a 4-point Likert scale, ranging from 1 (*never*) to 4 (*always*). The total score ranges from 20 to 80, and a higher score indicates a greater level of loneliness. The scale was found to have good internal consistency in the literature (Cronbach's α = .89 to .94;

Russell, 1996) and in this study (Cronbach's α = 0.90). Convergent validity was supported by the positive correlations of this scale with the NYU Loneliness Scale and the Differential Loneliness Scale (Russell, 1996). Construct validity was supported by the significant positive association with the Neuroticism subscale and negative association with the Introversion-Extroversion subscale in the Eysenck Personality Inventory (Russell, 1996).

4.2.2.3.2 Depression, Anxiety and Stress. Levels of depression, anxiety, and stress were measured by the 21-item Chinese Version of Depression Anxiety and Stress Scale-21 (DASS-21; Wang et al., 2016). Items were rated on a 4-point Likert scale, ranging from 0 (*did not apply to me at all*) to 3 (*applied to me very much or most of the time*). It asked for the situations over the past week and comprised three subscales (i.e., depression, anxiety, and stress). The total score ranges from 0 to 126 (i.e., the sum of the three subscales), and a higher score indicates a higher level of depression, anxiety or stress. The scale demonstrated excellent reliability of the total score in previous studies (Cronbach's α = .92; Wang et al., 2016) and in this study (Cronbach's α = 0.95). It also showed moderate convergent validity of the depression and anxiety subscales (the depression subscale significantly correlated with the Chinese version of the Beck Depression Inventory, and the anxiety subscale significantly correlated with the Chinese version of State-Trait Anxiety Inventory subscale). Given that this study aimed to examine the relationships between leisure activity participation and mental health from a broad perspective, the total score of the scale was used as the measure for DASS.

4.2.2.4 Daily Functions. Functional independence was assessed by the 9-item Chinese Lawton Instrumental Activities of Daily Living Scale (IADL-CV; Tong & Man, 2002). Items were rated on a 3-point scale, ranging from 0 (*unable to do*) to 2 (*independent*). The total score ranges from 0 to 18, and a higher score indicates a better level of functional independence. The scale showed good reliability in previous studies (Cronbach's α = .86; Tong & Man, 2002) and in this study (Cronbach's α = 0.86). It also demonstrated good content validity (satisfactory percentage of agreement from the expert panel) and construct validity (a prediction ability of 78% to discriminate residents in the hostel and care-and-attention home correctly; Tong & Man, 2002).

4.2.3 Demographics

Demographic data such as age, sex, years of education, marital status, family income, occupation, employment status, smoking and drinking habits, and household composition were also obtained using a questionnaire.

4.2.4 Data analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, version 29) with a level of significance of 5%. The normality of the data was assessed using the criteria of skewness > 3 and kurtosis > 10. Univariate outliers with a z-score higher than 3.29 standard deviations (*SD)* were screened out. Multivariate outliers were assessed and removed based on Mahalanobis distance with an alpha level of .001. All items in the online survey were forced responses, therefore, there was no missing data. The multicollinearity and singularity between predictors were also assessed, in which VIF > 10 and tolerance < 0.1 were used as the criteria.

Pearson's correlations were computed to explore the associations between the DVs and all the other variables. Demographic variables such as age, sex, years of education, marital status, family income, employment status, smoking and drinking habits were considered as covariates if significant associations ($p < .001$ was adopted as a more conservative level given the number of *r*s calculated) were found with the

DVs.

Descriptive statistics of each activity were calculated to describe the nature and extent of overall leisure activity and mahjong playing participation. The statistics included the rate of participation among the whole sample (%), mean frequency of participation among engaged participants, and mean duration of participation among engaged participants (hours).

Multivariate hierarchical regression analyses were conducted to investigate the relationships between leisure activity participation and cognitive, psychological, and daily functions. Assumptions related to normality, linearity, homoscedasticity of residuals, multicollinearity, and singularity were tested and met. The DVs were the scores of the COBRA-C, DEX, UCLA loneliness scale, DASS-21, and IADL-CV. The first step included adding the demographic variables with significant correlations with the DV as predictors. The second step included adding the total number of subtypes (i.e., $V_{intellectual}$, V_{social}, $V_{recreational}$, and $V_{physical}$), total frequency (i.e., $F_{intellectual}$, F_{social}, $F_{recreational}$, and $F_{physical}$), and total hours per week (i.e., $H_{intellectual}$, H_{social}, $H_{recreational}$, and $H_{physical}$) in each leisure activity domain.

Another set of multivariate hierarchical regression analyses were conducted to examine the relationship between mahjong playing and the cognitive, psychological and daily functions. The DVs were the scores of the COBRA-C, DEX, UCLA loneliness scale, DASS-21, and IADL-CV. The first step included adding the demographic variables with significant correlations with the DV as predictors. The second step included adding the predictors related to mahjong playing, namely, frequency and total hours per week.

For the regression analyses, beta values, R-squared, and semi-partial correlation (sr^2) were reported. There was no significant difference in the overall model significance between the analyses with and without multivariate outliers, results without multivariate outliers were, therefore, reported.

4.3 Results

4.3.1 Sample Characteristics

Table 4.1 presents the demographic characteristics of the participants. The sample had a mean age of 64.77 years (*SD* = 4.99 years) and 44.8% were females. They received an average of 13.46 years (*SD* = 4.87 years) of education. Table 4.2 shows the descriptive statistics of the cognitive, psychological and daily functions. Tables 4.3 and 4.4 report the descriptive statistics of leisure activity participation and mahjong playing in older adults, respectively. All participants took part in at least one type of leisure activity.

Table 4.1

Demographics of the Participants (N = 525)

Characteristics	*M*/frequency	*SD*/percentage
Age (years)	64.77	4.99
Gender		
Male	290	55.2%
Female	235	44.8%
Education (years)	13.46	4.87
Marital status		
Married	404	77%
Single/ Divorced/ Widowed	121	23%
Household composition		
Living with others	472	89.9%
Living alone	53	10.1%
Employment status		
Employed	206	39.2%
Retired/ Unemployed/ Student	319	60.8%
Family income (per month)		
HKD 29,999 or below	222	42.3%
HKD 30,000 or above	303	57.7%
Smoking habit		
No	438	83.4%
Yes	87	16.6%
Drinking habit		
No	397	75.6%
Yes	128	24.4%

Table 4.2

Descriptive Statistics for the Cognitive, Psychological and Daily Functions

Characteristics	*M*	*SD*
COBRA-C	14.59	7.97
DEX	22.72	12.88
UCLA loneliness scale	44.6	9.67
DASS-21	27.74	23.03
IADL-CV	16.03	2.84

Note. COBRA-C = Chinese Version of Cognitive Complaints in Bipolar Disorder Rating Assessment; DEX = Chinese Version of Dysexecutive Questionnaire; DASS-21 = Chinese Version of Depression Anxiety and Stress Scale-21; IADL-CV = Chinese Lawton Instrumental Activities of Daily Living Scale.

Table 4.3

Leisure Activity Participation in Hong Kong Older Adults

Leisure activity subscales	Mean	*SD* (range)	Valid *N*
Intellectual			
Total number of subtypes	2.04	1.61 (0-13)	525
Total frequency	7.74	6.3 (0-36.26)	525
Total hours per week	17.42	19.64 (0-108.5)	524#
Social			
Total number of subtypes	1.2	1.32 (0-8)	525
Total frequency	1.16	2.01 (0-17)	525
Total hours per week	3.12	6.53 (0-77.08)	525
Recreational			
Total number of subtypes	2.28	1.74 (0-9)	525
Total frequency	11.56	9.02 (0-39)	525
Total hours per week	27.14	25.47 (0-150.38)	517#
Physical			
Total number of subtypes	2.79	2.08 (0-18)	525
Total frequency	8.30	7.17 (0-49.5)	525
Total hours per week	10.05	16.24 (0-165.97)	525

The valid number dropped due to some participants reporting impossible numbers of more than 168 hr per week of participation.

Table 4.4

Descriptive Statistics of Mahjong Playing in Hong Kong Older Adults (N = 525)

Mahjong Playing	Mean/frequency	SD/percentage
Participation		
Yes	142	27%
No	383	73%
Frequency		
Never	383	73%
Yearly	48	9.1%
Monthly	37	7%
Weekly or above	57	10.9%
Hours per week	1.49	6.77
Acquisition of basic mahjong skills		
Yes	377	71.8%
No	148	28.2%
Time per year	11.64	31.35

4.3.2 Nature and Extent of Leisure Activity Participation

Figures 4.2 to 4.4 present the descriptive statistics of each activity, in terms of the rate of participation in the overall sample (%), frequency (times per week), and duration of each time (hours) among the engaged participants. Data pertaining to the participation was listed alongside each activity in the figures.

The five activities that showed the highest rate of participation were (i) watching television (70%), (ii) slow walking (68%), (iii) using a computer or surfing the Internet (53%), (iv) reading books, newspaper, or magazines (48%), and (v) shopping (40%). Mahjong playing was ranked 12th and had a participation rate of 27%.

Considering the engaged participants in each activity, the five most frequently participated activities were (i) keeping pets (6.69 times per week), (ii) watching television (6.69 times per week), (iii) using a computer or surfing the Internet (6.52 times per week), (iv) listening to the radio (5.80 times per week), and (v) cooking for pleasure (5.19 times per week). Mahjong playing reported a mean frequency of 1.82 times per week (viz., almost twice a week) and occupied the 33rd position on the list.

The five activities that showed the longest duration of the engagement in each session were (i) keeping pets (5.81 hr), (ii) mahjong playing (4.06 hr), (iii) Chinese martial arts (3.82 hr), (iv) fishing (3.24 hr), and (v) meeting relatives or friends (3.07 hr). Mahjong playing reported a mean duration of 4.06 hr each time and occupied the 2nd position on the list.

Figure 4.2

Rate of Participation (%) of Each Activity in the Overall Sample (N = 525)

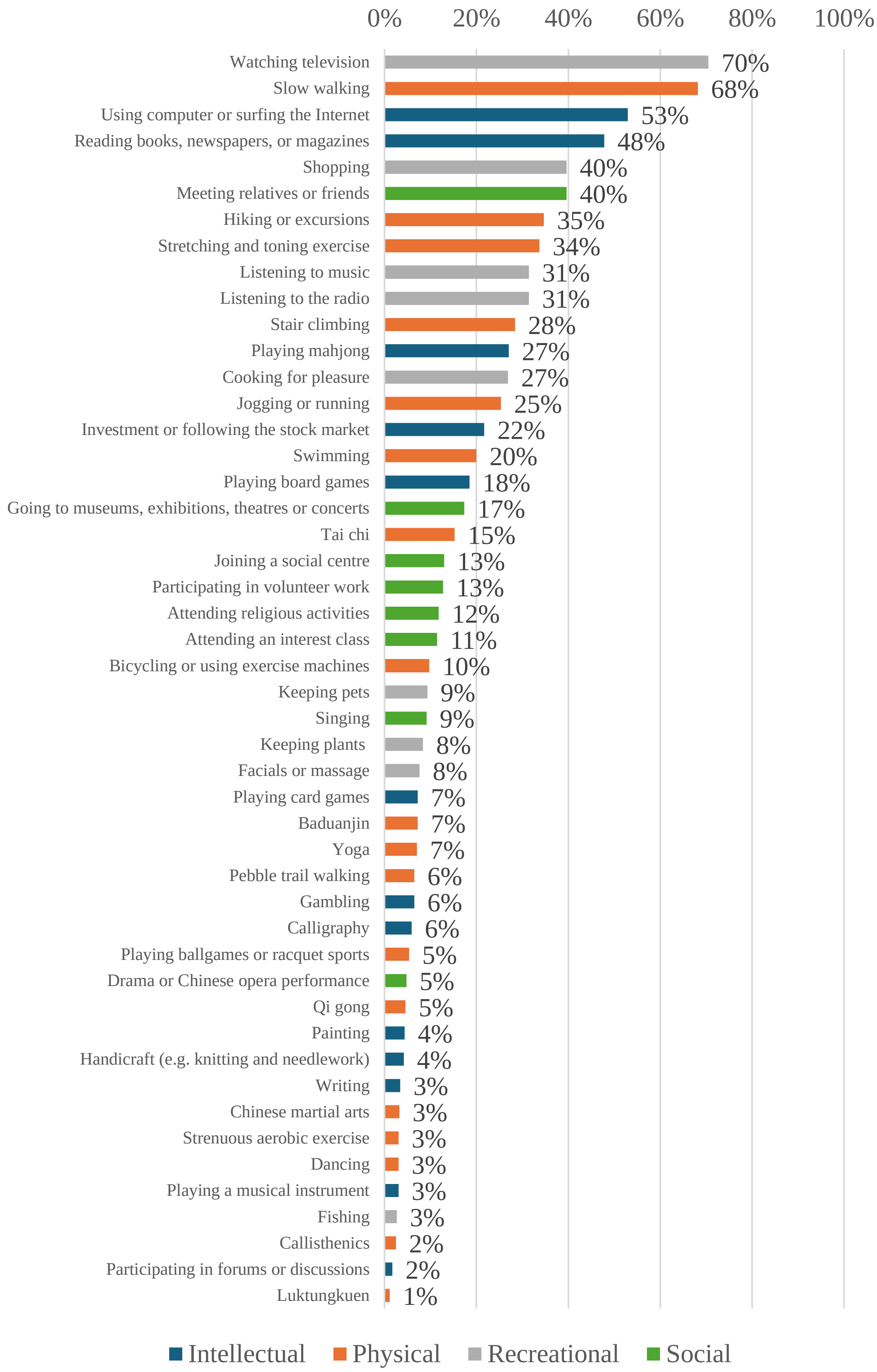


Figure 4.3

Mean Frequency of Each Activity Among Engaged Participants

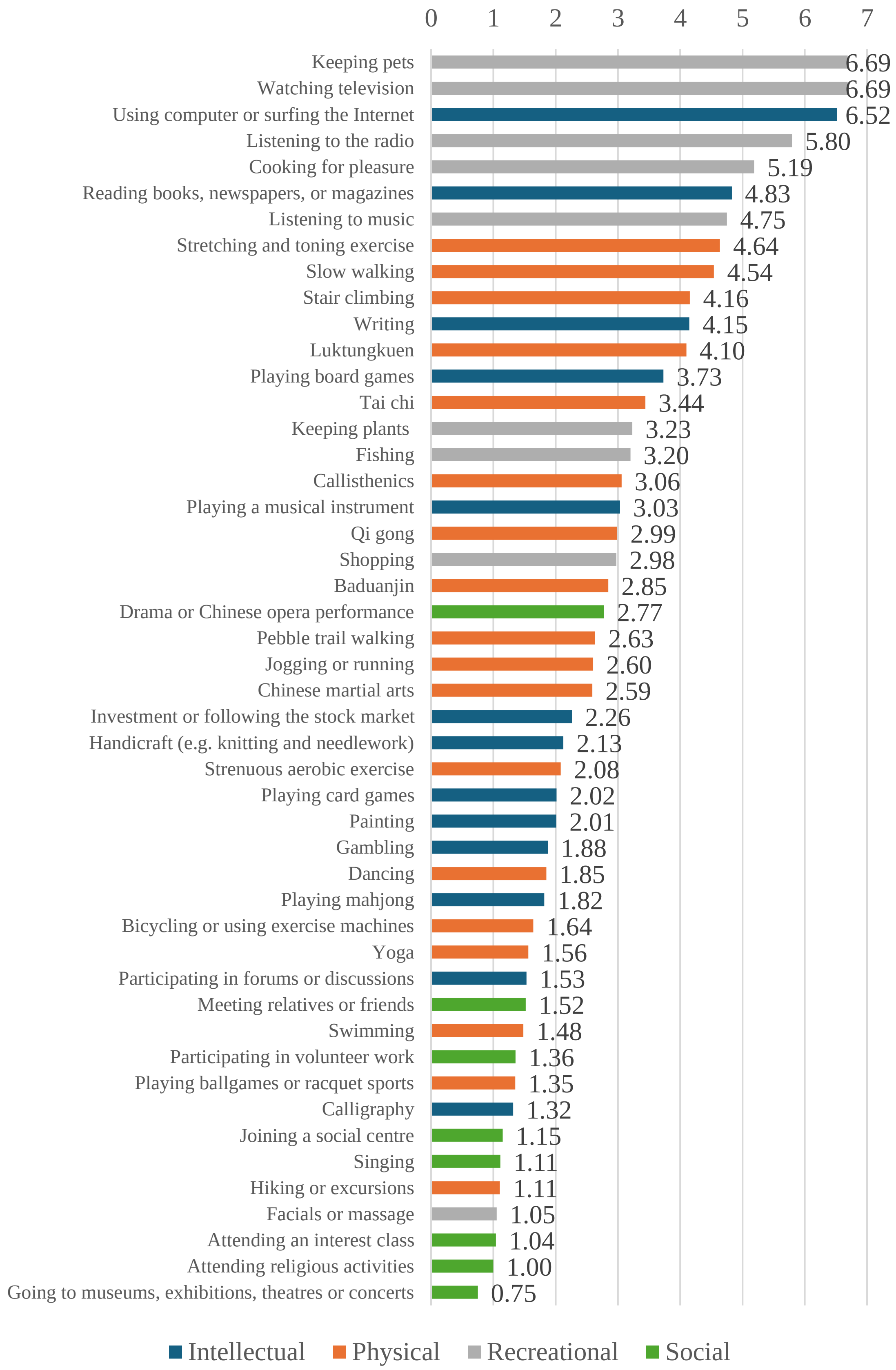
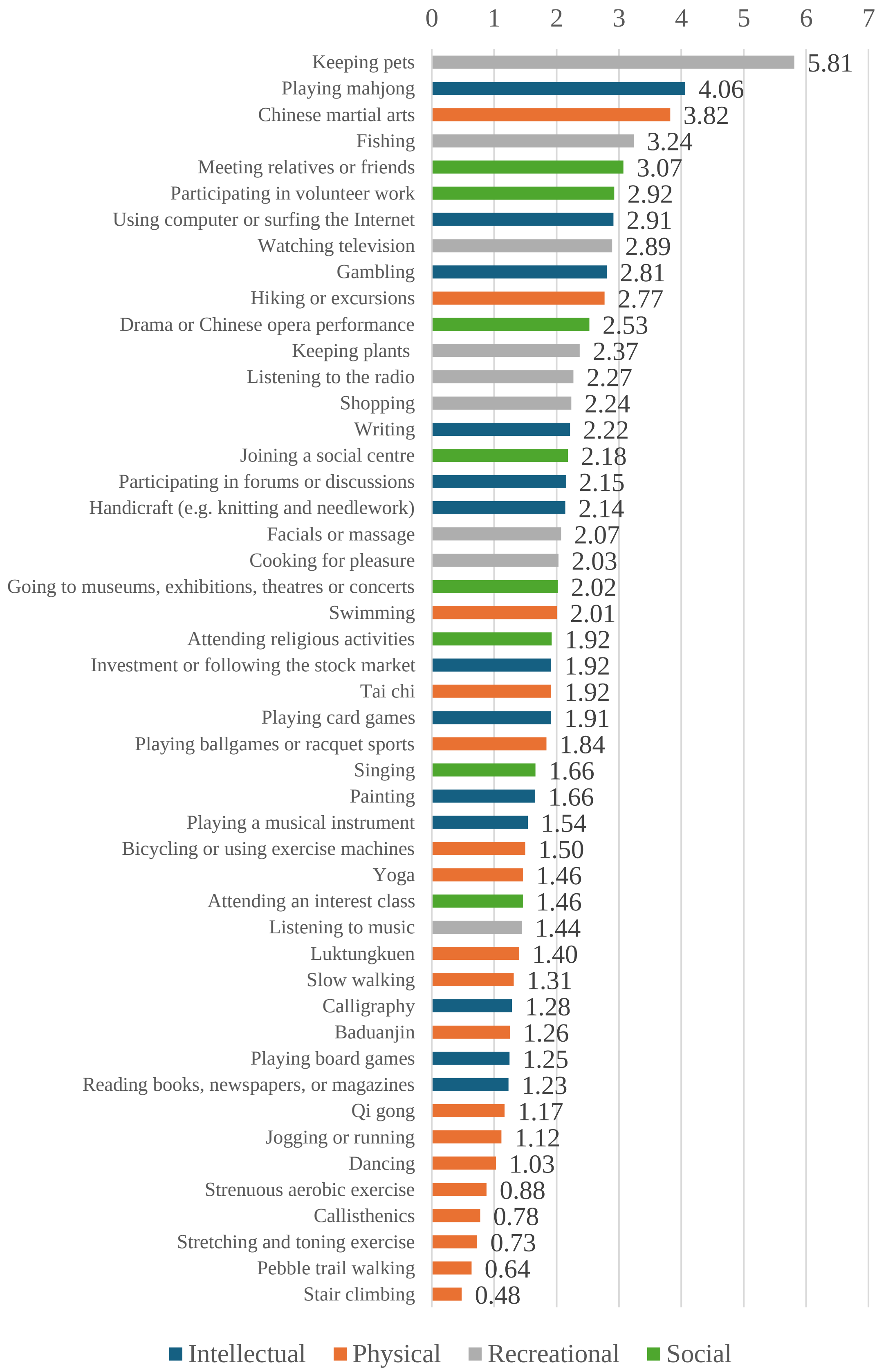


Figure 4.4

Mean Duration (Hours) of Each Activity Among Engaged Participants



4.3.3 Correlations between Demographics and DVs

Pearson correlations were computed to examine the relationships between potential covariates and DVs. Table 4.5 summarises the correlation coefficients after the removal of univariate outliers. No bivariate outliers were identified. It aimed to examine if the nine potential covariates (i.e., age, gender, years of education, marital status, residential arrangements, employment status, family income, smoking habit and drinking habit) were correlated with the five DVs (i.e., COBRA-C, DEX, UCLA Loneliness Scale, DASS-21 and IADL-CV).

Demographic variables with significant relationships with the DVs were entered into the regression models at the first step for each DV ($p < .001$ was adopted as a more conservative level given the number of *r*s calculated). UCLA loneliness scale did not correlate significantly with any demographic variables. Both smoking and drinking habits were included in the regression models of DEX and DASS-21. Smoking habit was included in the regression model of COBRA-C. Employment status, smoking and drinking habits were included in the regression model of IADL-CV.

Table 4.5

Correlations Coefficients among the Dependent and Demographic Variables (After Removal of Univariate Outliers)

Predictors	COBRA-C	DEX	UCLA Loneliness Scale	DASS-21	IADL-CV
1. Age	.03	.01	-.04	-.05	-.09
2. Gender	-.02	-.06	-.08	-.08	.04
3. Years of education	-.06	-.04	.10	.04	.04
4. Marital status	-.04	-.03	.11	-.05	.11
5. Residential arrangements	.01	.01	.14	.02	.08
6. Employment status	.13	.06	.05	.04	-.27***
7. Family income	-.12	-.03	-.12	-.05	.14
8. Smoking habit	.18***	.19***	.04	.23***	-.29***
9. Drinking habit	.12	.16***	.00	.20***	-.15***

Note. COBRA-C = Chinese Version of Cognitive Complaints in Bipolar Disorder Rating Assessment; DEX = Chinese Version of Dysexecutive Questionnaire; DASS-21 = Chinese Version of Depression Anxiety and Stress Scale-21; IADL-CV = Chinese Lawton Instrumental Activities of Daily Living Scale.

*** $p < .001$.

4.3.4 Assumptions of Regression Models

Prior to the analyses, the DVs, predictors, and demographic variables were examined using SPSS for accuracy of data entry, missing values, and fit between their distributions and the assumptions of multivariate analysis.

The normality of variables was examined by skewness, kurtosis, and visual inspection of histograms and normal P-P plot of regression standardised residual. Univariate outliers (i.e., z-scores above 3.29 or below -3.29) and multivariate outliers (i.e., Mahalanobis distance with $p < .001$) were examined and excluded from all DVs, predictors and demographic variables. To preserve the sample size, the pairwise deletion option was used. After removing univariate outliers, all variables were normally distributed (skewness < 3, kurtosis < 10), except for the total hours per week of mahjong playing (skewness = 4.59, kurtosis = 24.99). Square root transformation was applied to this variable, and it was normally distributed (total hours per week of mahjong playing: skewness = 2.67, kurtosis = 6.86). Analyses were repeated with and without the transformed variables, and the results with transformed variables were reported. Table 4.6 summarises the remaining sample size after the removal of univariate and multivariate outliers for the DVs. The number of participants after the removal of univariate and multivariate outliers for each DV was sufficient to fulfil the minimum sample size requirement.

Linearity and homoscedasticity of residuals were examined by visual inspection of the residuals scatterplots. No issues with normality, linearity, or homoscedasticity of residuals were found. For multicollinearity and singularity, all predictors reported VIF < 10 and tolerance > 0.1.

Ten hierarchical or standard multiple regressions were conducted to determine if leisure activity participation and mahjong playing predict COBRA-C, DEX, UCLA loneliness scale, DASS-21, and IADL-CV beyond that afforded by demographic characteristics such as smoking and drinking habits, and employment status.

Table 4.6

Number of Participants Remained in the DVs after Removing Univariate and Multivariate Outliers

DVs	*N* Original	*N* after removing univariate outliers	*N* after removing univariate and multivariate outliers
COBRA-C	525	523	508
DEX	525	525	509
UCLA Loneliness Scale	525	524	509
DASS-21	525	525	509
IADL-CV	525	524	512

Note. DV = Dependent variable; COBRA-C = Chinese Version of Cognitive Complaints in Bipolar Disorder Rating Assessment; DEX = Chinese Version of Dysexecutive Questionnaire; DASS-21 = Chinese Version of Depression Anxiety and Stress Scale-21; IADL-CV = Chinese Lawton Instrumental Activities of Daily Living Scale.

4.3.5 Leisure Activity Participation and Cognitive, Psychological and Daily Functions

4.3.5.1 General Cognition – COBRA-C. A hierarchical regression was conducted to determine if the addition of leisure activity participation could improve the prediction of general cognition as measured by COBRA-C after controlling for the significant demographic variables (viz., smoking habit). The correlations between the 13 predictors and the DV (i.e., COBRA-C) were examined before conducting the hierarchical regression. Table 4.7 displays the correlations between the variables, and Table 4.8 displays the unstandardized regression coefficients (B), the standardized regression coefficients (β), sr^2, R, R^2, and adjusted R^2 after the entry of all 13 independent variables (IVs). The results of the hierarchical regression on COBRA-C are elaborated in the following paragraph.

R was significantly different from zero at the end of each step. In Step 1, with smoking habit in the equation, $R^2 = .03$, $F(1, 483) = 14.41$, $p < .001$. Smoking habit ($\beta = .17$, t

= 3.80, $p < .001$) was a significant predictor of COBRA-C. In Step 2, with all IVs in the equation, the final model was significant, $F(13, 471) = 3.00$, $p < .001$. The addition of the 12 predictors of leisure activity participation to the prediction of COBRA-C by smoking habit significantly accounted for additional variance, $R^2 = .08$ (adjusted $R^2 = .05$), $F_{inc}(12, 471) = 2.02$, $p = .021$. The 95% confidence limits ranged from .03 to .12. The adjusted R^2 value of .05 indicated that 5% of the variability in COBRA-C was predicted by the model. In the final model, the total frequency of social activity ($\beta = .22$, $t = 2.08$, $p = .039$), and total hours per week of social activity ($\beta = -.25$, $t = -2.33$, $p = .020$) significantly contributed to the prediction of the COBRA-C scores. As a demographic variable, smoking habit ($\beta = .14$, $t = 3.00$, $p = .003$) remained significant in Step 2. The size and direction of the relationship suggested that a non-smoking lifestyle, less frequent social activity, and longer duration of social activity predicted better general cognition among older adults.

Table 4.7

Correlations among the COBRA-C and the Predictors

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. COBRA-C	-												
2. Smoking	.17***	-											
3. Intellectual: *V*	-.05	-.12**	-										
4. Social: *V*	.01	-.11**	.36***	-									
5. Recreational: *V*	-.13**	-.20***	.51***	.34***	-								
6. Physical: *V*	.04	-.07	.45***	.33***	.38***	-							
7. Intellectual: *F*	-.12**	-.13**	.72***	.23***	.45***	.28***	-						
8. Social: *F*	.03	-.02	.15***	.58***	.10*	.13**	.05	-					
9. Recreational: *F*	-.13**	-.22***	.43***	.28***	.91***	.31***	.45***	.08*	-				
10. Physical: *F*	-.01	-.04	.25***	.26***	.34***	.60***	.22***	.16***	.34***	-			
11. Intellectual: *H*	-.08*	-.03	.50***	.11**	.28***	.13**	.63***	-.03	.27***	.08*	-		
12. Social: *H*	-.02	-.04	.09*	.56***	.08*	.07*	0	.90***	.06	.16***	-.02	-	
13. Recreational: *H*	-.07	-.19***	.27***	.10*	.64***	.10*	.29***	-.05	.73***	.15***	.25***	-.03	-
14. Physical: *H*	.05	.10*	.17***	.20***	.18***	.44***	.13**	.14***	.17***	.69***	.08*	.17***	.08*

Note. COBRA-C = = Chinese Version of Cognitive Complaints in Bipolar Disorder Rating Assessment; *V* = total number of subtypes; *F* = total frequency; *H* = total hours per week.

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

Table 4.8

Hierarchical Regression of Significant Demographics and Leisure Activity Participation on COBRA-C

Entered variables		*B*	*SE* (*B*)	*β*	*t*	*p*	*sr*^{2}	R^2 change	*F* change	*df*	*p*
Step 1								.03	14.41	1, 483	<.001
	Smoking habit	3.58***	.94	.17	3.80	<.001	.17				
Step 2								.05	2.02	12, 471	.021
	Smoking habit	2.93**	.98	.14	3.00	.003	.13				
	Intellectual: Number of subtypes	.42	.41	.08	1.02	.308	.05				
	Social: Number of subtypes	.44	.38	.07	1.16	.247	.05				
	Recreational: Number of subtypes	-.62	.53	-.14	-1.17	.243	-.05				
	Physical: Number of subtypes	.40	.30	.08	1.33	.186	.06				
	Intellectual: Total frequency	-.17	.10	-.13	-1.72	.086	-.08				
	Social: Total frequency	1.20*	.58	.22	2.08	.039	.09				
	Recreational: Total frequency	-.06	.11	-.07	-.57	.570	-.03				
	Physical: Total frequency	-.05	.09	-.04	-.62	.536	-.03				
	Intellectual: Total hours per week	-.01	.03	-.03	-.44	.660	-.02				
	Social: Total hours per week	-.51*	.22	-.25	-2.33	.020	-.10				
	Recreational: Total hours per week	.04	.02	.11	1.61	.108	.07				
	Physical: Total hours per week	.06	.06	.06	1.00	.319	.04				
	Intercept =	14.20	.83		17.10	<.001					
Final model:											
	R =	.28									
	R^2 =	.08[a]									
	Adjusted R^2 =	.05									
	F(13, 471) =	3.00									
	p =	<.001									

Note. COBRA-C = Chinese Version of Cognitive Complaints in Bipolar Disorder Rating Assessment.

[a] 95% confidence limits ranged from .03 to .12.

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

4.3.5.2 EF-DEX. A hierarchical regression was conducted to determine if the addition of leisure activity participation could improve the prediction of EF as measured by DEX after controlling for the significant demographic variables (viz., smoking and drinking habits). The correlations between the 14 predictors and the DV (i.e., DEX) were examined before conducting the hierarchical regression. Table 4.9 displays the correlations between the variables, and Table 4.10 displays B, β, sr^2, R, R^2, and adjusted R^2 after the entry of all 14 IVs. The results of the hierarchical regression on DEX are elaborated in the following paragraph.

R was significantly different from zero at the end of each step. In Step 1, with smoking and drinking habits in the equation, $R^2 = .04$, $F(2, 481) = 9.38$, $p < .001$. Both smoking habit ($\beta = .13$, $t = 2.52$, $p = .012$) and drinking habit ($\beta = .10$, $t = 2.06$, $p = .040$) were significant predictors of DEX. In Step 2, with all IVs in the equation, the final model was significant, $F(14, 469) = 3.85$, $p < .001$. The addition of the 12 predictors of leisure activity participation to the prediction of DEX by smoking and drinking habits significantly accounted for additional variance, $R^2 = .10$ (adjusted $R^2 = .08$), $F_{\text{inc}}(12, 469) = 2.85$, $p < .001$. The 95% confidence limits ranged from .05 to .15. The adjusted R^2 value of .08 indicated that 8% of the variability in DEX was predicted by the model. In the final model, total number of subtypes of intellectual activity ($\beta = .21$, $t = 2.79$, $p = .005$), total frequency of intellectual activity ($\beta = -.26$, $t = -3.41$, $p < .001$), and total hours per week of physical activity ($\beta = .13$, $t = 2.12$, $p = .034$) significantly contributed to the prediction of the DEX scores. Meanwhile, smoking habit and drinking habit became not significant when predictors of leisure activity participation were added to Step 2. The size and direction of the relationship suggested that fewer subtypes of intellectual activity, more frequent intellectual activity, and shorter duration of physical activity predicted better EF among older adults.

Table 4.9

Correlations among the DEX and the Predictors

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. DEX	-													
2. Smoking	.17***	-												
3. Drinking	.16***	.44***	-											
4. Intellectual: *V*	-.02	-.12**	.16***	-										
5. Social: *V*	-.06	-.11**	.04	.36***	-									
6. Recreational: *V*	-.15***	-.20***	.07	.51***	.34***	-								
7. Physical: *V*	.03	-.08*	.17***	.46***	.33***	.38***	-							
8. Intellectual: *F*	-.16***	-.13**	.04	.72***	.23***	.45***	.28***	-						
9. Social: *F*	-.03	-.01	.06	.14***	.58***	.10*	.13**	.05	-					
10. Recreational: *F*	-.15***	-.21***	.06	.43***	.28***	.91***	.32***	.45***	.07*	-				
11. Physical: *F*	-.04	-.04	.09*	.25***	.26***	.34***	.61***	.22***	.16***	.34***	-			
12. Intellectual: *H*	-.08*	-.03	.08*	.50***	.11**	.28***	.12**	.63***	-.03	.27***	.08*	-		
13. Social: *H*	-.05	-.04	.02	.09*	.56***	.08*	.08*	0	.90***	.06	.16***	-.02	-	
14. Recreational: *H*	-.10*	-.19***	-.03	.27***	.10*	.64***	.10*	.29***	-.05	.72***	.15***	.26***	-.03	-
15. Physical: *H*	.07	.09*	.19***	.17***	.21***	.18***	.44***	.13**	.15***	.18***	.70***	.07	.17***	.09*

Note. DEX = Chinese Version of Dysexecutive Questionnaire; *V* = total number of subtypes; *F* = total frequency; *H* = total hours per week.

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

Table 4.10

Hierarchical Regression of Significant Demographics and Leisure Activity Participation on DEX

Entered variables		*B*	*SE* (*B*)	*β*	*t*	*p*	*sr*^{2}	R^2 change	*F* change	*df*	*p*
Step 1								.04	9.38	2, 481	<.001
	Smoking habit	4.37*	1.74	.13	2.52	.012	.11				
	Drinking habit	3.11*	1.51	.10	2.06	.040	.09				
Step 2								.07	2.85	12, 469	<.001
	Smoking habit	3.07	1.79	.09	1.71	.087	.07				
	Drinking habit	2.31	1.57	.08	1.48	.141	.06				
	Intellectual: Number of subtypes	1.91**	.68	.21	2.79	.005	.12				
	Social: Number of subtypes	-.29	.62	-.03	-.46	.647	-.02				
	Recreational: Number of subtypes	-1.28	.87	-.17	-1.46	.145	-.06				
	Physical: Number of subtypes	.56	.49	.07	1.15	.252	.05				
	Intellectual: Total frequency	-.54***	.16	-.26	-3.41	<.001	-.15				
	Social: Total frequency	.78	.95	.09	.83	.407	.04				
	Recreational: Total frequency	.05	.18	.03	.28	.783	.01				
	Physical: Total frequency	-.24	.14	-.12	-1.66	.098	-.07				
	Intellectual: Total hours per week	.00	.05	.00	.00	1.000	.00				
	Social: Total hours per week	-.44	.35	-.13	-1.24	.216	-.05				
	Recreational: Total hours per week	.01	.04	.02	.30	.761	.01				
	Physical: Total hours per week	.21*	.10	.13	2.12	.034	.09				
	Intercept =	23.31	1.35		17.20	<.001					
Final model:											
	R =	.32									
	R2 =	.10[a]									
	Adjusted *R2* =	.08									
	F(14, 469) =	3.85									
	p =	<.001									

Note. DEX = Dysexecutive Questionnaire.

[a] 95% confidence limits ranged from .05 to .15.

* $p < .05$. ** $p < .01$.

4.3.5.3 Loneliness – UCLA Loneliness Scale. Given that demographic variables did not correlate with the UCLA loneliness score, a standard multiple regression was conducted to determine if leisure activity participation could predict loneliness. The correlations between the 12 predictors and the DV (i.e., UCLA Loneliness Scale) were examined before conducting the standard multiple regression. Table 4.11 displays correlations between the variables, and Table 4.12 displays the B, β, R^2, and adjusted R^2 after the entry of all 12 IVs. The results of the standard multiple regression on UCLA Loneliness Scale are elaborated in the following paragraph.

R was significantly different from zero, $F(12, 472) = 2.32$, $p = .007$, with R^2 at .06 (adjusted $R^2 = .03$) and 95% confidence limits ranged from .02 to .09. No individual significant predictor was found in the model. Altogether, 6% (3% adjusted) of the variability in the UCLA loneliness scale was predicted by the 12 predictors of leisure activity participation together.

Table 4.11

Correlations among the UCLA Loneliness Scale and the Predictors

	1	2	3	4	5	6	7	8	9	10	11	12
1. UCLA loneliness scale	-											
2. Intellectual: *V*	-.04	-										
3. Social: *V*	-.13**	.36***	-									
4. Recreational: *V*	-.11**	.50***	.34***	-								
5. Physical: *V*	-.11**	.46***	.33***	.38***	-							
6. Intellectual: *F*	-.08*	.72***	.23***	.45***	.28***	-						
7. Social: *F*	-.14**	.15***	.59***	.09*	.12**	.05	-					
8. Recreational: *F*	-.12**	.42***	.28***	.91***	.31***	.44***	.06	-				
9. Physical: *F*	-.15***	.24***	.26***	.34***	.60***	.22***	.14***	.33***	-			
10. Intellectual: *H*	-.01	.50***	.10**	.28***	.13**	.63***	-.02	.27***	.08*	-		
11. Social: *H*	-.15***	.10*	.56***	.07	.07*	0	.90***	.04	.14***	-.02	-	
12. Recreational: *H*	-.05	.26***	.10*	.64***	.10*	.29***	-.05	.73***	.16***	.25***	-.03	-
13. Physical: *H*	-.14***	.17***	.20***	.18***	.44***	.13**	.14***	.17***	.70***	.08*	.16***	.08*

Note. *V* = total number of subtypes; *F* = total frequency; *H* = total hours per week.

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

Table 4.12

Standard Multiple Regression of Leisure Activity Participation on UCLA Loneliness Scale

Entered variables		*B*	*SE* (*B*)	*β*	*t*	*p*
Step 1						
	Intellectual: Number of subtypes	.82	.51	.12	1.61	.109
	Social: Number of subtypes	-.20	.48	-.03	-.43	.669
	Recreational: Number of subtypes	-.05	.66	-.01	-.08	.937
	Physical: Number of subtypes	-.27	.37	-.05	-.72	.472
	Intellectual: Total frequency	-.19	.12	-.12	-1.59	.111
	Social: Total frequency	.22	.72	.03	.30	.764
	Recreational: Total frequency	-.10	.13	-.09	-.73	.468
	Physical: Total frequency	-.03	.11	-.02	-.29	.768
	Intellectual: Total hours per week	.02	.03	.04	.69	.492
	Social: Total hours per week	-.38	.26	-.15	-1.45	.148
	Recreational: Total hours per week	.01	.03	.03	.43	.671
	Physical: Total hours per week	-.09	.07	-.08	-1.22	.224
	Intercept =	47.64	.98		48.58	<.001
Final model:						
	R =	.24				
	R^2 =	.06[a]				
	Adjusted R^2 =	.03				
	$F(12, 472)$ =	2.32				
	p =	.007				

[a] 95% confidence limits ranged from .02 to .09.

* $p < .05$. ** $p < .01$.

4.3.5.4 Depression, Anxiety and Stress – DASS-21. A hierarchical regression was conducted to determine if the addition of leisure activity participation could improve the prediction of the overall level of depression, anxiety and stress as measured by DASS-21 after controlling for the significant demographic variables (viz., smoking and drinking habits). The correlations between the 14 predictors and the DV (i.e., DASS-21) were examined before conducting the hierarchical regression. Table 4.13 displays the correlations between the variables, and Table 4.14 displays B, β, sr^2, R, R^2, and adjusted R^2 after the entry of all 14 IVs. The results of the hierarchical regression on DASS-21 are elaborated in the following paragraph.

R was significantly different from zero at the end of each step. In Step 1, with smoking and drinking habits in the equation, $R^2 = .06$, $F(2, 481) = 15.79$, $p < .001$. Both smoking habit ($\beta = .16$, $t = 3.34$, $p < .001$) and drinking habit ($\beta = .13$, $t = 2.59$, $p = .010$) were significant predictors of DASS-21. In Step 2 with all IVs in the equation, the final model was significant, $F(14, 469) = 5.02$, $p < .001$. The addition of the 12 predictors of leisure activity participation to the prediction of DASS-21 by smoking and drinking habits significantly accounted for additional variance, $R^2 = .13$ (adjusted $R^2 = .10$), $F_{inc}(12, 469) = 3.09$, $p < .001$. The 95% confidence limits ranged from .08 to .18. The adjusted R^2 value of .10 indicated that 10% of the variability in DASS-21 was predicted by the model. In the final model, total number of subtype of intellectual activity ($\beta = .16$, $t = 2.14$, $p = .033$), total frequency of intellectual activity ($\beta = -.27$, $t = -3.66$, $p < .001$), total frequency of social activity ($\beta = .21$, $t = 2.03$, $p = .043$) and total hours per week of social activity ($\beta = -.25$, $t = -2.45$, $p = .015$) significantly predicted the DASS-21 scores. Besides, smoking habit ($\beta = .12$, $t = 2.28$, $p = .023$) and drinking habit ($\beta = .13$, $t = 2.63$, $p = .009$) remained significant in Step 2. The size and direction of the relationship suggested that a non-smoking and non-drinking lifestyle, fewer subtypes of intellectual activity, more frequent intellectual activity, less frequent social activity, and longer duration of social activity predicted better mental health among older adults.

Table 4.13

Correlations among the DASS-21 and the Predictors

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. DASS-21	-													
2. Smoking	.22***	-												
3. Drinking	.20***	.44***	-											
4. Intellectual: *V*	-.07	-.12**	.16***	-										
5. Social: *V*	-.04	-.11**	.04	.36***	-									
6. Recreational: *V*	-.16***	-.20***	.07	.51***	.34***	-								
7. Physical: *V*	-.08*	-.08*	.17***	.46***	.33***	.38***	-							
8. Intellectual: *F*	-.19***	-.13**	.04	.72***	.23***	.45***	.28***	-						
9. Social: *F*	0	-.01	.06	.14***	.58***	.10*	.13**	.05	-					
10. Recreational: *F*	-.17***	-.21***	.06	.43***	.28***	.91***	.32***	.45***	.07*	-				
11. Physical: *F*	-.13**	-.04	.09*	.25***	.26***	.34***	.61***	.22***	.16***	.34***	-			
12. Intellectual: *H*	-.08*	-.03	.08*	.50***	.11**	.28***	.12**	.63***	-.03	.27***	.08*	-		
13. Social: *H*	-.05	-.04	.02	.09*	.56***	.08*	.08*	0	.90***	.06	.16***	-.02	-	
14. Recreational: *H*	-.15***	-.19***	-.03	.27***	.10*	.64***	.10*	.29***	-.05	.72***	.15***	.26***	-.03	-
15. Physical: *H*	-.05	.09*	.19***	.17***	.21***	.18***	.44***	.13**	.15***	.18***	.70***	.07	.17***	.09*

Note. DASS-21 = Chinese Version of Depression Anxiety and Stress Scale-21; *V* = total number of subtypes; *F* = total frequency; *H* = total hours per week.

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

Table 4.14

Hierarchical Regression of Significant Demographics and Leisure Activity Participation on DASS-21

Entered variables		*B*	*SE* (*B*)	*β*	*t*	*p*	sr^2	R^2 change	*F* change	*df*	*p*
Step 1								.06	15.79	2, 481	<.001
	Smoking habit	10.32***	3.09	.16	3.34	<.001	.15				
	Drinking habit	6.97**	2.69	.13	2.59	.010	.11				
Step 2								.07	3.09	12, 469	<.001
	Smoking habit	7.25*	3.18	.12	2.28	.023	.10				
	Drinking habit	7.33**	2.78	.13	2.63	.009	.11				
	Intellectual: Number of subtypes	2.60*	1.22	.16	2.14	.033	.09				
	Social: Number of subtypes	.72	1.11	.04	.65	.517	.03				
	Recreational: Number of subtypes	-.75	1.55	-.06	-.49	.627	-.02				
	Physical: Number of subtypes	-.51	.87	-.04	-.59	.556	-.03				
	Intellectual: Total frequency	-1.04***	.28	-.27	-3.66	<.001	-.16				
	Social: Total frequency	3.41*	1.68	.21	2.03	.043	.09				
	Recreational: Total frequency	-.01	.31	.00	-.03	.975	.00				
	Physical: Total frequency	-.34	.25	-.10	-1.33	.184	-.06				
	Intellectual: Total hours per week	.05	.08	.04	.62	.537	.03				
	Social: Total hours per week	-1.54*	.63	-.25	-2.45	.015	-.11				
	Recreational: Total hours per week	-.04	.07	-.04	-.61	.540	-.03				
	Physical: Total hours per week	.07	.18	.02	.37	.713	.02				
	Intercept =	32.73	2.41		13.61	<.001					
Final model:											
	R =	.36									
	R^2 =	.13[a]									
	Adjusted R^2 =	.10									
	F(14, 469) =	5.02									
	p =	<.001									

Note. DASS-21 = Depression Anxiety and Stress Scale-21.

[a] 95% confidence limits ranged from .08 to .18.

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

4.3.5.5 Functional Independence – IADL-CV. A hierarchical regression was conducted to determine if the addition of leisure activity participation could improve the prediction of functional independence as measured by IADL-CV after controlling for the significant demographic variables (viz., employment status, smoking, and drinking habits). The correlations between the 15 predictors and the DV (i.e., IADL-CV) were examined before conducting the hierarchical regression. Table 4.15 displays the correlations between the variables, and Table 4.16 displays B, β, sr^2, R, R^2, and adjusted R^2 after the entry of all 15 IVs. The results of the hierarchical regression on IADL-CV are elaborated in the following paragraph.

R was significantly different from zero at the end of each step. In Step 1, with employment status, smoking, and drinking habits in the equation, $R^2 = .16$, $F(3, 484) = 30.91$, $p < .001$. Employment status ($\beta = -.27$, $t = -6.55$, $p < .001$) and smoking habit ($\beta = -.27$, $t = -5.74$, $p < .001$) were the significant predictors of IADL-CV, while drinking habit was not significant in the model. In Step 2, with all IVs in the equation, the final model was significant, $F(15, 472) = 12.61$, $p < .001$. The addition of the 12 predictors of leisure activity participation to the prediction of IADL-CV by employment status, smoking, and drinking habits significantly accounted for additional variance, $R^2 = .29$ (adjusted $R^2 = .26$), $F_{inc}(12, 472) = 6.91$, $p < .001$. The 95% confidence limits ranged from .22 to .35. The adjusted R^2 value of .26 indicated that 26% of the variability in IADL-CV was predicted by the model. In the final model, total frequency of intellectual activity ($\beta = .19$, $t = 2.85$, $p = .005$), total frequency of social activity ($\beta = -.23$, $t = -2.59$, $p = .010$), total hours per week of social activity ($\beta = .22$, $t = 2.54$, $p = .011$), total hours per week of recreational activity ($\beta = .15$, $t = 2.51$, $p = .012$) and total hours per week of physical activity ($\beta = -.12$, $t = -2.13$, $p = .033$) significantly predicted the IADL-CV scores. Also, drinking habit ($\beta = -.10$, $t = -2.11$, $p = .036$) became significant and employment status ($\beta = -.23$, $t = -5.56$, $p < .001$) and smoking habit (β = -.15, t = -3.38, p < .001) remained significant in Step 2. The size and direction of the relationship suggested that being employed, engaging in a non-smoking and non-drinking lifestyle, more frequent intellectual activity, less frequent social activity, longer duration of social activity, longer duration of recreational activity, and shorter duration of physical activity predicted better daily functions among older adults.

Table 4.15

Correlations among the IADL-CV and the Predictors

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. IADL-CV	-														
2. Employment status	-.26***	-													
3. Smoking	-.29***	-.01	-												
4. Drinking	-.15***	-.11**	.44***	-											
5. Intellectual: *V*	.26***	-.20***	-.12**	.16***	-										
6. Social: *V*	.13**	-.07	-.12**	.04	.37***	-									
7. Recreational: *V*	.35***	-.15***	-.20***	.06	.51***	.34***	-								
8. Physical: *V*	.18***	-.22***	-.08*	.17***	.46***	.33***	.39***	-							
9. Intellectual: *F*	.31***	-.14***	-.13**	.04	.73***	.23***	.45***	.28***	-						
10. Social: *F*	-.04	.07	0	.07	.13**	.57***	.09*	.12**	.04	-					
11. Recreational: *F*	.34***	-.08*	-.22***	.06	.43***	.29***	.91***	.32***	.45***	.07	-				
12. Physical: *F*	.12**	.01	-.04	.09*	.25***	.26***	.34***	.59***	.22***	.16***	.34***	-			
13. Intellectual: *H*	.21***	-.17***	-.03	.09*	.50***	.11**	.29***	.15***	.63***	-.04	.27***	.08*	-		
14. Social: *H*	.01	.08*	-.04	.01	.09*	.56***	.08*	.08*	0	.89***	.06	.16***	-.03	-	
15. Recreational: *H*	.30***	.01	-.20***	-.03	.27***	.10*	.64***	.12**	.29***	-.06	.73***	.15***	.26***	-.03	-
16. Physical: *H*	-.02	.05	.10*	.18***	.17***	.20***	.18***	.43***	.13**	.14***	.17***	.69***	.07*	.17***	.08*

Note. IADL-CV = Chinese Lawton Instrumental Activities of Daily Living Scale; *V* = total number of subtypes; *F* = total frequency; *H* = total hours per week. Employment status was coded as 1 = employed, 2 = retired/ unemployed/ student.

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

Table 4.16

Hierarchical Regression of Significant Demographics and Leisure Activity Participation on IADL-CV

Entered variables		*B*	*SE* (*B*)	*β*	*t*	*p*	sr^2	R^2 change	*F* change	*df*	*p*
Step 1								.16	30.91	3, 484	<.001
	Employment status	-1.57***	.24	-.27	-6.55	<.001	-.27				
	Smoking habit	-2.01***	.35	-.27	-5.74	<.001	-.24				
	Drinking habit	-.45	.31	-.07	-1.48	.141	-.06				
Step 2								.13	6.91	12, 472	<.001
	Employment status	-1.33***	.24	-.23	-5.56	<.001	-.22				
	Smoking habit	-1.17***	.35	-.15	-3.38	<.001	-.13				
	Drinking habit	-.64*	.30	-.10	-2.11	.036	-.08				
	Intellectual: Number of subtypes	-.07	.13	-.04	-.53	.595	-.02				
	Social: Number of subtypes	.04	.12	.02	.29	.768	.01				
	Recreational: Number of subtypes	.22	.17	.13	1.27	.206	.05				
	Physical: Number of subtypes	.05	.09	.03	.54	.587	.02				
	Intellectual: Total frequency	.09**	.03	.19	2.85	.005	.11				
	Social: Total frequency	-.45*	.17	-.23	-2.59	.010	-.10				
	Recreational: Total frequency	-.01	.03	-.03	-.31	.756	-.01				
	Physical: Total frequency	.04	.03	.10	1.59	.112	.06				
	Intellectual: Total hours per week	.00	.01	.00	.00	.998	.00				
	Social: Total hours per week	.16*	.06	.22	2.54	.011	.10				
	Recreational: Total hours per week	.02*	.01	.15	2.51	.012	.10				
	Physical: Total hours per week	-.04*	.02	-.12	-2.13	.033	-.08				
	Intercept =	17.01	.49		34.36	<.001					
Final model:											
	R =	.53									
	R^2 =	.29 [a]									
	Adjusted R^2 =	.26									
	F(15, 472) =	12.61									
	p =	<.001									

Note. IADL-CV = Chinese Lawton Instrumental Activities of Daily Living Scale.

[a] 95% confidence limits ranged from .22 to .35.

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

4.3.5.6 Summary of Significant Predictors in Each Regression Model. All regression models reported that leisure activity participation could significantly predict general cognition, EF, loneliness, levels of depression, anxiety and stress, and functional independence. Table 4.17 summarises the significant predictors of leisure activity participation and the directions in the five regression models.

Table 4.17

A Summary of Significant Predictors in Step 2 Hierarchical Regression Models or Standard Multiple Regression Models on COBRA-C, DEX, UCLA Loneliness Scale, DASS-21 and IADL-CV

Functions and Significant Predictors	Direction of Relationship
COBRA-C[#]	
Smoking habit	Non-smoking habit predicted better general cognition.
Social: Total frequency	Less frequent social activity predicted better general cognition.
Social: Total hours per week	Longer duration of social activity predicted better general cognition.
DEX[#]	
Intellectual: Total number of subtypes	Less diversity in intellectual activity predicted better EF.
Intellectual: Total frequency	More frequent intellectual activity predicted better EF.
Physical: Total hours per week	Shorter duration of physical activity predicted better EF.
UCLA loneliness scale[#]	
N/A	N/A
DASS-21[#]	
Smoking habit	Non-smoking habit predicted better mental health.
Drinking habit	Non-drinking habit predicted better mental health.
Intellectual: Total number of subtypes	Less diversity in intellectual activity predicted better mental health.
Intellectual: Total frequency	More frequent intellectual activity predicted better mental health.
Social: Total frequency	Less frequent social activity predicted better mental health.
Social: Total hours per week	Longer duration of social activity predicted better mental health.
IADL-CV	
Employment status	Being employed predicted better functional independence.
Smoking habit	Non-smoking habit predicted better functional independence.
Drinking habit	Non-drinking habit predicted better functional independence.
Intellectual: Total frequency	More frequent intellectual activity predicted better functional independence.
Social: Total frequency	Less frequent social activity predicted better functional independence.
Social: Total hours per week	Longer duration of social activity predicted better functional independence.
Recreational: Total hours per week	Longer duration of recreational activity predicted better functional independence.
Physical: Total hours per week	Shorter duration of physical activity predicted better functional independence.

Note. COBRA-C = Chinese Version of Cognitive Complaints in Bipolar Disorder Rating Assessment; DEX = Chinese Version of Dysexecutive Questionnaire; DASS-21 = Chinese Version of Depression Anxiety and Stress Scale-21; IADL-CV = Chinese Lawton Instrumental Activities of Daily Living Scale.

[#] A higher score represents worse performance.

4.3.6 Mahjong Playing and Cognitive, Psychological and Daily Functions

Four hierarchical regressions and one standard multiple regression were conducted to determine if mahjong playing predicted COBRA-C, DEX, UCLA loneliness scale, DASS-21, and IADL-CV. Results of the evaluation of assumptions led to the transformation of variables to reduce skewness and improve normality, linearity and homoscedasticity of the residuals. A square root transformation was performed on the total hours per week of mahjong playing.

4.3.6.1 General Cognition – COBRA-C. A hierarchical regression was conducted to determine if the addition of mahjong playing predicted general cognition as measured by COBRA-C after controlling for the significant demographic variables (viz., smoking habit). The correlations between the 3 predictors and the DV (i.e., COBRA-C) were examined before conducting the hierarchical regression. Table 4.18 displays the correlations between the variables, and Table 4.19 displays B, β, sr^2, R, R^2, and adjusted R^2 after entry of all three IVs. The results of the hierarchical regression on COBRA-C are elaborated in the following paragraph.

R was significantly different from zero at the end of each step. In Step 1, with smoking habit in the equation, $R^2 = .02$, $F(1, 501) = 11.73$, $p < .001$. Smoking habit ($\beta = .15$, $t = 3.43$, $p < .001$) was a significant predictor of COBRA-C. In Step 2, with all IVs in the equation, the final model was significant, $F(3, 499) = 12.96$, $p < .001$. The addition of the two predictors related to mahjong playing to the prediction of COBRA-C by smoking habit significantly accounted for additional variance, $R^2 = .07$ (adjusted $R^2 = .07$), $F_{inc}(2, 499) = 13.29$, $p < .001$. The 95% confidence limits ranged from .03 to .11. The adjusted R^2 value of .07 indicated that 7% of the variability in COBRA-C was predicted by the model. In the final model, frequency of mahjong playing ($\beta = .54$, $t = 5.03$, $p < .001$), and total hours per week of mahjong playing ($\beta = -.44$, $t = -4.14$, $p < .001$) significantly contributed to additional variance in the prediction of the COBRA-C scores. Smoking habit ($\beta = .12$, $t = 2.80$, $p = .005$) remained significant in

Step 2. The size and direction of the relationship suggested that a non-smoking lifestyle, less frequent mahjong playing and longer duration of mahjong playing predicted better general cognition among older adults.

Table 4.18

Correlations among the COBRA-C and the Predictors

	1	2	3	4
1. COBRA-C	-			
2. Smoking	.15***	-		
3. Mahjong: Frequency	.15***	.11**	-	
4. Mahjong: Total hours per week#	.06	.07	.91***	-

Note. COBRA-C = Chinese Version of Cognitive Complaints in Bipolar Disorder Rating Assessment. Frequency was coded as 0 = never, 1 = yearly, 2 = monthly, 3 = weekly or above.

Variables that have applied a square root transformation.

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

Table 4.19

Hierarchical Regression of Significant Demographics and Mahjong Playing on COBRA-C

Entered variables		*B*	*SE B*	*β*	*t*	*p*	sr^2	R^2 change	*F* change	*df*	*p*
Step 1								.02	11.73	1, 501	<.001
	Smoking habit	3.22***	.94	.15	3.43	<.001	.15				
Step 2								.05	13.29	2, 499	<.001
	Smoking habit	2.59**	.93	.12	2.80	.005	.12				
	Mahjong: Frequency	4.28***	.85	.54	5.03	<.001	.22				
	Mahjong: Total hours per week#	-5.17***	1.25	-.44	-4.14	<.001	-.18				
	Intercept =	13.15	.40		32.87	<.001					
Final model:											
	R =	.27									
	R^2 =	.07[a]									
	Adjusted R^2 =	.07									
	F(3, 499) =	12.96									
	p =	<.001									

Note. COBRA-C = Chinese Version of Cognitive Complaints in Bipolar Disorder Rating Assessment.

[a] 95% confidence limits ranged from .03 to .11.

Variables that have applied a square root transformation.

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

4.3.6.2 EF-DEX. A hierarchical regression was conducted to determine if the addition of mahjong playing predicted EF as measured by DEX after controlling for the significant demographic variables (viz., smoking and drinking habits). The correlations between the 4 predictors and the DV (i.e., DEX) were examined before conducting the hierarchical regression. Table 4.20 displays the correlations between the variables, and Table 4.21 displays B, β, sr^2, R, R^2, and adjusted R^2 after the entry of all four IVs. The results of the hierarchical regression on DEX are elaborated in the following paragraph.

R was significantly different from zero at the end of each step. In Step 1, with smoking and drinking habits in the equation, $R^2 = .03$, $F(2, 502) = 8.05$, $p < .001$. Only smoking habit ($\beta = .13$, $t = 2.62$, $p = .009$) was a significant predictor of DEX, while drinking habit was not significant in the model. In Step 2, with all IVs in the equation, the final model was significant, $F(4, 500) = 11.02$, $p < .001$. The addition of the two predictors related to mahjong playing to the prediction of DEX by smoking and drinking habits significantly accounted for additional variance, $R^2 = .08$ (adjusted $R^2 = .07$), $F_{inc}(2, 500) = 13.59$, $p < .001$. The 95% confidence limits ranged from .04 to .13. The adjusted R^2 value of .07 indicated that 7% of the variability in DEX was predicted by the model. In the final model, frequency of mahjong playing ($\beta = .51$, $t = 4.81$, $p < .001$) and total hours per week of mahjong playing ($\beta = -.37$, $t = -3.55$, $p < .001$) significantly contributed to additional variance in the prediction of the DEX scores. The smoking habit ($\beta = .11$, $t = 2.26$, $p = .024$) remained significant in Step 2. The size and direction of the relationship suggested that a non-smoking lifestyle, less frequent mahjong playing and longer duration of mahjong playing predicted better EF among older adults.

Table 4.20

Correlations among the DEX and the Predictors

	1	2	3	4	5
1. DEX	-				
2. Smoking	.16***	-			
3. Drinking	.13**	.41***	-		
4. Mahjong: Frequency	.19***	.11**	.19***	-	
5. Mahjong: Total hours per week#	.11**	.07	.17***	.91***	-

Note. DEX = Chinese Version of Dysexecutive Questionnaire. Frequency was coded as 0 = never, 1 = yearly, 2 = monthly, 3 = weekly or above.

Variables that have applied a square root transformation.

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

Table 4.21

Hierarchical Regression of Significant Demographics and Mahjong Playing on DEX

Entered variables		*B*	*SE* (*B*)	*β*	*t*	*p*	sr^2	R^2 change	*F* change	*df*	*p*
Step 1								.03	8.05	2, 502	<.001
	Smoking habit	4.45**	1.70	.13	2.62	.009	.12				
	Drinking habit	2.48	1.45	.08	1.71	.088	.08				
Step 2								.05	13.59	2, 500	<.001
	Smoking habit	3.76*	1.66	.11	2.26	.024	.10				
	Drinking habit	1.61	1.43	.05	1.13	.261	.05				
	Mahjong: Frequency	6.77***	1.41	.51	4.81	<.001	.21				
	Mahjong: Total hours per week[#]	-7.31***	2.06	-.37	-3.55	<.001	-.15				
	Intercept =	20.00	.69		29.13	<.001					
Final model:											
	R =	.28									
	R^2 =	.08[a]									
	Adjusted R^2 =	.07									
	F(4, 500) =	11.02									
	p =	<.001									

Note. DEX = Dysexecutive Questionnaire.

[a] 95% confidence limits ranged from .04 to .13.

[#] Variables that have applied a square root transformation.

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

4.3.6.3 Loneliness – UCLA Loneliness Scale. A standard multiple regression was conducted to determine if mahjong playing predicted loneliness as measured by the UCLA loneliness scale. The correlations between the 2 predictors and the DV (i.e., UCLA Loneliness Scale) were examined before conducting the standard multiple regression. Table 4.22 displays the correlations between the variables, and Table 4.23 displays B, β, R^2, and adjusted R^2 after the entry of all two IVs related to mahjong playing. The results of the standard multiple regression on UCLA Loneliness Scale are elaborated in the following paragraph.

R was significantly different from zero, $F(2, 499) = 3.38$, $p = .035$, with R^2 at .01 (adjusted $R^2 = .01$) and 95% confidence limits ranged from -.01 to .03. Frequency of mahjong playing ($\beta = .27$, $t = 2.50$, $p = .013$) and total hours per week of mahjong playing ($\beta = -.28$, $t = -2.58$, $p = .010$) were significant predictors of UCLA loneliness scale. Altogether, 1% (1% adjusted) of the variability in the UCLA loneliness scale was predicted by the total hours per week of mahjong playing. The size and direction of the relationship suggested that less frequent mahjong playing and longer duration of mahjong playing predicted less loneliness among older adults.

Table 4.22

Correlations among the UCLA Loneliness Scale and the Predictors

	1	2	3
1. UCLA Loneliness Scale	-		
2. Mahjong: Frequency	.02	-	
3. Mahjong: Total hours per week#	-.03	.91***	-

Note. Frequency was coded as 0 = never, 1 = yearly, 2 = monthly, 3 = weekly or above.

Variables that have applied a square root transformation.

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

Table 4.23

Standard Multiple Regression of Mahjong Playing on UCLA Loneliness Scale

Entered variables		*B*	*SE* (*B*)	*β*	*t*	*p*
Step 1						
Mahjong: Frequency		2.73*	1.09	.27	2.50	.013
Mahjong: Total hours per week#		-4.27*	1.66	-.28	-2.58	.010
Intercept =		44.40	.49		91.51	44.40
Final model:						
R =	.12					
R^2 =	.01[a]					
Adjusted R^2 =	.01					
$F(2, 499)$ =	3.38					
p =	.035					

[a] 95% confidence limits ranged from -.01 to .03.

Variables that have applied a square root transformation.

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

4.3.6.4 Depression, Anxiety and Stress – DASS-21. A hierarchical regression was conducted to determine if the addition of mahjong playing predicted the overall level of depression, anxiety, and stress as measured by DASS-21 after controlling for the significant demographic variables (viz., smoking and drinking habits). The correlations between the 4 predictors and the DV (i.e., DASS-21) were examined before conducting the hierarchical regression. Table 4.24 displays the correlations between the variables, and Table 4.25 displays B, β, sr^2, R, R^2, and adjusted R^2 after the entry of all four IVs. The results of the hierarchical regression on DASS-21 are elaborated in the following paragraph.

R was significantly different from zero at the end of each step. In Step 1, with smoking and drinking habits in the equation, $R^2 = .06$, $F(2, 502) = 15.21$, $p < .001$. Smoking habit ($\beta = .17$, $t = 3.55$, $p < .001$) and drinking habit ($\beta = .11$, $t = 2.41$, $p = .016$) were the significant predictors of DASS-21. In Step 2, with all IVs in the equation, the final model was significant, $F(4, 500) = 11.86$, $p < .001$. The addition of the two predictors related to mahjong playing to the prediction of DASS-21 by smoking and drinking habits significantly accounted for additional variance, $R^2 = .09$ (adjusted $R^2 = .08$), $F_{inc}(2, 500) = 8.08$, $p < .001$. The 95% confidence limits ranged from .04 to .13. The adjusted R^2 value of .08 indicated that 8% of the variability in DASS-21 scores was predicted by the model. In the final model, frequency of mahjong playing ($\beta = .42$, $t = 4.02$, $p < .001$) and total hours per week of mahjong playing ($\beta = -.38$, $t = -3.58$, $p < .001$) significantly contributed to additional variance in the prediction of the DASS-21 scores. Smoking habit ($\beta = .15$, $t = 3.25$, $p = .001$) and drinking habit ($\beta = .10$, $t = 2.13$, $p = .033$) remained significant in Step 2. The size and direction of the relationship suggested that a non-smoking and non-drinking lifestyle, less frequent mahjong playing, and longer duration of mahjong playing predicted better mental health among older adults.

Table 4.24

Correlations among the DASS-21 and the Predictors

	1	2	3	4	5
1. DASS-21	-				
2. Smoking	.21***	-			
3. Drinking	.18***	.41***	-		
4. Mahjong: Frequency	.12**	.11**	.19***	-	
5. Mahjong: Total hours per week[#]	.04	.07	.17***	.91***	-

Note. DASS-21 = Chinese Version of Depression Anxiety and Stress Scale-21. Frequency was coded as 0 = never, 1 = yearly, 2 = monthly, 3 = weekly or above.

[#] Variables that have applied a square root transformation.

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

Table 4.25

Hierarchical Regression of Significant Demographics and Mahjong Playing on DASS-21

Entered variables		*B*	*SE* (*B*)	*β*	*t*	*p*	sr^2	R^2 change	*F* change	*df*	*p*
Step 1								.06	15.21	2, 502	<.001
	Smoking habit	10.70***	3.02	.17	3.55	<.001	.15				
	Drinking habit	6.22*	2.58	.11	2.41	.016	.10				
Step 2								.03	8.08	2, 500	<.001
	Smoking habit	9.69**	2.98	.15	3.25	.001	.14				
	Drinking habit	5.50*	2.58	.10	2.13	.033	.09				
	Mahjong: Frequency	10.15***	2.53	.42	4.02	<.001	.17				
	Mahjong: Total hours per week#	-13.27***	3.70	-.38	-3.58	<.001	-.15				
	Intercept =	23.04	1.23		18.69	<.001					
Final model:											
	R =	.29									
	R^2 =	.09[a]									
	Adjusted R^2 =	.08									
	F(4, 500) =	11.86									
	p =	<.001									

Note. DASS-21 = Depression Anxiety and Stress Scale-21.

[a] 95% confidence limits ranged from .04 to .13.

Variables that have applied a square root transformation.

* *p* < .05. ** *p* < .01. *** *p* < .001.

4.3.6.5 Functional Independence – IADL-CV. A hierarchical regression was conducted to determine if the addition of mahjong playing related variables predicted functional independence as measured by IADL-CV after controlling for the significant demographic variables (viz., employment status, smoking and drinking habits). The correlations between the 5 predictors and the DV (i.e., IADL-CV) were examined before conducting the hierarchical regression. Table 4.26 displays the correlations between the variables, and Table 4.27 displays B, β, sr^2, R, R^2, and adjusted R^2 after the entry of all five IVs. The results of the hierarchical regression on IADL-CV are elaborated in the following paragraph.

R was significantly different from zero at the end of each step. In Step 1, with employment status, smoking and drinking habits in the equation, $R^2 = .18$, $F(3, 500) = 35.98$, $p < .001$. Employment status ($\beta = -.29$, $t = -7.17$, $p < .001$) and smoking habit ($\beta = -.28$, $t = -6.33$, $p < .001$) were the significant predictors of IADL-CV, while drinking habit was not significant in the model. In Step 2 with all IVs in the equation, the final model was significant, $F(5, 498) = 25.50$, $p < .001$. The addition of the two predictors related to mahjong playing to the prediction of IADL-CV by employment status, smoking and drinking habits significantly accounted for additional variance, $R^2 = .20$ (adjusted $R^2 = .20$), $F_{inc}(2, 498) = 8.22$, $p < .001$. The 95% confidence limits ranged from .14 to .27. The adjusted R^2 value of .20 indicated that 20% of the variability in IADL-CV was predicted by the model. In the final model, frequency of mahjong playing ($\beta = -.39$, $t = -3.94$, $p < .001$) and total hours per week of mahjong playing ($\beta = .39$, $t = 3.98$, $p < .001$) significantly contributed to additional variance in the prediction of the IADL-CV scores. Employment status ($\beta = -.30$, $t = -7.44$, $p < .001$) and smoking habit ($\beta = -.27$, $t = -6.06$, $p < .001$) remained significant in Step 2. The size and direction of the relationship suggested that being employed, engaging in a non-smoking lifestyle, less frequent mahjong playing, and longer duration of mahjong playing predicted better daily functions among older adults.

Table 4.26

Correlations among the IADL-CV and the Predictors

	1	2	3	4	5	6
1. IADL-CV	-					
2. Employment status	-.28***	-				
3. Smoking	-.30***	-.02	-			
4. Drinking	-.15***	-.11**	.41***	-		
5. Mahjong: Frequency	-.07	-.03	.11**	.19***	-	
6. Mahjong: Total hours per week#	.01	-.01	.07	.17***	.91***	-

Note. IADL-CV = Chinese Lawton Instrumental Activities of Daily Living Scale.

Employment status was coded as 1 = employed, 2 = retired/ unemployed/ student. Frequency was coded as 0 = never, 1 = yearly, 2 = monthly, 3 = weekly or above.

Variables that have applied a square root transformation.

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

Table 4.27

Hierarchical Regression of Significant Demographics and Mahjong Playing on IADL-CV

Entered variables		*B*	*SE* (*B*)	*β*	*t*	*p*	sr^2	R^2 change	*F* change	*df*	*p*
Step 1								.18	35.98	3, 500	<.001
	Employment status	-1.68***	.23	-.29	-7.17	<.001	-.29				
	Smoking habit	-2.18***	.34	-.28	-6.33	<.001	-.26				
	Drinking habit	-.47	.30	-.07	-1.59	.113	-.06				
Step 2								.03	8.22	2, 498	<.001
	Employment status	-1.72***	.23	-.30	-7.44	<.001	-.30				
	Smoking habit	-2.07***	.34	-.27	-6.06	<.001	-.24				
	Drinking habit	-.45	.30	-.07	-1.50	.134	-.06				
	Mahjong: Frequency	-1.14***	.29	-.39	-3.94	<.001	-.16				
	Mahjong: Total hours per week[#]	1.69***	.42	.39	3.98	<.001	.16				
	Intercept =	19.38	.40		48.00	<.001					
Final model:											
	R =	.45									
	R^2 =	.20[a]									
	Adjusted R^2 =	.20									
	F(5, 498) =	25.50									
	p =	<.001									

Note. IADL-CV = Chinese Lawton of Instrumental Activities of Daily Living Scale.

[a] 95% confidence limits ranged from .14 to .27.

[#] Variables that have applied a square root transformation.

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

4.3.6.6 Summary of Significant Predictors in Each Regression Model. All regression models reported that mahjong playing could significantly predict general cognition, EF, loneliness, levels of depression, anxiety and stress and functional independence. Table 4.28 summarises the significant predictors of mahjong playing and the directions in the five regression models.

Table 4.28

A Summary of Significant Predictors in Step 2 Hierarchical Regression Models or Standard Multiple Regression Models on COBRA-C, DEX, UCLA Loneliness Scale, DASS-21 and IADL-CV

Functions and Significant Predictors	Directions of Relationship
COBRA-C#	
Smoking habit	Non-smoking habit predicted better general cognition.
Mahjong: Frequency	Less frequent mahjong playing predicted better general cognition.
Mahjong: Total hours per week	Longer duration of mahjong playing predicted better general cognition.
DEX#	
Smoking habit	Non-smoking habit predicted better general cognition.
Mahjong: Frequency	Less frequent mahjong playing predicted better EF.
Mahjong: Total hours per week	Longer duration of mahjong playing predicted better EF.
UCLA loneliness scale#	
Mahjong: Frequency	Less frequent mahjong playing predicted less loneliness.
Mahjong: Total hours per week	Longer duration of mahjong playing predicted less loneliness.
DASS-21#	
Smoking habit	Non-smoking habit predicted better mental health.
Drinking habit	Non-drinking habit predicted better mental health.
Mahjong: Frequency	Less frequent mahjong playing predicted better mental health.
Mahjong: Total hours per week	Longer duration of mahjong playing predicted better mental health.
IADL-CV	
Employment status	Being employed predicted better functional independence.
Smoking habit	Non-smoking habit predicted better functional independence.
Mahjong: Frequency	Less frequent mahjong playing predicted better functional independence.
Mahjong: Total hours per week	Longer duration of mahjong playing predicted better functional independence.

Note. COBRA-C = Chinese Version of Cognitive Complaints in Bipolar Disorder Rating Assessment; DEX = Chinese Version of Dysexecutive Questionnaire; DASS-21 = Chinese Version of Depression Anxiety and Stress Scale-21; IADL-CV = Chinese Lawton Instrumental Activities of Daily Living Scale.

A higher score represents worse performance.

4.4 Discussion

This study examined the relationships between leisure activity participation, mahjong playing, and cognitive, psychological, and daily functions. The results partially supported the four hypotheses. First, a similar pattern of the nature and extent of leisure activity participation in previous studies was found in this updated survey. Second, engaging in different domains of activities (viz., intellectual, social, recreational and physical) and different dosages of participation (viz., diversity, frequency, and duration) were shown to significantly predict cognitive, psychological and daily functions of older adults. However, not all the domains contributed to the predictions, and not all the significant predictions were in the expected direction. Third, mahjong playing was found to have a prevalence rate of 27% among Hong Kong older adults, which is similar to the average prevalence rate of 25.8% reported in previous studies (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990). Although the results of the present survey did not reveal mahjong playing as one of the top 10 most frequently participated leisure activities, this game invented in China was found to be the 2nd ranked activity that older adults engaged in for the longest duration each time. Lastly, the frequency and total hours per week of mahjong playing were also found to predict the functions of older adults significantly. Interestingly, only the number of hours of mahjong playing predicted the functions in a positive direction, while the frequency of mahjong playing predicted the functions in the opposite direction.

Each of these findings will be discussed in turn.

4.4.1 Nature and Extent of Leisure Activity Participation

The results partially supported the first hypothesis: a similar pattern of the nature and extent of leisure activity participation was observed in this updated survey when compared to previous studies in Hong Kong (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990; Zhao & Chen, 2013).

4.4.1.1 Participation Rate. In the current study, the activities with the highest participation rate were (i) watching television, (ii) slow walking, (iii) using a computer or surfing the Internet, (iv) reading books, newspapers, or magazines and (v) shopping.

Watching television (70%) was the most popular leisure activity among older adults in this study. This, however, is lower than the results of previous studies, in which the participation rate was 98.1% in Chou et al. (2004), 99.6% in Cheung et al. (2009), and 99.1% in Zhao and Chen (2013). The decrease in the participation rate in watching television may reflect the fact that, in recent years, there are more leisure-activity options available for older adults. Results of this project revealed that more older adults were engaging in using the computer (53%), as compared to 8.2% as measured by Cheung et al. (2009) and 19.8% by Zhao and Chen (2013). Compared to 10-15 years ago, older adults were more likely to use the Internet because of its popularity and ease of use. The increased usage of the Internet also suggests a switch from recreational activity (viz., watching television) to intellectual activity (viz., using computers or surfing the Internet). Some research has found positive impacts of using the Internet on social engagement, subjective health, and cognitive function of older adults (Huang & Chen, 2022; Liu et al., 2024; Yu et al., 2022). A review by Aggarwal et al. (2020) explained that Internet usage fostered older adults to connect with their family and friends, promote the maintenance of social networks, and improve the accessibility of information and online activities. Another review by Leung et al. (2022) also found that the application of technology, such as computerised cognitive training, virtual-reality interventions, and robot-assisted interventions, would help to improve the cognitive functions of older adults. Besides, in light of the advantages of using technology, more studies are expected to explore how technology or the Internet could be further implemented for the benefit of older adults.

Consistent with previous studies, reading books/ newspapers/ magazines and strolling on the street or shopping were also found in this study to be popular activities among older adults (Cheung et al., 2009; Chou et al., 2004; Zhao & Chen, 2013). However, these activities were shown to have a lower participation rate (i.e., reading: 48%; shopping: 40% in the current study) than previous studies (i.e., reading: 63.2% to 72.6%; shopping: 61.4% to 94.8%). One possible reason may be that older adults can access more information, such as e-books and online shopping, on the Internet. Therefore, this may reduce their participation in reading printed books and shopping. To understand the change, additional analyses on the frequency and duration of the activities and more research are needed.

4.4.1.2 Frequency. Among the engaged participants, the most frequently participated activities reported in this study were (i) keeping pets, (ii) watching television, (iii) using a computer or surfing the Internet, (iv) listening to the radio, and (v) cooking for pleasure.

This study showed that, in addition to watching television, keeping pets was also reported by older adults as the most frequent activity. Different from previous studies, which have reported that watching television was the most frequent activity among others (Cheung et al., 2009; Chou et al., 2004; Zhao & Chen, 2013). It should be noted that previous studies did not often include keeping pets as an activity (Chou et al., 2004; Zhao & Chen, 2013). Cheung et al. (2009) measured the frequency of "caring pets/plants" in older adults.[10] Results showed that 44.2% of participants engaged in "caring pets/plants" for at least one to three days per month, and 37.5% of them engaged in the activity on a daily basis. The average frequency of "caring pets/plants" as reported by Cheung et al. (2009) was similar to the current findings (i.e., around six days per week). Regarding the low participation rate of keeping pets in this study (i.e., 8% vs. 44.2% in Cheung et al., 2009), it may imply that a small group of older adults are willing to spend time caring for and accompanying their pets.

Interestingly, using computers and cooking for pleasure have also become frequent activities among older adults in more recent years. The frequent engagement in using computers supports the claim that older adults have increased the frequency of using computers, which could potentially decrease participation rate and frequency in other leisure activities such as reading and shopping. Similar to keeping pets, cooking for pleasure was not measured in previous studies, except for Kwan (1990), who collected participation rate instead of the frequency of cooking. The current study reported a participation rate of 27% in cooking for pleasure, which highlighted that a group of older adults enjoyed cooking frequently.

4.4.1.3 Duration. Among the engaged participants, the activities that reported the longest duration of the engagement in each session in this study were (i) keeping pets, (ii) mahjong playing, (iii) Chinese martial arts, (iv) fishing, and (v) meeting relatives or friends.

As mentioned earlier, some leisure activities relating to the Chinese culture, such as mahjong playing and Chinese martial arts, were reported by older adults to have a

[10] The scale did not separate caring pets and plants.

long duration of participation in the current study. Note that both mahjong playing and Chinese martial arts did not report a very high participation rate and frequency, but they were found to rank as the second and third longest-duration activities (i.e., mahjong playing: 4.06 hr; Chinese martial arts: 3.82 hr). It may imply that older adults in Hong Kong are more likely to spend time on specific leisure activities related to Chinese culture once they are engaged in it. However, these specific leisure activities related to Chinese culture have received little attention in previous studies. Mahjong playing has been investigated along with other activities such as playing cards and chess (Chou et al., 2004; Kwan, 1990), while Chinese martial arts was not included in the measurement scale in previous studies (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990; Zhao & Chen, 2013). In light of the long duration of these culturally specific activities, the current findings also highlighted the potential of promoting these activities among older adults to boost their activity levels.

In sum, the findings implied that including the dosages of duration in a survey was useful to capture additional information regarding leisure activity engagement in older adults.

4.4.2 Prediction of Cognitive, Psychological and Daily Functions by Leisure Activity Participation

The results of Study 1 partially support the second hypothesis, which stated that only some domains of activities and a certain dosage of participation would predict better cognitive, psychological and daily functions.

4.4.2.1 General Cognition. After controlling for smoking habit, frequency and duration of social activity significantly predicted general cognition as measured by COBRA-C. It should be noted that a longer duration of social activity predicted better general cognition. More frequent social activity, in contrast, was found to predict poorer general cognition.

As expected, this study found that a longer duration of social activity predicted better general cognition. This is likely to be because by extending the duration of participation, older adults could establish stable and high-quality social interactions. This finding is consistent with a recent scoping review, which found that a longer duration of leisure activity participation had a positive impact on cognition in older individuals (Wenzel et al., 2024). The continuous engagement with longer duration was suggested to promote the positive impact of leisure activity: active engagement, enjoyment, and self-direction.

However, results of this study showed that more frequent social activity predicted poorer general cognition. The finding of frequent engagement in social activities would predict poorer general cognition is inconsistent with that of a previous study. A large-scale longitudinal study with 1,138 older adults reported that frequent engagement in social activities was associated with less cognitive decline, as measured by 21 cognitive tests (James et al., 2011). The discrepancy between the current results and those reported in James et al.'s study could be because too many social activities could lead to social exhaustion or overload in older adults. Although the social activities included in this study were highly socialised, engaging in social activities also involved cognitive or physical energy, such as attending an interest class, joining a social centre, and participating in volunteer work. Frequently engaging in these activities may lead to physical and mental fatigue in older adults (Hu et al., 2025). Besides, as older adults have limited cognitive resources according to the processing speed theory (Salthouse, 1996), frequently engaging in social activities may also be drained by constant social interactions, resulting in fatigue and leading to poorer general cognition.

Among the four domains of leisure activities, only the social domain significantly predicted general cognition. This provides evidence to support cross-domain benefits. It was surprising that intellectual and physical activities were not found to predict general cognition in this study, which is different from the results of some previous studies (Su et al., 2022; Wang et al., 2012). It is difficult to explain the discrepancy between the observed results and the expected outcomes. Su et al. (2022) conducted a systematic review and meta-analysis and found that participating in intellectual, physical and social activities may help reduce the risk of all-cause dementia, AD and vascular dementia. Another systematic review by Wang et al. (2012) also supported the positive impact of intellectual and physical activities on cognitive functions, as measured by cognitive tests such as MMSE and Short Portable Mental Status Questionnaire. One possible explanation may be that the number of intellectual and physical activities included in the Checklist was relatively large (i.e., 13 intellectual activities and 18 physical activities), which might have increased the variance of the predictors related to intellectual and physical activities and made it challenging to achieve statistical significance. More research is needed to clarify the issue. Future studies may examine the relative importance of each activity and only include those influential activities in the prediction.

In this study, recreational activities were not found to predict general cognition, which is different from the findings of some previous studies (Gavett et al., 2024; Raichlen et al., 2022). It may be explained by the fact that recreational activities were sedentary and socially isolated, which may have made it challenging to stimulate cognitive functions and resulted in no significant prediction of general cognition. Raichlen et al. (2022) reported that the increasing time spent in cognitively passive activity (i.e., watching television) was associated with an increased risk of incident dementia. Fancourt and Steptoe (2019) also found that watching television for more than 3.5 hr per day was associated with verbal memory decline over the following six years. These studies suggested that long-term participation in cognitively passive activities might be associated with a decline in cognitive trajectory. While the current study employed a cross-sectional design, more longitudinal studies are warranted to find out the long-term effects of engaging in cognitively passive activities. Moreover, some active recreational activities, such as cooking for pleasure and keeping pets, were included in the current study, which may have cancelled out the negative effects of the cognitively passive activities (i.e., watching television). Future studies are suggested to conduct subgroup analyses on the types of recreational activities (i.e., cognitively passive or active activities) and examine whether they could predict general cognition in different directions.

In terms of the significant demographic variables, smoking habit significantly predicted poorer general cognition across both Steps 1 and 2. These findings are consistent with the results of previous studies, which indicated that smoking habit was associated with poorer general cognition in healthy older adults (Benito-León et al., 2023; Bloomberg et al., 2024). Bloomberg et al. (2024) explained that an unhealthy lifestyle would be associated with an accelerated cognitive decline.

Overall, the observed results supported the cross-domain benefits of social activities on general cognition, and varying dosage levels predicted general cognition in different directions.

4.4.2.2 EF. After controlling for smoking and drinking habits, diversity of intellectual activity, frequency of intellectual activity, and duration of physical activity were found to significantly predict EF as measured by DEX. However, it should be noted that only more frequent intellectual activity predicted better EF, while greater diversity in intellectual activity and longer duration of physical activity were found to predict poorer EF.

As expected, more frequent participation in intellectual activity predicted better EF. Crucially, this pattern may also underscore the importance of regular participation in intellectual activities to yield these advantages: enhanced executive control, and increased cognitive control beliefs (i.e., the belief that an individual could impact and mitigate age-related cognitive decline). Previous studies found that participating frequently in intellectual activity was associated with higher levels of executive control (Lin et al., 2014). In a 10-year longitudinal study, it was also suggested that cognitive control beliefs were enhanced with frequent participation in intellectual activities, and this further led to positive changes in EF in older adults (Schiloski & Lachman, 2024). The same study also suggested that older adults with better self-regulatory processes found it easier to initiate and maintain intellectual activities that could facilitate positive changes in cognitive functioning, thus resulting in better EF (Schiloski & Lachman, 2024).

However, participation in more diverse intellectual activities was found to predict poorer EF, contradicting a previous study that reported a positive association between more diverse leisure activity participation and better cognitive functioning and EF (Lee et al., 2021). It is difficult to explain why a more diverse participation in intellectual activity in this study was found to be associated with poorer EF. Possibly, older adults who participate in a greater diversity of intellectual activities may need to allocate additional resources to manage their schedules and arrangements, which is cognitively demanding and may lead to cognitive fatigue in older adults (Ren et al., 2019). Indeed, older adults were found to perform poorer than younger adults on the dual-task, as it added additional processing steps to them (Verhaeghen & Cerella, 2002). Therefore, it is suggested that a greater diversity of intellectual activities may predict worse EF in older adults.

Moreover, this study also found that a longer duration of physical activity was associated with poorer EF, contradicting the positive effects reported in previous studies (Eggermont et al., 2009; Xiong et al., 2021). While Eggermont et al. (2009) did not consider the duration of participation and Xiong et al. (2021) evaluated the intervention with a constant duration (i.e., range from 20 to 90 min per session and three sessions weekly; 1 to 4.5 hr per week), it is possible that the older adults in this study may have exceeded the optimal duration of physical activity participation (M = 10.05 hr per week, SD = 16.24 hr per week). The literature has also reported the mixed effects of physical activity on EF (Iso-Markku et al., 2024). A longer length of exercise training was shown to have the least impact on EF, as compared with short and mid-length exercising (Chen et al., 2020). The results suggest that physical activity may have some impact on EF, but the optimal duration and the effect size still need further investigation.

Among the four domains, only the intellectual and physical domains significantly predicted EF. EF is a higher-order cognitive function, and it is reasonable that engaging in intellectual activities could predict better EF. In line with the current literature, engaging in intellectual activities helped to foster better executive control (Lin et al., 2014; Schiloski & Lachman, 2024). Cross-domain benefits were supported by the fact that engaging in physical activities could help to predict EF. Nonetheless, the direction was not as expected, given that the literature had reported positive benefits of participation in physical activities on EF in older adults (Eggermont et al., 2009; Xiong et al., 2021). A meta-analysis of RCTs also showed that physical activity interventions were beneficial for improving EF in older adults with AD or related dementia (Zeng et al., 2023). The discrepancy may be attributed to the explanation provided above, older adults in this study might have exceeded the optimal duration, resulting in the negative association between physical activity participation and EF. There were no significant results found in the social and recreational domains. It is reasonable to suggest that these two domains generally may not be directly related to EF, as this higher-order cognitive function utilises complex cognitive skills.

In terms of the significant demographic variables, smoking and drinking habits significantly predicted poorer EF in Step 1 only. The findings are consistent with the results of previous studies, which found that smoking and drinking habits were associated with poorer EF in healthy older adults (Sabia et al., 2014; Sabia et al., 2012). Smoking has been associated with adverse effects on the physical functions of older adults, such as cardiovascular fitness and lung function, consequently leading to poorer performance in the EF tasks (Sabia et al., 2012). Likewise, heavy alcohol consumption could also lead to detrimental effects on the brain, which may potentially increase the risk of cognitive impairment and accelerate the decline in EF (Sabia et al., 2012).

Overall, the EF results supported the cross-domain benefits of physical activities on EF, and varying dosage levels predicted EF in different directions.

4.4.2.3 Loneliness. Leisure activity participation was found to significantly predict the level of loneliness. However, no significant individual predictors were identified.

While no significant predictors were identified, it may suggest that the whole set of predictors contributed to the prediction of loneliness, without emphasising the importance of one specific predictor. These findings were inconsistent with previous findings, which found that intellectual, social, recreational and physical activities were associated with lower level of loneliness (J. T. H. Chen et al., 2024; Du et al., 2024; Fingerman et al., 2022; Teh & Tey, 2019).

One possible explanation may be that the domains of activities and dosage of participation were not the critical factors to predict loneliness. There may be some other influencing factors contributing to the prediction, potentially including interaction effects between the predictors or the specific characteristics of the activities being included (i.e., individual vs. group activities). A systematic review showed that group exercise was one of the promising intervention components in reducing loneliness (Ahn et al., 2024). Given that this study has included both individual and group activities in one domain of activities, this may have cancelled out the significant effect of each predictor on loneliness. For example, the physical domain has included both individual exercises (e.g., stretching and toning exercises, stair climbing, swimming) and group exercises (e.g., playing ballgames or racquet sports). Similarly, the intellectual domain also included both individual activities (e.g., writing, painting and reading) and group activities (e.g., playing mahjong and card games). Hence, it would be reasonable to suggest that the significant relationship contributed by multiple-person activity, such as playing chess or mahjong, was offset by some individual activities, such as reading and writing. It would be valuable for future studies to investigate whether a multiple-person activity helps to eliminate loneliness better than an individual activity.

Another explanation for the lack of significant individual predictors could be that activities aimed at reducing loneliness among older adults should be meaningful, enjoyable and able to provide social support to them (Chang et al., 2021). While individuals may have varying interpretations of meaningfulness and enjoyment, it is reasonable to observe the absence of significant results when multiple activities were grouped in a single domain (i.e., intellectual, physical and recreational) in the analyses. To further investigate the issue, future studies should delve into the effects of selected and specific activities on loneliness in older adults (e.g., Teh & Tey, 2019).

Overall, there was no evidence supporting cross-domain benefits or varying levels of dosage.

4.4.2.4 Depression, Anxiety and Stress. After controlling for smoking and drinking habits, frequency of intellectual activity and duration of social activity were found to significantly predict depression, anxiety, and stress in older adults. The direction of the relationships was partially in line with what were expected, such that more frequent intellectual activity and longer duration of social activity predicted a decrease in depression, anxiety, and stress levels (i.e., better mental health). Conversely, a greater diversity in intellectual activity and more frequent social activity predicted mental health in the opposite direction.

As expected, more frequent participation in intellectual activity was found to predict better mental health. This finding is consistent with that of a previous study which found that frequent engagement in intellectual activities might help to accumulate cognitive reserve and result in fewer mental health symptoms (Porricelli et al., 2024). It was explained that older adults with better cognitive reserve might have a greater capacity to cope with age-related cognitive declines (Stern et al., 2023). The accumulated cognitive reserve might also serve as a protective factor for mental health (Porricelli et al., 2024).

This study also found that a longer duration of social activity predicted better mental health. Frank and Oscar (2023) suggested that sufficient engagement in social activities might foster social support and resulted in better mental health of older adults. Longer duration of social activity might also help to promote a better social network and foster social connectedness among older adults, thus offering social support and eliminating the risk of social isolation (Toepoel, 2013). In other words, the results of this study suggested that the quality of the social relationship and social interaction are important factors to consider during social activity participation. However, the available research in this field is limited. The existing literature has only started to examine the frequency of social activity participation (Thapa et al.,2020) and measured early-life participation in intellectual activity (Qiu et al., 2024). More research is needed to expand this field of research.

However, in this study, participating in diverse intellectual activities was found to be associated with poorer mental health, which is inconsistent with the results of previous studies (Bone et al., 2022). It may be because engaging in diverse intellectual activities is cognitively demanding for older adults, as they needed additional processing resources for dual-tasking or planning (Verhaeghen & Cerella, 2002). These cognitively demanding activities might also lead to physical and mental fatigue in older adults (Ren et al., 2019). Hence, it may increase the levels of depression, anxiety and stress of older adults.

Finally, frequent engagement in social activity was found to predict poorer mental health, which is inconsistent with the results of previous studies (Gao et al., 2024). It is possible that frequent engagement in social activities may lead to physical and mental fatigue in older adults (Hu et al., 2025), resulting in an increased level of depression, anxiety and stress in older adults (i.e., poorer mental health).

Among the four domains, only the social and intellectual domains reported significant findings in this study, which provides evidence to support cross-domain benefits. It may be because these two domains could provide personal growth and social support to older adults. Literature reported that engaging in social and intellectual activities, such as interest groups, playing chess and card games, and knowledge lectures, help to provide social support and reduce perceived stress, thus improving the mental health of older adults (Zhang et al., 2021). Participation in social activities was a significant protective factor against stress (Thapa et al., 2020); while participation in intellectual activities was a protective factor against late-life depression and anxiety (Qiu et al., 2024). However, limited research has been conducted regarding the relationships between intellectual and social activities and the levels of depression, anxiety, and stress in older adults. More studies are, therefore, needed to explore this topic.

Surprisingly, this study did not find a significant buffering effect of physical activity on depression, anxiety and stress in older adults. Participation in physical activities had been found to be associated with better mental health, especially a reduced level of depression, anxiety and stress (Mahindru et al., 2023; White et al., 2024). It is possible that the underlying mechanism of how physical activity participation promotes mental health is related to social support (Sasidharan et al., 2006; Siegmund et al., 2021). Research showed that social support may help to promote physical activity participation and thus result in better mental health and well-being (Sasidharan et al., 2006). Additionally, Siegmund et al. (2021) also showed that social isolation might decrease engagement in physical activity, and it would further result in a higher level of depression. While the physical activities included in this study have combined individual and group exercises (e.g., swimming vs. playing ballgames or racquet sports), it is difficult to examine which activities have provided better social support and further led to the promotion of better mental health. Considering that social support is an important factor, future studies should explore if social support is a significant mediator between physical activity participation and mental health.

Results also showed that recreational activities did not significantly predict the level of depression, anxiety and stress of older adults. However, as there is limited literature in this research area, it is difficult to explain the absence of association between recreational activities and mental health in older adults. Smith et al. (2024) reported that sedentary behaviour was positively associated with problems of depression and stress and further results in a higher risk for wish to die. Therefore, while most recreational activities were sedentary and socially isolated, it is possible to suggest that recreational activities participation may lead to poor mental health. The inconsistency between the current results and those reported by previous studies could be because some included recreational activities that are enjoyable and quite active (e.g., keeping plants, cooking for pleasure and shopping). These activities could potentially cancel out the negative effects typically associated with recreational activities.

In terms of the significant demographic variables, smoking and drinking habits significantly predicted poorer mental health across Steps 1 and 2. The findings are consistent with the results of previous studies, indicating that smoking and drinking habits were associated with poorer mental health in older adults (Burns et al., 2017; Vaughan et al., 2014). Furthermore, Mitrou et al. (2024) also reported that poorer mental health could have an impact on addictive behaviours, highlighting the reciprocal relationship between smoking and drinking habits and mental distress.

Overall, results in the depression, anxiety and stress area supported the cross-domain benefits of intellectual activities on the levels of depression, anxiety and stress, and varying dosage levels predicted the levels of depression, anxiety and stress in different directions.

4.4.2.5 Functional Independence. After controlling for employment status, smoking and drinking habits, the current study found that the frequency of intellectual activity, frequency of social activity, duration of social activity, duration of recreational activity, and duration of physical activity were significant predictors of instrumental activities of daily living (IADL). The directions of the relationships were partially in line with expectations, in which more frequent of intellectual activity, longer duration of social activity, and longer duration of recreational activity could predict better functional independence. Unexpectedly, more frequent social activity and longer duration of physical activity were found to predict poorer functional independence.

As expected, this study found that the frequency of intellectual activity was positively associated with functional independence, which suggested that regular and frequent participation is important to maintain/enhance IADL. Results of previous studies support this claim. For example, Fujiwara et al. (2009) reported that an increase or maintenance of intellectual activity engagement was associated with better IADL functioning. These researchers explained that intellectual activities could stimulate the cognitive functions of older adults, resulting in an accumulated cognitive reserve and better functional independence (Fujiwara et al., 2009).

Results of this study also found a positive relationship between the duration of recreational activity and IADL, which is consistent with Zhu et al. (2023). It may be because there are some overlaps between the selected recreational activities in this study and the activities in IADL, such as cooking for pleasure and shopping. As older adults spend more time in recreational activities, they would practise those skills, gain experience, and ultimately achieve better functional independence.

Furthermore, the results suggested that spending longer duration and persistently engaging in social activity would be beneficial to the IADL. One possible reason may be that the older adults who reported a longer duration have established a stable social circle with others (Toepoel, 2013). More research is needed to clarify the optimal dosage of social activity.

However, in this study, the frequency of social activity was found to have an effect in the opposite direction, that is, more frequent social activity predicted a decrease in functional independence. Previous studies have reported that only moderate social participation was associated with a decreased risk of IADL declines, as compared with frequent participation (Tomioka, Kurumatani, & Saeki, 2018). It is suspected that frequent social participation might induce human-relation problems in older adults, which further create a mental burden and result in poorer functional independence.

Finally, in this study, a longer duration of physical activity was found to predict poorer functional independence, and this is contrary to the results of previous studies (Paterson & Warburton, 2010). One possible reason may be that the older adults have exceeded the optimal duration of physical activity participation (M = 10.05 hr per week, SD = 16.24 hr per week) in this study, which might have result in neglect of other skills and lead to greater functional limitations. More research is needed to explore the optimal duration of physical activity to derive benefits for daily functions.

All four domains, including the intellectual, social, recreational and physical domains were found to be related to the functional independence of older adults, which suggested cross-domain benefits. The results are consistent with a retrospective study that analysed longitudinal data, which showed that engaging in intellectual, recreational and social activities could significantly decrease the risk of IADL disorder (Zhu et al., 2023). Previous studies have found that intellectual activity participation may help to preserve thinking and attention control, thereby supporting neuronal plasticity and compensation capacity for improved IADL skills (Fujiwara et al., 2009). However, the mechanism of how social and recreational activities promote functional independence warrants further investigation, as research conducted in this area is limited. Although engaging in physical activities could predict functional independence, the direction was not as expected. The literature reported that engaging in physical activity may promote an active lifestyle among older adults and is associated with a reduced risk of functional disability (Paterson & Warburton, 2010). The discrepancy may be because the older adults in this study might have exceeded the optimal duration.

In terms of the significant demographic variables, being unemployed or retired, and having smoking habit significantly predicted poorer functional independence across both Steps 1 and 2. Drinking habit significantly predicted poorer functional independence in Step 2. All these findings are consistent with the results of previous studies, which indicated that unemployment, retirement and smoking habit were associated with poorer functional independence in older adults (Abe et al., 2023; Moore et al., 2003; Tomioka, Kurumatani, & Hosoi, 2018). It is suggested that unhealthy behaviours may have a negative impact on functional independence. Additionally, unemployment and retirement may limit opportunities to engage in activities related to IADL, such as transportation, shopping, home maintenance, and financial management, potentially leading to a decline in functional independence (Tomioka, Kurumatani, & Hosoi, 2018).

Overall, the IADL results supported the cross-domain benefits of intellectual, social and recreational activities on functional independence, and varying dosage levels predicted functional independence in different directions.

4.4.3 Nature and Extent of Mahjong Playing

The results of this study partially support the third hypothesis: mahjong playing exhibited a similar prevalence rate as previous studies (i.e., 27% in the current study [rank = 12th] vs. 25.8% in previous studies; Cheung et al., 2009; Chou et al., 2004; Kwan, 1990), a similar frequency (i.e., almost twice a week vs. one to three days per week in Cheung et al., 2009; rank = 33rd), but with a long duration (i.e., 4.06 hr each time; rank = 2nd) compared to other activities. These results suggest that although mahjong playing is not a prevalent activity compared to television watching (70%) and slow walking (68%), older adults who engage in it were willing to spend time on the activity (i.e., activity with the second longest duration).

Similar to the Chinese martial arts discussed in section 4.4.1.3, as a culturally specific leisure activity, mahjong playing seems to possess a unique element that motivates older adults to sustain their participation. Cheng et al. (2006) highlighted the novelty of mahjong playing, wherein each game presents a different combination of stimuli to players. This distinctive feature retains the uncertainty and flexibility in the game, thereby fostering a novel and exciting experience for players during gameplay. In summary, the results suggest that mahjong playing is a potential activity to boost the activity level of older adults.

4.4.4 Prediction of Cognitive, Psychological and Daily Functions by Mahjong Playing

The results partially support the fourth hypothesis, whereby only longer duration but less frequent mahjong playing predicted better cognitive, psychological and daily functions in older adults.

4.4.4.1 General Cognition. After controlling for smoking habit, this study found that a longer duration of mahjong playing predicted better general cognition, but more frequent mahjong playing predicted poorer general cognition. The observed results partially aligned with the expectations, suggesting that a longer duration provided sufficient exposure to mental exercise. As the game needs time to develop and the players also require time to devise strategies to claim the win, it is reasonable that a longer engagement could predict better general cognition. Some mahjong intervention studies suggested that 1 to 1.5 hr was sufficient to yield cognitive benefits in older adults with dementia (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014). Insufficient duration may imply that the player does not spend enough time devising strategies, or the exposure is limited to derive cognitive benefits.

Unexpectedly, frequent engagement in mahjong playing did not predict better general cognition. The findings contradicted the results of previous studies, as Zhao et al. (2023) reported that engaging in mahjong playing could predict more successful ageing (i.e., including better cognitive, psychological and daily functions), compared to older adults who never participated in the activity. Other studies, such as Ding et al. (2022) and Ho and Chan (2005), have reported no significant relationship between the frequency of mahjong playing and cognitive functions. This underscored the mixed evidence within the literature. One possible explanation for the unexpected results could be because frequent engagement in mahjong playing may potentially disrupt their daily routines or ignore other aspects of everyday life, resulting in a negative association between the frequency of mahjong playing and general cognition. Mahjong playing is a sedentary game, and playing it frequently may lead to addictive or gambling behaviour, reduced physical fitness and decreased blood circulation to the brain (Subramaniam et al., 2015). Another possible explanation may be due to the difference in age of the older adults included in the two studies (current study: M = 64.77 years, SD = 4.99 years vs. Zhao et al., 2023: pooled M = 81.83 years, pooled SD

= 10.44 years). The sample of this study was younger than that of the previous study, and the cognitive declines associated with age might not be substantial for the participants in this study to show the relationship. It is possible that the positive relationship between frequency and general cognition may be age-dependent. J. Wang et al. (2022) conduted a subgroup analyses stratified by age and revealed that the significant positive association between the frequency of mahjong playing and general cognition only existed in age groups older than 70 years. Therefore, age groups older than 70 years would be more likely to be benefited from mahjong playing.

Smoking habit significantly predicted poorer general cognition across both Steps 1 and 2. The findings are consistent with previous discussions on overall leisure activity participation and the results of previous studies (Benito-León et al., 2023; Bloomberg et al., 2024). It is generally accepted that an unhealthy lifestyle would lead to poorer general cognition in older adults.

Overall, for mahjong playing to be effective, older adults need to spend enough time in the activity to allow the positive impact of the activity to take effect. However, overly frequent engagement may also have negative effects on general cognition in older adults.

4.4.4.2 EF. After controlling for smoking habit, a longer duration of mahjong playing predicted better EF, while more frequent mahjong playing predicted worse EF. Limited studies have been conducted to explore the relationship between mahjong playing and EF, and the investigation regarding dosage is even more scarce. As expected, a longer duration of mahjong playing predicted better EF. It is possible that if older adults spent enough time playing the game, they would accumulate cognitive reserve and derive cognitive benefits for EF. Similar to the explanations in general cognition, the game needs time to develop, and the players also need time to devise strategies. Increasing the duration of mahjong playing can potentially provide older adults with more exposure to cognitive stimulation, which may lead to better EF. Another explanation may be because of the similarity between the game strategies and the characteristics of the EF. For instance, sorting and arranging the sequence of the mahjong tiles is highly similar to the working memory of EF (i.e., the ability to hold and manipulate information in the mind). Due to the comparable characteristics, it is possible that if older adults have engaged in the game for a sufficient duration, they would show a positive performance in EF due to adequate exposure. Similarly, previous intervention study suggested a promising therapeutic effect of mahjong playing on EF, with a duration of three hours per week (Zhang et al., 2020). Note that the intervention study did not aim to investigate the dosages of mahjong playing, and it recruited a clinical population (Zhang et al., 2020); therefore, it offered limited generalisability. More studies are needed to confirm the observed effect and fully elucidate the underlying mechanisms.

However, it is difficult to explain why an increased frequency was negatively predicted EF. Two possible explanations are that the benefits of mahjong playing on EF might be age-dependent and exclusively observable in clinical populations, akin to the relationship noted in general cognition. Significant improvement in EF was observed in the mahjong training group in a study that implemented mahjong training three times a week for older adults with MCI (mean age = 74.3 years; Zhang et al., 2020). Given that the current sample has a mean age of 64.77 years, the healthy older adults may either be in the early stage of retirement or still part of the work population. Participating in mahjong playing with a higher frequency may interrupt the normal activities and possibly result in a negative association with EF.

In this study, smoking habit was found to significantly predict poorer EF in both

Steps 1 and 2. The findings are consistent with previous studies that showed smoking habit was associated with poorer EF in healthy older adults (e.g., Sabia et al., 2012). It is generally accepted that an unhealthy lifestyle could contribute to poorer EF in older adults.

Overall, older adults need to spend sufficient time playing mahjong to experience the positive effects on EF. However, overly frequent engagement may lead to negative effects on EF in older adults.

4.4.4.3 Loneliness. A longer duration of mahjong playing was found to predict less loneliness, while more frequent mahjong playing was found to predict a higher level of loneliness. Spending a longer time in mahjong playing predicted less loneliness. This finding is consistent with those reported in previous studies, such that compared with those who never played mahjong, older adults who played mahjong were significantly less likely to feel persistently lonely, albeit the study focused on frequency rather than duration (Teh & Tey, 2019). One possible explanation could be because the game involves multiple players, and it may facilitate social interactions during gameplay. For example, players are required to vocalise their actions if they would like to draw tiles from the pool or claim victory; conversations may also be involved during the gameplay. Engaging in mahjong playing for a longer duration allows sufficient exposure to establish higher-quality social interactions and stable connections among older adults. In this connection, it helps to reduce loneliness. Nonetheless, the literature did not extensively explore the effects of dosage on loneliness, more research is necessary to confirm the observed effect.

However, more frequent mahjong playing predicted greater loneliness was inconsistent with the results of the previous study, which revealed a protective effect against loneliness for older adults who frequently engaged in mahjong playing (Teh &

Tey, 2019). This could be attributed to the idea that social connectedness requires time for development rather than mere frequency, and an adequate duration ensures the formation of higher-quality social relationships. Specifically, it is also possible that the quality of the social relationship may not be good among the frequent players, as they may be passively participating in the game to pass the time (Kim, 2020). This may potentially lead to an increased level of loneliness among older adults.

Overall, older adults need to spend sufficient time playing mahjong to experience a reduced level of loneliness. Frequent engagement may not necessarily lead to better quality of social relationships and reduce the level of loneliness in older adults.

4.4.4.4 Depression, Anxiety and Stress. After controlling for smoking and drinking habits, a longer duration of mahjong playing was found to predict better mental health, while more frequent mahjong playing was found to predict worse mental health.

A longer duration of mahjong playing was found to predict better mental health. It is possible that the older adults have grouped themselves within the same social circle; therefore, they share similar personalities and can enjoy the game together with fewer unfavourable outcomes. Upon establishing a secure social connection and discovering that players are compatible with each other, older adults were more likely to continue playing the game, resulting in a longer duration. Hence, a positive social environment may be built to promote the mental health of older adults.

On the other hand, more frequent mahjong playing was found to predict increased levels of depression, anxiety and stress. This finding is inconsistent with the results of a previous study, in which playing mahjong or cards was a protective factor against depression (Tang et al., 2021). The absence of a positive relationship between mahjong playing and mental health may be because mahjong involves social interactions during the game. Literature showed that frequently engaging in the game may induce human relationship problems in older adults and result in a worse level of mental health (Tomioka, Kurumatani, & Saeki, 2018). According to a practical handbook for mahjong interventions in Hong Kong (Yan Chi Hospital Social Services Department et al., 2005), some older adults may become more easily frustrated during the game or may have difficulty tolerating the slower pace of others. Besides, the game may lead to poor mental health when the game involves money, and some older adults take losing money seriously, leading to a higher level of depression, anxiety and stress in older adults.

In this study, smoking and drinking habits was found to significantly predict poorer mental health across both Steps 1 and 2. The findings are consistent with previous discussions on overall leisure activity participation and the results of previous studies (Burns et al., 2017; Vaughan et al., 2014). It is generally accepted that an unhealthy lifestyle may lead to poorer mental health in older adults.

Overall, spending sufficient time in mahjong playing could potentially contribute to better mental health in older adults. However, overly frequent engagement may lead to relationship problems and poorer mental health in older adults.

4.4.4.5 Functional Independence. After controlling for employment status, smoking and drinking habits, this study found that a longer duration of mahjong playing predicted better functional independence. Conversely, more frequent mahjong playing predicted worse functional independence.

Longer duration of mahjong playing was found to predict better functional independence. This finding is consistent with the results of a previous study, in which engaging in intellectual activities was found to maintain functional independence in older adults (Fujiwara et al., 2009). Functional independence and cognitive functioning are closely related (Vidoni et al., 2010), and Fujiwara et al. (2009) proposed that these intellectual activities could preserve thinking and attention control, thereby improving IADL skills. Although the study considered the dosage of diversity instead of duration (Fujiwara et al., 2009), it is reasonable to suggest that participating in mahjong playing (i.e., a cognitively stimulating activity that requires extensive cognitive demands) for an extended period might also accumulate the reserve and generalise the benefits to functional independence.

Unexpectedly, more frequent mahjong playing was found to predict worse functional independence. The results were inconsistent with the literature, which reported no significant relationship between playing cards or mahjong and the risk of IADL disability in a four-year follow-up survey (Ren et al., 2023). It is possible that a frequent engagement may result in neglect of other skills, or did not provide enough exposure to derive benefits, leading to worse functional independence.

Unemployment or retirement, and smoking habit significantly predicted poorer functional independence across both Steps 1 and 2. The findings are consistent with the results of previous studies (Abe et al., 2023; Tomioka, Kurumatani, & Hosoi, 2018). It is understandable that unhealthy behaviours and limited opportunities to engage in activities related to IADL may lead to a decline in functional independence.

Overall, older adults need to spend sufficient time playing mahjong to experience positive effects on functional independence. However, overly frequent engagement may have negative effects on functional independence in older adults.

4.4.5 Limitations and Future Directions

Since this survey study adopted a cross-sectional design and used regression analyses, it should be pointed out that no causal relationship could be established from the results. In other words, the positive coefficients may have two interpretations: (i) a greater extent of participation would result in better functions, or (ii) older adults with better functions engaged in more leisure activities. Despite the fact that previous studies may help to confirm and explain some of the directions, future studies are recommended to conduct experimental or longitudinal research to draw conclusions about the casual inferences. Future studies can also explore potential mediators that can help to explain the effect of leisure activity participation on cognitive, psychological, and daily functions of older adults.

The way the leisure activities were categorised and combined is another limitation of this study. While the scale from G. T. Y. Leung, K. F. Leung, et al. (2011) has included a wide range of activities within a single domain, it limited exploration through additional, more detailed ways of categorisation (e.g., light vs. strenuous physical activities; active vs. passive activities; solitary vs. individual activities). This limitation may help to explain some unexpected or contradictory results. For example, within the domain of physical activity, there are light activities (e.g., general stretching and toning exercise) and strenuous activities (e.g., bicycling or using exercise machines). As light activities with longer duration may hinder memory performance (Hammond & Stinchcombe, 2022), future studies are recommended to conduct subgroup analyses to examine the difference between different forms of physical activities. The categorisation into four domains also limits the exploration of the difference between active activities (e.g., exercising; Çol et al., 2022) and passive activities (e.g., watching television; Blasko et al., 2014; Cho et al., 2018). Examining whether active activities enhance the activity level better than passive activities in older adults would be another promising research direction. It is because longer duration of sedentary activity may lead to negative consequences on health (Raichlen et al., 2022). Additionally, it is worth delving into more specific leisure activities (such as mahjong playing) in future studies and exploring their effects on cognitive, psychological and daily functions.

Another limitation of the study is the use of subjective questionnaires or scales, such as COBRA-C and DEX, to measure general cognition and EF. Compared with objective measures (e.g., MoCA and the Digit Span Test) that have established norms to evaluate performance, subjective measures may reflect the self-awareness of the abilities measured. Therefore, how leisure activity participation promotes better functions could then be affected by the level of self-awareness of older adults. However, it is difficult to administer objective tests to a large sample over the Internet. It should also be noted that older adults often notice and experience subjective complaints before experiencing objective impairments. Given that the participants recruited for the current study are relatively healthy and live in the community, they are unlikely to have significant self-awareness issues. Considering the comprehensiveness of measures and predictors included in this study, the findings still provided some new results and findings for the healthy ageing literature.

This study only included older adults as participants. The group of older adults in the study were not very old (*M* = 64.77 years, *SD* = 4.99 years), as compared to those in previous studies (Zhao et al., 2023: pooled *M* = 81.83 years, pooled *SD* = 10.44 years; Ding et al., 2022: *M* = 70.91 years, *SD* = 8.68 years; and Ho & Chan, 2005; *M* = 68.34 years, *SD* = 7.41 years). Hence, the restriction of range in responses for some of the measures could have led to mixed findings and difficulties in comparing the results. To better understand the relationship between leisure activity participation and functions of older people, it would be valuable to look at the changes in functions among older adults by using a longitudinal design. It may help to explain the long-term benefits of leisure activity participation and understand the impact of engagement in the early stages of ageing. For example, future research could include middle-aged adults and follow them over time, say three to five years, to understand the long-term benefits of engaging in leisure activities. Moreover, given that the data was collected via an online survey in this study, the population was limited to those older adults who were able to use computers and access the Internet. Future studies may expand the project by collecting data from community centres and comparing performances between those who have or do not have access to technology.

It should be noted that some significant predictors had a low correlation with the DV. It implies that a suppressor variable might be present in the regression model. A suppressor variable can be seen as one that increases the significance of other predictors by virtue of reducing irrelevant variance within them (Tabachnick et al., 2019). It is often identified by a substantially smaller correlation coefficient between the predictor and DV compared to the significant beta weights of the predictor. The current PhD project did not conduct subsequent analyses to further clarify how and why these suppressor variables worked due to limited time constraints. Future research is suggested to further investigate these interesting variables.

It is possible to suggest that the relationships between leisure activity participation and key functions of older adults may not be linear. For example, results of some previous studies suggested that the relationships may be non-linear in nature and showed trends such as quadratic (McDonough & Popp, 2020), cubic (Cansino et al., 2013) and exponential (Gupta et al., 2024). Future research should consider exploring non-linear models and re-examining the dataset with different statistical models, such as structural equation modelling and growth mixture modelling, to accommodate various shapes of the trends (Yu et al., 2021).

Chapter 5

Study 2: Does Playing Mahjong Benefit Older Individuals? A Scoping Review

This chapter had been published by the author of this thesis as a review article in "*The Journal of Prevention of Alzheimer's Disease*" in October 2024. Some preliminary findings were presented orally at *the Healthy Ageing Conference 2023* in Hong Kong, in October 2023 and at *the 13th Pan-Pacific Conference on Rehabilitation* in Chiang Mai, in November 2023. The manuscript has been slightly reformatted and revised to fit the requirements of the PhD thesis.[11]

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Review

Does Playing Mahjong Benefit Older Individuals? A Scoping Review

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Abstract

Playing mahjong is a popular intellectual and social leisure activity in Asian countries. It is culturally believed that this activity is beneficial to cognitive and psychological functioning in older adults. However, empirical evidence of the benefits of playing mahjong is scant and scattered across the Western and Asian literature. This scoping review comprehensively examined previous studies of the relationships between playing mahjong and cognitive, psychological, and functional abilities in older adults, highlighted gaps in the literature, and identified directions for future research. A systematic search of the literature was conducted across thirteen Western and Asian databases. Fifty-three studies, including forty-seven observational and six intervention studies, were identified. Overall, the results of the observational studies suggested that more mahjong-playing experience was associated with better cognitive, psychological, and functional abilities. As an intervention, playing mahjong was found to enhance general cognitive abilities and short-term memory and relieve depressive symptoms. However, because most of the reviewed studies adopted a correlational methodology, the neural mechanism underlying the benefits of playing mahjong awaits further elucidation. The findings of this review suggest that more randomized controlled trials should be conducted to explore the effects of playing mahjong on higher-level cognitive functioning in older populations.

Key words: Leisure activity, mahjong, rehabilitation, healthy aging.

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[11] After checking, the terminologies "playing mahjong", "intellectual component" and "functional outcomes" in the published paper have been modified to "mahjong playing", "cognitive component" and "daily functions", respectively, to ensure consistency throughout the thesis and maintain a scientific discourse. Some additional discussion points on the comparison of mahjong playing and mind-body exercise was added upon the request of the external examiner.

5.1 Introduction

How to maintain a good quality of life over the course of ageing is receiving increasing attention. A growing body of research has focused on ways of promoting active ageing, which emphasises the optimisation of health, participation, and security among older individuals. A potential method of promoting active ageing is to foster participation in leisure activities, defined as activities in which people engage for enjoyment or to enhance their well-being rather than for work or as ADL (Verghese et al., 2006). Research has revealed that among older adults, participating in leisure activities could help to prevent physical and cognitive decline (Fernandez-Mayoralas et al., 2015) and promote life satisfaction (Fastame, 2021) and subjective well-being (Cheng & Yan, 2021).

Mahjong, a traditional tile-based four-player game, is regarded as the national game in many Asian countries (Kim, 2020). A recent longitudinal study showed that from 2002 to 2018, almost a quarter (23.4% to 25.7%) of the Chinese population surveyed played mahjong or cards in their leisure time (Zhang et al., 2023). Although mahjong playing may be associated with gambling issues in the past and put a heavy emphasis on good fortune to win the game, its popularity was advocated regardless of socioeconomic status, gender, and geographic areas (Greene, 2015). The game usually involves 136 to 152 tiles and requires players to take turns in drawing and discarding tiles until one of them claims victory by presenting a certain set of combinations (Cheng et al., 2006). The literature on mahjong has classified the game as an intellectual and social leisure activity due to the complexity of its rules and because it involves multiple players (Tsang et al., 2016). It is a cognitively and socially demanding activity that requires players to develop skills such as identifying potential matches, mentally retaining relevant information, deciding which tiles to discard, and predicting other players' moves. Mahjong is regarded as a slow game in which players may plan the winning hands and revise the strategies simultaneously based on other players' feedback (Greene, 2015). The uncertainties and luck components of the game may create pleasure feelings and attraction to the players, which promote and foster the popularity of the game. As a popular and culturally important activity in Asian countries, mahjong has the potential to concurrently enhance cognitive and psychological outcomes in older adults in Asian populations.

Emerging evidence has shown that mahjong playing could slow cognitive deterioration (Cheng, Chow, Song, Yu, & Lam, 2014) and alleviate depressive symptoms in older adults with dementia (Cheng et al., 2012). Mahjong players aged at 60 years or above have been found to show stable or even improved cognitive function (Yu et al., 2021), exhibit better eye-hand coordination than non-players (Tsang et al., 2016), and experience a sense of being socially connected (Teh & Tey, 2019). Recognising these potential benefits, a group of researchers in Hong Kong published a handbook of practical guidelines to promote and implement the game as an intervention in the community (Yan Chi Hospital Social Services Department et al., 2005). Most of the literature on activities for older adults has focused on the benefits of culture-general activities such as reading, exercising, and playing memory games (Goodman-Casanova et al., 2020; Hulteen et al., 2017). Some culture-specific activities, such as Tai Chi and Qigong, have recently also become major topics of research (Park et al., 2023). Considering the popularity of mahjong in Asian countries, research on mahjong playing, which is also a culture-specific activity, could make important contributions to this literature.

Although a growing body of evidence has indicated that older adults might benefit from interventions promoting mahjong, the literature has generally remained inconclusive in this regard. While the studies described above emphasised the benefits of mahjong playing, certain other studies have reported no or limited benefits associated with the activity in older adults (Ho & Chan, 2005; Yang et al., 2022). Intervention studies have only partially supported the effectiveness of mahjong playing in achieving specific outcomes in older adults. For example, it has been found to support general cognitive performance and digit forward memory but not verbal or digit backward memory (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014). Therefore, it would be premature to conclude that mahjong playing improves general cognitive and psychological functioning in older adults. It is vital to review the results of previous studies to clarify which cognitive and psychological outcomes, such as memory, EF, or psychological distress, are improved or alleviated by mahjong playing.

Evidence regarding the benefits of mahjong playing were published in both the Western and the Asian literature. However, as many relevant Asian studies were written in Chinese, they have not been accessible to the wider research community; therefore, their findings have not been properly evaluated. This lack of access has made it challenging to synthesise the available evidence and identify directions for future research. Considering the popularity of mahjong in Asian countries, it is necessary to appraise the Asian literature together with the Western literature on this topic to enable a comprehensive understanding and interpretation of the findings. Only by summarising, synthesising, and analysing all of the relevant literature is it possible to identify the key characteristics of mahjong playing that lead to its potential benefits.

In the current review, the evidence on this topic was mapped from a broad perspective using a scoping review approach. Specifically, we evaluated the existing literature, identified gaps, and determined directions for future research. The review addressed the following three research questions. (i) What are the main characteristics of studies of mahjong playing for older adults? (ii) What is the relationship between mahjong playing and cognitive, psychological, and functional abilities in older adults? (iii) What are the limitations of previous studies and potential future research directions?

5.2 Method

This scoping review was conducted and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for scoping reviews checklist (Tricco et al., 2018), Arksey and O'Malley (2005) methodological framework, and the Cochrane Collaboration's recommendations (Armstrong et al., 2011). The review was registered on the Open Science Framework (https://doi.org/10.17605/OSF.IO/EDJ6G).

5.2.1 Selection Criteria

Both English and Chinese empirical papers on mahjong playing were included to enable a comprehensive analysis and summary. Studies in which the participants' mean age was 60 or above were included regardless of the participants' health or clinical conditions. Studies that administered cognitive, psychological, and/or daily functions measures were also included. There were no restrictions on the study design adopted in the selection criteria.

Studies that only reported the prevalence with which mahjong was played or focused on the problems associated with mahjong gambling were excluded. Studies that examined only physical outcomes, such as hypertension or mortality, rather than cognitive, psychological, or daily functions, were also excluded.

5.2.2 Search Strategies

Systematic searches were conducted in the following Western and Asian databases from their inception to July 4, 2023: the Cochrane Library, PsycINFO, PubMed, CINAHL, EMBASE, the Web of Science, Scopus, China National Knowledge Infrastructure (CNKI), Duxiu Academic Search, Chinese Social Sciences Citation Index (CSSCI), NCL Taiwan Periodical Literature, Taiwan Citation Index-Humanities and Social Sciences (TCi-HSS), and HKIChiP. Search terms were synonyms for "mahjong" and "older adults" and their translations in traditional and simplified Chinese (see Appendix B for an example). A university librarian was consulted for the database selection and keyword development, and the included Asian databases were representative and credible. The searches were not limited by language or date of publication.

5.2.3 Screening and Data Charting

The searches were conducted by the first author and their results were imported to Covidence (https://app.covidence.org/) for title and abstract screening, full-text screening, and data extraction. The authors and research assistants worked in pairs that independently evaluated the titles and abstracts of the publications and completed the full-text screening and data charting on the co-developed data charting form. A consensus on article inclusion and data extraction was reached by discussion with a third reviewer when needed.

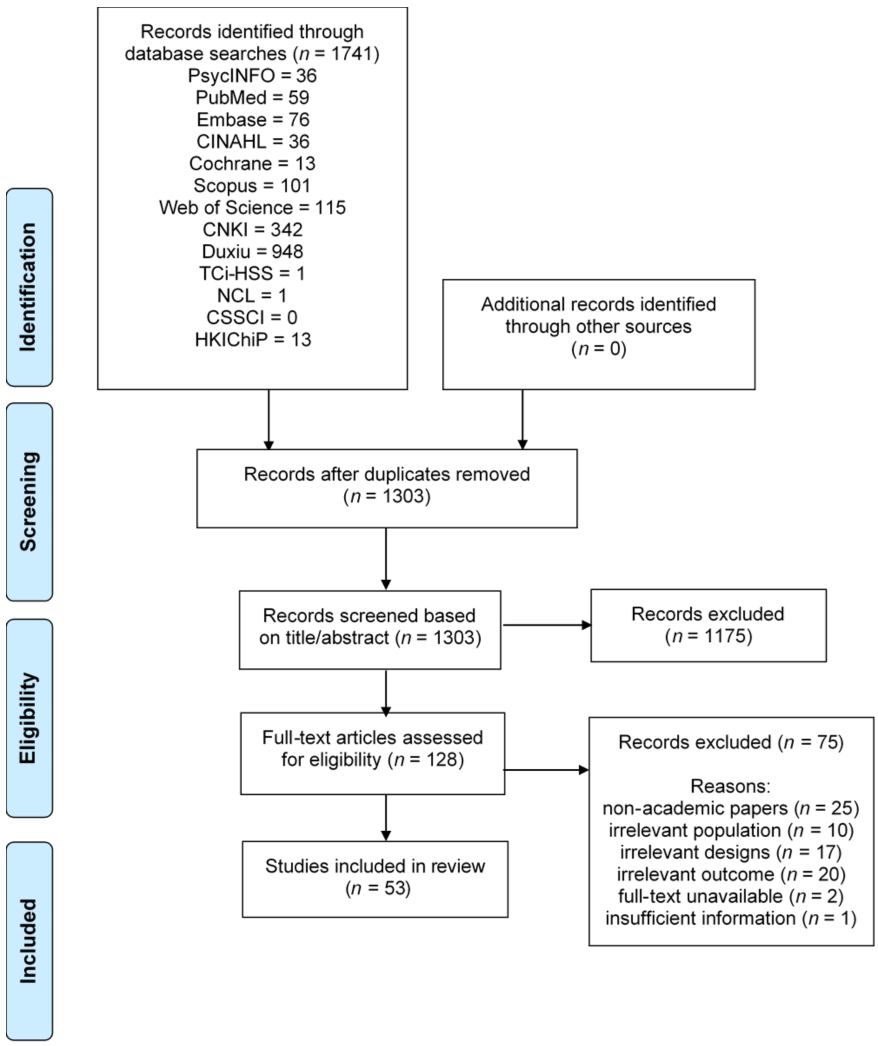
Data on sample characteristics (e.g., age, gender, years of education), the participants' mahjong playing (e.g., frequency, duration, and experience), cognitive, psychological, and daily functions, and the details and efficacy of the mahjong interventions (e.g., content of the training programs and pre-post differences in both quantitative and qualitative outcomes) were extracted. The types of the studies and their findings were summarised to understand the relationships between mahjong playing and cognitive, psychological, and functional abilities in older adults.

5.3 Results

The literature search yielded 1,741 results in total. After eliminating duplicates, 1,303 unique records remained, and their titles and abstracts were screened. Of these, 128 records were retained for full-text screening. Fifty-three records were included in the final charting. The PRISMA flowchart in Figure 5.1 depicts the number of records included and the reasons for exclusion at each screening stage.

Figure 5.1

PRISMA Flow-Chart of the Study Selection Process



5.3.1 Study Characteristics

Table 5.1 provides an overview of the characteristics of the reviewed studies. Most of the research was conducted in mainland China (*n* = 43, 81.1%). The remaining studies were conducted in Hong Kong (*n* = 7, 13.2%), Taiwan (*n* = 2, 3.8%), and New York (*n* = 1, 1.9%). Over half of the studies were in English (*n* = 30, 56.6%) and the remainder were in Chinese (*n* = 23, 43.4%).

The 53 studies were classified into two categories: observational studies (*n* = 47, 88.7%) and intervention studies (*n* = 6, 11.3%). Most of the observational studies utilised either a cross-sectional (*n* = 24, 51.1%) or a longitudinal (*n* = 16, 34%) design. The remainder adopted either a case-controlled design using clinical samples (*n* = 4, 8.5%) or qualitative interviews (*n* = 3, 6.4%). Among the six intervention studies, four were RCTs (66.7%) and two were non-RCTs (33.3%).

Most of the reviewed literature (*n* = 29, 54.7%) described mahjong playing as a general leisure activity and did not focus specifically on its cognitive or social characteristics in the research questions. The remaining studies considered mahjong an intellectual leisure activity (*n* = 10, 18.9%), a social leisure activity (*n* = 7, 13.2%), or "an intellectual and social leisure activity" (*n* = 7, 13.2%).

Another major characteristic of the studies was their widespread reference to mahjong in conjunction with card games and chess. Most of the studies defined mahjong as a general leisure activity, and these studies typically considered it together with card games and chess due to their similar nature. Specifically, the studies either investigated mahjong as an independent activity (*n* = 17, 32.1%) or considered it alongside card games ("mahjong or cards"; *n* = 27, 50.9%), chess ("mahjong or chess"; *n* = 1, 1.9%), or both ("mahjong, cards, or chess"; *n* = 8, 15.1%). Due to the limited number of studies on mahjong, excluding studies that combined it with card games and chess could have resulted in the loss of a significant proportion of the evidence. Therefore, instead of excluding those studies, we decided to include them and scope the mahjong literature and interpret the data cautiously. All of the intervention studies and qualitative studies investigated mahjong playing as an independent activity; only the observational studies grouped it along with the other two activities. The findings of this review remained qualitatively unchanged when the observational studies were excluded.

Among the cross-sectional, longitudinal and case-controlled studies (n = 44), 29 studies have reported the prevalence of mahjong playing among the population (M = 22.8%, SD = 9%, range = 2.6% to 42.9%). Apart from the dichotomous classification of mahjong play (yes/no), only 29 studies reported the ordinal frequency of mahjong playing in the population (e.g., everyday/ weekly/ monthly/ occasionally/ never).

Only a few of the studies examined the effects of mahjong playing across different demographic groups. Generally, mahjong playing was a protective factor for cognitive impairment regardless of gender, geographic area (i.e., urban or rural areas), and years of education (Zhang et al., 2023). One study found that males played mahjong with a higher frequency compared to females (Yang et al., 2022). However, other studies reported an equivalent effect of mahjong playing between males and females, in which mahjong playing was found to benefit cognitive ability (Tian et al., 2022), IADL (Zhao & Li, 2022) and promote successful ageing (Zhao et al., 2023). Only one study reported significant age differences between mahjong playing and cognitive function, in which the effects were negligible for the participants aged 60-69 years old (J. Wang et al., 2022). However, some studies found that mahjong playing was a protective factor for cognitive impairment across all ages in older adults (Tian et al., 2022; Zhao et al., 2023). Most studies focused on cognitive outcomes only (n = 31, 58.5%). Only a small proportion of the studies examined psychological (n = 10, 18.9%) or functional (n = 5, 9.4%) outcomes. The remaining studies investigated multiple outcomes (n = 7, 13.2%).

Table 5.1

Overview of the Studies Characteristics (n = 53)

Variable	Number of studies	Percentage of studies
Country of the study		
China	43	81.1%
Hong Kong	7	13.2%
Taiwan	2	3.8%
New York	1	1.9%
Language of the literature		
Chinese	23	43.4%
English	30	56.6%
Type of study		
Observational	47	88.7%
Intervention	6	11.3%
Study design		
Qualitative interviews	3	5.7%
Cross-sectional	24	45.3%
Longitudinal	16	30.2%
Case-control	4	7.5%
Randomised controlled trial	4	7.5%
Non-randomised controlled trial	2	3.8%
Definition of mahjong		
General leisure activity	30	56.6%
Intellectual leisure activity	10	18.9%
Social leisure activity	6	11.3%
Intellectual and social leisure activity	7	13.2%
IV		
Playing mahjong	17	32.1%
Playing mahjong or cards	27	50.9%
Playing mahjong or chess	1	1.9%
Playing mahjong, cards or chess	8	15.1%
Outcomes		
Cognitive	31	58.5%
Psychological	10	18.9%
Functional	5	9.4%
Cognitive and Psychological	3	5.7%
Cognitive and Functional	2	3.8%
Psychological and Functional	0	0%
Cognitive, Psychological and Functional	2	3.8%

The following subsections delineate the studies' results according to their objectives, types of outcomes, and findings.

5.3.2 Subjective Meaning Attached to Mahjong Playing

Three qualitative interview studies explored the benefits of mahjong playing by investigating its meaning for older adults in the community (Kim, 2020; Liu, 2015; Wu & Tang, 2011). Table 5.2 summarises these studies' findings regarding the meaning attached to mahjong playing for the participants and their experience of the activity.

Two of these three studies did not focus on a specific type of outcome (Kim, 2020; Wu & Tang, 2011), whereas one study covered loneliness (i.e., a psychological outcome; Liu, 2015). All of the studies agreed that mahjong playing provided benefits such as enhanced cognitive health and social and emotional support (Kim, 2020; Liu, 2015; Wu & Tang, 2011). The activity offered older adults a sense of competency and satisfaction and a feeling of youthfulness, and it also served as a form of mental exercise (Kim, 2020; Wu & Tang, 2011). Additionally, it helped older adults to fill their leisure time and prevented social isolation (Kim, 2020).

Table 5.2

Data Charting on Qualitative Studies (n = 3)

Study	*N*	Data analysis	Theme(s)	Categories and Findings
Kim (2020)	14	Thematic analysis	Healthy mahjong	To socialise, exercise the brain, and pass the time
Liu (2015)	42	Narrative analysis	Individual emotional or material satisfaction	To focus, get rid of worries, kill time, gain happiness, a sense of self-esteem and being young, and monetary reward
			Reciprocal societal support	To escape from loneliness and depression, also providing social support and "saving face"
			Lack of family support	To escape from the housework and being lazy
Wu and Tang (2011)	9	Grounded theory	Emotional support	To provide emotional support between the players via team building and social communication
			Meaningful participation	Mahjong is an active activity compared with watching television, also stimulates a feeling of youthfulness, and offers mental training opportunities
			Satisfaction	To gain a sense of accomplishment and self-confidence from winning the game

5.3.3 Short-term Benefits of Mahjong Playing

Thirteen cross-sectional studies examined the association between mahjong playing and cognitive, psychological, and daily functions. Table 5.3 summarises the findings.

Most of these studies focused on cognitive outcomes (*n* = 7, 53.8%; Ding et al., 2022; Fang & Shen, 2017; Ho & Chan, 2005; Liu, 2020; Mai et al., 2023; J. Wang et al., 2022; Zhou & Hu, 2020). Five of the studies investigated the effects of mahjong playing on psychological and daily functions such as depression, psychological distress, ADL, and eye-hand coordination (38.5%; Chou et al., 2004; Ren et al., 2021; Ross & Zhang, 2008; Tsang et al., 2016; Yang et al., 2022). One study (7.7%) created a composite variable named successful ageing that incorporated cognitive, psychological, and functional measures (Zhao et al., 2023).

Mahjong playing was positively related to general cognitive ability as measured by the MoCA (Fang & Shen, 2017; Zhou & Hu, 2020), the MMSE (Mai et al., 2023), and the simplified Community Dementia Screening scale (Liu, 2020). Compared with older adults who never played mahjong, those who were frequent and experienced players of mahjong exhibited better cognitive ability and reduced likelihood of having MCI (Ding et al., 2022; J. Wang et al., 2022). Three of the studies found that mahjong playing was negatively correlated with depression, psychological distress, and difficulties with ADL (Chou et al., 2004; Ren et al., 2021; Ross & Zhang, 2008). One study reported that mahjong players had better eye-hand coordination than non-players (Tsang et al., 2016) and another reported that mahjong players had a greater likelihood of successful ageing, as measured by cognitive, psychological, and daily functions (Zhao et al., 2023). One study reported no significant association between mahjong playing and dementia using the CDRS (Ho & Chan, 2005), and another found no significant association between mahjong playing and depression (Yang et al., 2022).

Table 5.3

Data Charting on Associations between Mahjong Playing and Cognitive, Psychological and Daily Functions (n = 13)

Study	Country	Activity	Aim	Age	*N*	Main outcomes	Key findings
Chou et al. (2004)	Hong Kong	Playing mahjong or cards	Relationships between leisure activity, socioeconomic and health characteristics	Aged 60 or above	2,144	• Leisure activity participation • SPMSQ • BADLs and IADL • Self-rated health status, number of diseases, sight, pain	• Playing mahjong/cards was uncommon among Hong Kong older adults (did not play mahjong or cards = 74.9%). • Socioeconomic variables such as age, employment, being on welfare and IADL were negatively associated with participation in mahjong/card playing. • Self-rated health and the number of diseases were positively associated with mahjong/card participation.
Zhou and Hu (2020)*	China	Playing mahjong	Relationship between intelligence games and cognitive function	Aged 60 or above	117	• Chess and card intelligence game participation • MoCA	Older adults who played mahjong (*n* = 3) showed better MoCA scores than those who did not (*n* = 114).
Fang and Shen (2017)*	China	Playing chess, cards, or mahjong	Relationship between playing chess, cards, or mahjong and cognitive function	Aged 60 or above	528	• Intellectual activity questionnaire • MoCA	Older adults who played mahjong/chess/card showed a higher score in MoCA compared to those who did not.
Liu (2020)*	China	Playing mahjong	Relationship between mahjong playing and cognitive function	Aged 60 or above	500	• Copeland's Geriatric Mental State Examination • Simplified CSI-D	Mahjong playing was positively correlated with cognitive functioning.

Study	Country	Activity	Aim	Age	*N*	Main outcomes	Key findings
Tsang et al. (2016)*	Hong Kong	Playing mahjong	Relationship between mahjong playing and eye-hand coordination	Aged 60 or above	41	• MMSE • EMG reaction time • EMG movement time • End-point accuracy of finger-pointing tasks	Compared with non-mahjong players, mahjong players showed better end-point accuracy in a finger-pointing test towards a stationary visual target on non-dominant hands; shorter EMG movement time on dominant hands and better EMG reaction time and end-point accuracy on non-dominant hands towards a moving target.
Ho and Chan (2005)	Hong Kong	Playing mahjong	Relationship between mahjong playing and cognitive function	Aged 55 to 88	204	• Leisure activities questionnaire • CDRS • IADL	Mahjong playing was negatively correlated with grip strength significantly, but it could not predict nor correlate with the CDRS score (i.e., the global cognitive functioning).
Ross and Zhang (2008)	China	Playing mahjong or cards	Effects of cognitively stimulating activities on the relationship between education and psychological distress	Aged 77 to 122	7,944	• Frequency of Activities • Psychological distress • Years of formal education, Exercise, Self-reported health	Mahjong playing is associated with a low level of distress.
Yang et al. (2022)	China	Playing mahjong or cards	Relationship between social activities and depression	Aged 60 to 69	704	• GDS • Social engagement	Mahjong playing could not predict depression score.

Study	Country	Activity	Aim	Age	*N*	Main outcomes	Key findings
Ren et al. (2021)	China	Playing mahjong or cards	Relationship between leisure activity and depression	Aged 65 or above	11,727	• CES-D-10 • Leisure activities (yes/no)	Mahjong playing showed a significant negative association with depression, and playing mahjong daily is a protective factor against depression.
Zhao et al. (2023)	China	Playing mahjong or cards	Relationship between leisure activity and successful ageing	Aged 60 or above	7,689	• Ascertainment of successful ageing[†] • Assessment of leisure activities (yes/no)	• Compared to older adults who never played mahjong, sometimes and usually playing cards or mahjong had greater odds for successful ageing. • No age difference was found.
J. Wang et al. (2022)	China	Playing mahjong or cards	Relationship between mahjong or card playing and cognitive function	Aged 60 or above	7,308	• Playing cards or mahjong (frequency) • MMSE	• There were statistically significant differences in MMSE total score and all subscales among the three types of frequencies in playing cards or mahjong, in which playing cards or mahjong regularly and occasionally had a significantly higher MMSE score compared to the non-participation. • Post hoc analyses showed age differences for the participants aged 70-79 and 80-80 years old but not for the participants aged 60-69 years old. • Playing cards or mahjong was the main component for explaining the MMSE score.

Study	Country	Activity	Aim	Age	*N*	Main outcomes	Key findings
Mai et al. (2023)	China	Playing mahjong or cards	Relationship between social engagement, loneliness and cognitive functions	Aged 65 or above	12,852	• Social engagement (frequency) • Loneliness (1-item) • Chinese version of MMSE	Playing cards or mahjong was significantly positively related to cognitive function.
Ding et al. (2022)	China	Playing mahjong	Relationship between mahjong playing and MCI	Aged 60 or above	676	• Chinese version of MoCA • Mahjong playing (frequency and experience)	• Compared with the older adults with little mahjong experience (≤ 1 year), older adults with midlife mahjong experience of more than one year were associated with reduced odds of having MCI. • The interaction terms "mahjong frequency and exercise" and "mahjong experience and exercise" were also associated with reduced odds of having MCI.

Note. SPMSQ = Short Portable Mental Status Questionnaire; BADL = Basic Activities of Daily Living; IADL = Instrumental Activities of Daily Living; MoCA = Montreal Cognitive Assessment Scale; MMSE = Mini-Mental State Examination; CDRS = Chinese version of the Mattis Dementia Rating Scale; EMG = Electromyography; CSI-D = Community Screening Instrument for Dementia; GDS = Geriatric Depression Scale; CES-D-10 = 10-item Centre for Epidemiological Studies Depression Scale; MCI = Mild cognitive impairment.

[*] Studies that have specified recruiting healthy older adults in the methodology.

[†] Measures for ascertainment of successful ageing included self-rated health, CES-D-10, MMSE, activities of daily life, and physical activity.

5.3.4 Long-term Benefits of Mahjong Playing

Sixteen longitudinal studies investigated the long-term benefits of mahjong playing. Table 5.4 summarises the findings of these studies.

All of these 16 studies used secondary data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), which is a large-scale population-based study that started in 1998. The survey examines factors related to healthy longevity using face-to-face interviews conducted every two to three years. The number of waves included in the 16 studies ranged from two to seven. Most of these studies (n = 12, 75%) examined the relationship between long-term participation in mahjong and the risk of cognitive, psychological, and functional decline (Gao et al., 2018; Lee et al., 2020; Mao et al., 2020; Ni et al., 2020; Qiu et al., 2019; Ren et al., 2023; Teh & Tey, 2019; Tian et al., 2022; S. Wang et al., 2022; Xue, 2020; Zhang et al., 2023; Zhao & Li, 2022). Three of the studies (18.8%) examined the factors influencing cognitive trajectories (Ye et al., 2021; Yi & Kang, 2008; Yu et al., 2021), and one pioneering study (6.3%) investigated the possibility of reversion from MCI (Sha et al., 2022). Most of the studies focused on cognitive outcomes (n = 10; 62.5%). Only three of the studies (18.8%) focused on psychological and daily functions, such as loneliness (Teh & Tey, 2019), functional disability (Gao et al., 2018), and sleep quality (Lee et al., 2020). Three studies (18.8%) examined cognitive function concurrently with negative affect (Ni et al., 2020), ADL and IADL (Ren et al., 2023), and subjective well-being and IADL (Zhao & Li, 2022).

Mahjong playing was found to be associated with a reduced risk of cognitive impairment or dementia (Mao et al., 2020; Qiu et al., 2019; Ren et al., 2023; Tian et al., 2022; S. Wang et al., 2022; Zhang et al., 2023), better cognitive functioning (Xue, 2020; Yi & Kang, 2008), and relatively stable or slow cognitive decline (Ni et al., 2020; Ye et al., 2021; Yu et al., 2021). Daily participation in mahjong was found to be associated with a higher possibility of reversion from MCI (Sha et al., 2022) and frequently playing the game decreased the risk of developing cognitive impairment (S. Wang et al., 2022). Another study reported that occasional participation was associated with a decreased risk of cognitive impairment (Qiu et al., 2019). Compared with older adults who did not participate in mahjong, those who played the game were less likely to experience persistent loneliness (Teh & Tey, 2019) and demonstrated a slower rate of negative affect increase (Ni et al., 2020). They also exhibited a lower risk of incident functional disability (Gao et al., 2018) and reported better sleep quality (Lee et al., 2020). However, two studies found no significant relationship between mahjong playing and the focal outcomes, namely cognitive functioning (Zhao & Li, 2022), subjective well-being (Zhao & Li, 2022), and ADL and IADL (Ren et al., 2023).

Table 5.4

Data Charting on Longitudinal Studies (n = 16)

Study	Waves	Age	*N*	Activity	Construct(s)	Main outcomes	Key findings
Xue (2020)	2002, 2005, 2008, 2011	aged 60 or above	2,514	Playing mahjong or cards	Cognitive function	• MMSE • Playing cards or mahjong (yes/no) • Playing cards or mahjong (frequency)	• Compared with the older adults who did not play mahjong or cards, older adults who played mahjong or cards would report a higher MMSE score and slower decline over time. • Compared with the older adults who did not play mahjong or cards, older adults who played mahjong nearly every day, once a week, once a month, and seldomly showed a higher MMSE score. Playing at least once a month showed the largest effect, followed by playing mahjong every day, once a week, and seldom playing.
Ye et al. (2021)	2002, 2005, 2008, 2011, 2014	aged 65 or above	1,040	Playing mahjong or cards	Cognitive function	• Chinese version of MMSE • Playing cards or mahjong (yes/no)	• Different patterns of cognitive decline showed different ratios of mahjong participation. There were significantly more older adults who played mahjong in the "medium and increasing group" than in the "high and declining group". • No significant difference was observed between the "high and declining" and "low and declining" groups.

Study	Waves	Age	*N*	Activity	Construct(s)	Main outcomes	Key findings
Yi and Kang (2008)	1998, 2000, 2002	aged 80 or above	2,251	Playing mahjong or cards	Cognitive function	• MMSE • Playing cards or mahjong (yes/no)	Older adults who played mahjong or cards showed significantly higher MMSE scores than those who did not. Two-level repeated measures analyses showed that playing mahjong/cards may significantly contribute to a higher level of cognitive functioning.
Yu et al. (2021)	2008, 2011/12, 2014, 2018	aged 61 or above	2,439	Playing mahjong or cards	Cognitive function	• MMSE • Playing cards or mahjong (yes/no)	Compared with the "low initial level-cognitive decline group", there were more older adults in the "stable cognitive group" and the "high initial level-cognitive decline group" played mahjong/cards. The "high initial level-cognitive decline group" also showed a higher odds ratio than the "stable cognitive group", which indicated a higher proportion of mahjong players in the "high initial level-cognitive decline group".
Lee et al. (2020)	2012, 2014	aged 65 or above	4,718	Playing mahjong	Sleep	• Sleep quality • Average hours of sleep daily • Predictors (1. group social activity and 2. playing the Mahjong card game)	• Older adults who played mahjong card game daily reported a higher prevalence of good-quality sleep than those who participated less frequently. Compared with daily participation, older adults who did not play mahjong reported lower odds of reporting good sleep quality. Weekly participation was negatively associated with sleep quality. • Participation in the Mahjong card game was not associated with the recommended hours of sleep duration.

Study	Waves	Age	*N*	Activity	Construct(s)	Main outcomes	Key findings
Teh and Tey (2019)	2005, 2008, 2011	aged 65 or above	15,163	Playing mahjong or cards	Loneliness	• Frequency of leisure activities • Loneliness	• Compared with those who never played cards/mahjong, older adults who frequently and occasionally played cards/mahjong were significantly less likely to feel persistently lonely. Compared with the baseline in 2005, older adults who frequently played cards/mahjong reported significantly lower odds ratios of persistent loneliness in 2011. No significant effect was observed for the occasional players. • No significant effects were observed in the 2008 wave.
Gao et al. (2018)	2005, 2008, 2011	aged 65 or above	104,468	Playing mahjong or cards	Functional disability	• Functional disability • Age of onset of ADL disability • Frequency of social participation • Mediators (physical exercise, positive emotions, MMSE)	• Older adults who never played cards/mahjong showed a more rapid decline of ADL than those who have frequent participation. Playing mahjong/cards reduced the risk of having an incident functional disability. • Cognitive ability, positive emotions and physical exercise were the significant mediators of the relationship between playing cards/mahjong and functional disability. Cognitive ability was the strongest mediator.

Study	Waves	Age	*N*	Activity	Construct(s)	Main outcomes	Key findings
Qiu et al. (2019)	1998, 2000, 2002, 2005, 2008, 2011, 2014	aged 80 or above	4,830	Playing mahjong or cards	Cognitive function	• MMSE • Frequency of cognitive leisure activities	• Compared with older adults who "never" played cards/mahjong, those who participated "sometimes" or "almost every day" did not show a significant trend. • Sometimes playing cards or mahjong was associated with a decreased risk of cognitive impairment.
Mao et al. (2020)	1998, 2000, 2002, 2005, 2008, 2011	aged 80 or above	10,741	Playing mahjong or cards	Cognitive function	• Chinese version of MMSE • Frequency of leisure activity • Depressive symptoms	• Compared with older adults who "never" played cards/mahjong, those who participated "almost every day" and "sometimes" showed significantly lower hazard ratios. • Compared with those who "never" engaged in playing cards or mahjong, the estimated effects of engaging in these activities "sometimes" or "almost every day" showed a significantly reduced risk of cognitive impairment in the octogenarians and nonagenarians, but not in the centenarians. An interaction between the years of education and frequencies of "sometimes" and "never" was found, indicating that older adults with more than two years of education have a lower hazard ratio.

Study	Waves	Age	*N*	Activity	Construct(s)	Main outcomes	Key findings
Ni et al. (2020)	2002, 2005, 2008, 2011, 2014	aged 60 or above	1,314	Playing mahjong	Negative affect and cognitive function	• MMSE • Negative affect	During the 5 waves, mahjong players were associated with slower rates of negative affect increase and cognitive decline.
Zhao and Li (2022)	2002, 2005, 2008-09, 2011-12, 2014, 2017-18	aged 65 or above	2,406	Playing mahjong or cards	Cognitive function, subjective well-being and IADL	• Playing cards or mahjong (frequency) • IADL • MMSE • Negative subjective well-being	• Frequent participation in playing mahjong or cards buffered the detrimental effect of widowhood on IADL abilities in both men and women. • No significant interaction effects between widowhood and mahjong playing were found on cognitive ability and negative subjective well-being.
Zhang et al. (2023)	2002, 2005, 2008, 2011, 2014	aged 65 or above		Playing mahjong or cards	Cognitive function	• Chinese version of MMSE • Frequency of leisure activity (yes/no)	• Playing cards/mah-jong was associated with decreased probabilities of cognitive impairment at the next wave. • Playing cards/mah-jong was associated with reduced probabilities of cognitive impairment.

Study	Waves	Age	*N*	Activity	Construct(s)	Main outcomes	Key findings
S. Wang et al. (2022)	2002-2005, 2005-2008, 2008-2011, 2011-2014	aged 65 or above	12,280	Playing mahjong or cards	Cognitive function	•Leisure activity (frequency) MMSE	• Compared with older adults who "rarely or never" played cards/mahjong, those who played mahjong showed a decreased risk of cognitive impairment. • Compared with those whose behaviour did not change, the associations of playing less mahjong or cards were more likely to develop cognitive impairment. • Compared with individuals who did not change the frequency of playing mahjong or cards, those who played a little bit more or played much more decreased the risk of developing cognitive impairment.
Sha et al. (2022)	2002, 2005, 2008, 2011, 2014	aged 65 or above	7,422	Playing mahjong or cards	Cognitive function	• Chinese version of MMSE • Playing cards or mahjong (frequency)	• Playing cards or mah-jongg daily was associated with a higher possibility of reversion than those who occasionally or never did them. • Further restriction on MMSE change (≥2 and ≥3 points) to the definition of reversion, daily playing mah-jongg or other card games continued to be significantly associated with reversion.

Study	Waves	Age	*N*	Activity	Construct(s)	Main outcomes	Key findings
Ren et al. (2023)	2014, 2018	aged 65 or above	ADL: 6,047 IADL: 6,216 Cognitive function: 5,916	Playing mahjong or cards	Cognitive function, ADL and IADL	• Leisure activity (frequency) • ADL • IADL • Chinese version of MMSE	• Playing cards or mahjong was correlated with a 33.1% decreased risk of cognitive impairment. • No significant effects were found on ADL and IADL disability.
Tian et al. (2022)	2008, 2011, 2014, 2018	aged 65 or above	11,821	Playing mahjong or cards	Cognitive function	• Playing cards or mahjong (frequency) • MMSE	• With the increase in playing cards/mahjong frequency, the crude rate of dementia events decreased gradually. • Compared with participants who rarely or never played cards/mahjong, participants who played cards/mahjong almost every day had a significantly lower risk of dementia. • Similar results were found in subgroup analyses based on sex, age, regular exercise and MMSE score.

Note. MMSE = Mini-Mental State Examination; ADL = activities of daily living; IADL = Instrumental activities of daily living.

5.3.5 Mahjong Playing and Disease Prevalence

Eleven cross-sectional (20.8%) and four case-control studies (7.5%) examined whether mahjong playing was associated with the prevalence of clinical conditions and factors related to clinical conditions. Table 5.5 summarises the findings of the cross-sectional and case-control studies.

Most of the 11 cross-sectional studies (n = 7; 63.6%) focused on cognitive disorders such as cognitive impairment (Cao, Wang, et al., 2017b; Guo et al., 2020), MCI (Wang, Cao, Deng, et al., 2017; Wang, Cao, Liu, et al., 2017), and dementia (Cao, Wang, et al., 2017a; Cao, Wang, Deng, Yan, Lian, Wang, et al., 2017; Deng et al., 2018). Four of the studies (36.4%) focused on psychological and functional disorders such as depression (Ayijiamali et al., 2015; Tang et al., 2021), Parkinsonism (Juan. Wang et al., 2020), and ADL impairment (Cai et al., 2020).

Most of the 11 cross-sectional studies (n = 9, 81.8%) reported significant differences in mahjong participation in terms of disease prevalence (Ayijiamali et al., 2015; Cai et al., 2020; Cao, Wang, et al., 2017a; Deng et al., 2018; Guo et al., 2020; Tang et al., 2021; Juan. Wang et al., 2020; Wang, Cao, Deng, et al., 2017; Wang, Cao, Liu, et al., 2017). Two of the studies (18.2%) found no significant differences between those who participated in mahjong and those who did not in the prevalence of cognitive impairment (Cao, Wang, et al., 2017b) and dementia (Cao, Wang, Deng, Yan, Lian, Wang, et al., 2017).

Additional analyses focused on ascertaining whether mahjong playing is a risk or protective factor for clinical conditions. In seven of the studies (77.8%), mahjong playing was found to be a protective factor against various clinical conditions, namely cognitive impairment (Guo et al., 2020), MCI (Wang, Cao, Deng, et al., 2017), dementia (Cao, Wang, et al., 2017a), Parkinsonism (Juan. Wang et al., 2020), ADL impairment (Cai et al., 2020), and depression (Ayijiamali et al., 2015; Tang et al., 2021). Two of the studies (22.2%) reported no significant effects on MCI (Wang, Cao, Liu, et al., 2017) and dementia (Deng et al., 2018).

The four case-control studies that probed the factors pertaining to cognitive-related disorders examined cognitive impairment (Qiu et al., 2019; Sun et al., 2023), MCI (Xue et al., 2012), and AD (Shi et al., 2012). After matching the controlled subjects on sex, age, and residential area, all of them reported that mahjong playing was a significant protective factor against the focal clinical conditions. Sun et al. (2023) reported that the protective effect was similar for carriers and noncarriers of the apolipoprotein E (APOE) gene.

Table 5.5

Data Charting on Associations between Mahjong Playing and Disease Prevalence (n = 11) and the Case-Control Studies (n =4)

Study	Designs	Disease/ Construct	Activity	*N*	Main outcomes	Key findings
Wang, Cao, Deng, et al. (2017)*	Cross-sectional	Prevalence of MCI	Playing chess, cards, or mahjong	1,781	MMSE, IADL, GDS	Older adults who played mahjong/chess/cards showed a significantly different rate of MCI prevalence, in which playing mahjong every day was a protective factor for MCI compared to no participation.
Cao, Wang, et al. (2017a)	Cross-sectional	Prevalence of cognitive impairment	Playing chess, cards, or mahjong	84	MMSE, IADL, GDS	Older adults who played mahjong/chess/cards did not show a significantly different rate of cognitive impairment prevalence.
Cao, Wang, et al. (2017b)	Cross-sectional	Prevalence of dementia	Playing chess, cards, or mahjong	84	MMSE, IADL, GDS	Older adults who played mahjong/chess/cards showed a significantly different rate of dementia prevalence, in which playing mahjong at least once a week was a protective factor against dementia compared to no participation.
Juan. Wang et al. (2020)	Cross-sectional	Prevalence of Parkinsonism	Playing mahjong or cards	3,996	PDSI	• Older adults who played mahjong/cards showed a significantly different rate of Parkinsonism prevalence, in which always playing mahjong/cards was a protective factor against Parkinsonism compared to no participation. • Seldom playing mahjong/cards showed no significant effects.

Study	Designs	Disease/ Construct	Activity	*N*	Main outcomes	Key findings
Wang, Cao, Liu, et al. (2017)*	Cross-sectional	Prevalence of MCI	Playing chess, cards, or mahjong	84	MMSE, IADL, GDS	Older adults who played mahjong/chess/cards showed a significantly different rate of MCI prevalence, but it was neither a protective nor risk factor for MCI.
Cai et al. (2020)	Cross-sectional	Prevalence of ADL impairment	Playing mahjong or cards	3,978	IADL	• Older adults who played mahjong/cards showed a significantly different rate of ADL impairment prevalence, in which always playing mahjong was a protective factor against ADL impairment compared to no participation. • Seldom playing mahjong/cards showed no significant effects.
Guo et al. (2020)	Cross-sectional	Prevalence of cognitive impairment	Playing mahjong or cards	3,996	AD8, MMSE	Older adults who played mahjong/cards showed a significantly different rate of cognitive impairment prevalence, in which always and seldom playing mahjong/cards was a protective factor against cognitive impairment compared to no participation.
Ayijiamali et al. (2015)	Cross-sectional	Prevalence of depression	Playing mahjong	1,329	GMS	Mahjong playing was a protective factor against depression compared to no participation.
Cao, Wang, Deng, Yan, Lian, Wang, et al. (2017)*	Cross-sectional	Prevalence of dementia	Playing chess, cards, or mahjong	415	MMSE, IADL, GDS	Older adults who played mahjong/chess/cards did not show a significantly different rate of dementia prevalence.

Study	Designs	Disease/ Construct	Activity	*N*	Main outcomes	Key findings
Deng et al. (2018)*	Cross-sectional	Prevalence of dementia	Playing mahjong or chess	1,781	MMSE, IADL, GDS	Older adults who played mahjong/chess showed a significantly different rate of dementia prevalence, but it was neither a protective nor risk factor for dementia.
Tang et al. (2021)	Cross-sectional	Prevalence of depression	Playing mahjong or cards	19,420	PHQ-9, MMSE	Older adults who played mahjong or cards showed a significantly different rate of depression prevalence, in which playing mahjong or cards usually was a protective factor for depression compared to seldom participation.
Qi et al. (2018)	Case-control	Factors related to cognitive impairment	Playing mahjong or cards	1,300 cognitive impairment, 2,600 healthy controls	AD8, MMSE	• There was a significant difference in the frequency of playing mahjong/cards between the control and people with cognitive impairment. • Compared to older adults who never played mahjong/cards, always and seldom playing mahjong/cards was a significant protective factor against cognitive impairment.
Shi et al. (2012)	Case-control	Factors related to AD	Playing chess, cards, or mahjong	78 AD, 156 healthy controls	MMSE, CDR	Playing chess/cards/mahjong was a significant protective factor against AD.
Xue et al. (2012)	Case-control	Factors related to MCI	Playing chess, cards, or mahjong	84 MCI, 168 healthy controls	MMSE, CDR	Playing chess/cards/mahjong was a significant protective factor against MCI.

Study	Designs	Disease/ Construct	Activity	*N*	Main outcomes	Key findings
Sun et al. (2023)	Case-control	Factors related to cognitive impairment	Playing mahjong or cards	1,300 cognitive impairment, 2,600 healthy controls	AD8, MMSE	• There was a significant difference in the behaviour of playing mahjong/cards between the control and people with cognitive impairment in APOE e4 carrier and noncarrier. • Playing cards or mahjong was a significant protective factor against cognitive impairment in APOE carriers and noncarriers.

Note. All of the 11 cross-sectional studies were analysed by Chi-square and logistic regression except Ayijiamali et al. (2015) using the Chi-square test only. All of the 11 cross-sectional studies and 4 case-control studies were analysed by univariate and multivariate regression. All of the 11 cross-sectional studies and 4 case-control studies recruited older adults aged 60 years or above. Protective factors were indicated by odds ratios larger than 1 while risk factors were indicated by odds ratios smaller than 1. MCI = Mild cognitive impairment; ADL = Activities of daily living; MMSE = Mini-Mental State Examination; IADL = Instrumental Activities of Daily Living; GDS = Geriatric Depression Scale; GMS = Geriatric Mental State Schedule; PDSI = Parkinson's disease symptom inventory; AD8 = Chinese version of 8-item Ascertain Dementia; PHQ-9 = Patient Health Questionnaire-9; AD = Alzheimer’s disease; CDR = Clinical Dementia Rating; APOE = Apolipoprotein E.

* Studies that have specified recruiting healthy older adults in the methodology.

5.3.6 Effectiveness of Mahjong Interventions

Six intervention studies, including four RCTs and two non-RCTs, examined the effects of mahjong interventions on different populations and across different outcomes. Table 5.6 summarises their designs and findings, and Table B5.1 (see Appendix B) presents their effect sizes.

Five of the studies (83.3%) examined the effects of a 12-week mahjong intervention in which participants played an hour of mahjong three times a week.[12] Only one study (16.7%), which investigated the effects of a 16-week mahjong intervention, manipulated the frequency of playing (Cheng et al., 2006). All of the studies involved at least one control group that participated either passively or actively by engaging in different activities such as Tai Chi or handicrafts.

Most of the intervention studies (*n* = 5; 83.3%) recruited clinical populations with cognitive impairments such as MCI and dementia. One study (16.7%), conducted in Taiwan, included healthy populations (Lu et al., 2015). Most of the studies (*n* = 5; 83.3%) focused on cognitive functioning aspects such as general cognition, digit span and verbal memory, EF, attention, and reasoning (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014; Lu et al., 2015; Zhang et al., 2020). Aspects of psychological functioning (specifically depressive symptoms; Cheng et al., 2012) and functional independence (Zhang et al., 2020) were the least studied.

All of the studies revealed that a mahjong intervention lasting for at least 12 weeks resulted in significant positive benefits in terms of cognitive, psychological, and daily functions. The interventions improved general cognitive abilities, with small

[12] Except for Lu et al. (2015), who have implemented training sessions for 70 to 90 min.

to large effect sizes, as measured by the MMSE (*d* = 0.77 [medium]), MoCA (*d* = 1.26 [large]), and the sum-of-boxes of the Clinical Dementia Rating (CDR) scale (*d* = -0.34 [small]; Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014; Zhang et al., 2020). They also enhanced performance, with effect sizes ranging from small to large, in cognitive tasks such as the Forward Digit Span Task (*d* = 0.58 [medium]), Forward Digit Sequencing Task (*d* = 0.69 [large]), Corsi Block-Tapping Test (immediate block span; *d* = 0.62 [medium]), and Focused Attention Tests (average reaction time; *d* = -0.2 [small]; Cheng, Chow, Song, Yu, Chan, et al., 2014; Lu et al., 2015). The interventions also improved higher-order cognitive abilities, such as logical reasoning and EF, measured using Raven's Colored Progressive Matrices Test (*d* = 2.02 [large]), Categorical Fluency Test (*d* = 0.27 [small]), and the Shape Trail Test (*d* = -1.43 [large]) with either small or large effect sizes (Cheng, Chow, Song, Yu, Chan, et al., 2014; Lu et al., 2015; Zhang et al., 2020). Improvements with medium to large effect sizes were also observed in psychological and daily functions upon the completion of the mahjong interventions, as measured by the Geriatric Depression Scale (*d* = -0.57 [medium]; Cheng et al., 2012) and the Functional Activities Questionnaire (*d* = -1.31 [large]; Zhang et al., 2020), respectively.[13] However, the intervention did not improve scores in verbal recall and the Backward Digit Span and Backward Digit Sequencing Tasks (Cheng, Chow, Song, Yu, Chan, et al., 2014).

[13] The computed effect sizes, as reported in Table B5.1, refer to group X time interaction effects unless specified.

Table 5.6

Data Charting on Intervention Studies (n = 6)

Study	Country	Designs	Population	*N*	Construct(s)	Main outcomes	Key findings
Zhang et al. (2020)	China	RCT	MCI	• 28 mahjong intervention • 28 passive control	• EF • IADL	• MoCA-B • STT • FAQ	Mahjong playing significantly improved EF and IADL over time, but the differences were not observed in the control group.
Cheng et al. (2006)*	Hong Kong	non-RCT	Dementia	• 29 (4X) • 33 (2X)	• cognitive functioning (digit forward memory, verbal memory, MMSE)	• MMSE • the Chinese Digit Span Test-digit forward span and sequence • the Chinese Auditory Verbal Learning Test	There was no significant difference between the 2X and 4X groups, which suggested similar benefits for playing twice and playing four times a week.
Cheng, Chow, Song, Yu, & Lam et al. (2014)	Hong Kong	RCT	Dementia	• 36 mahjong intervention • 39 Tai Chi • 35 handicrafts	• cognitive and functional deterioration	• CDR sum-of-box score	Compared with the control, mahjong playing showed a slower progression over time.

Study	Country	Designs	Population	*N*	Construct(s)	Main outcomes	Key findings
Lu et al. (2015)	Taiwan	non-RCT	Healthy	• 45 mahjong intervention • 47 passive control	• short-term memory • attention • logical reasoning	• Corsi Block Tapping Test • Focused Attention Test • Raven's Coloured Progressive Matrices Test	Mahjong playing significantly improved short-term memory, attention and logical reasoning capacity.
Cheng et al. (2012)	Hong Kong	RCT	Dementia	• 12 mahjong intervention • 12 Tai Chi • 12 handicrafts	• depression	• GDS	Mahjong playing showed immediate benefits on depression, but the effect was reverted to the baseline level at the follow-up.
Cheng, Chow, Song, Yu, Chan, et al. (2014)	Hong Kong	RCT	Dementia	• 36 mahjong intervention • 39 Tai Chi • 35 handicrafts	• cognitive functioning (MMSE, digit forward and backward memory, verbal and episodic memory, semantic memory)	• MMSE • Digit forward memory-span and sequence • Digit backward memory-span and sequence • Verbal memory-immediate and delayed recall • Categorical verbal fluency	Mahjong playing showed long-term benefits in the short-term memory of numerical units.

Note. All assessments were assumed using the Chinese version. RCT = randomised controlled trial; MCI = Mild Cognitive Impairment; IADL = Instrumental Activities of Daily Living; MoCA-B = the Montreal Cognitive Assessment Scale-Beijing; STT = Shape Trial Test; FAQ = Functional Activities Questionnaire; MMSE = Mini-Mental State Examination; 4X = four times a week; 2X = two times a week; GDS = Geriatric Depression Scale; CDR = Clinical Dementia Rating; EF = executive functions.

[*] This study examined playing mahjong twice or four times a week for 16 weeks. The remaining studies examined mahjong intervention for 12 weeks.

5.4 Discussion

This review scoped the literature on mahjong playing across Western and Asian databases, aiming to identify research gaps and provide directions for future research. Consistent with expectations, both the observational and intervention studies supported the idea that mahjong playing is a beneficial leisure activity. Cheng et al. (2006) suggested that the complex game rules and social nature of mahjong promote cognitive, psychological, and functional abilities. The review systematically classified the areas explored in the literature on mahjong into five major themes: (i) subjective meaning attached to mahjong playing, (ii) short-term benefits of mahjong playing, (iii) long-term benefits of mahjong playing, (iv) association between mahjong playing and disease prevalence, and (v) the effectiveness of mahjong interventions. Most of the studies on the subject adopted a correlational analysis approach. Only a few of them were RCTs, indicating that more high-quality RCTs are necessary to establish the utility of mahjong in improving various outcomes.

5.4.1 Qualitative Findings on the Benefits of Mahjong Playing

The qualitative evidence supported the proposition that mahjong playing has cognitive and psychological benefits. The qualitative studies used a bottom-up approach to explore the meaning of mahjong playing to the older community instead of investigating specific outcomes using scales such as the MMSE, MoCA, or the Geriatric Depression Scale. They complemented the studies that used questionnaires and explained the benefits of mahjong playing by revealing that it helped older adults gain a sense of self-esteem and competence, alleviated their worries, and facilitated greater social support. An interesting explanation of the value that mahjong playing provided to the older adults, revealed in one of the studies, was that it stimulated a sense of youthfulness. This finding suggested that mahjong playing not only enhanced performance in cognitive and psychological tests but also fostered a positive self-concept. A positive outlook on ageing increases self-efficacy in health, which further reinforces a health-promoting lifestyle (Yao, 2019). The positive feedback obtained from mahjong playing may help to cultivate psychological health and encourage a positive ageing experience.

These studies discussed the benefits of mahjong playing from a qualitative viewpoint. Interviewing the older adults revealed how and why mahjong playing is effective. However, they did not clarify which aspects of health and well-being it improved and the extent of those improvements. Whereas the qualitative findings revealed the benefits of mahjong playing at a conceptual level, they did not explain the mechanisms underlying these effects or the importance of each contributing factor. Additional research is necessary to test the hypotheses generated from the qualitative research, such as by manipulating the identified contributing factors and examining their effects on cognitive, psychological, and daily functions.

5.4.2 Quantitative Findings on the Benefits of Mahjong Playing

Three categories of quantitative findings on the effects of mahjong playing emerged from the observational studies: short-term benefits, long-term benefits, and protective effects on clinical conditions.

The studies that examined the short-term benefits showed that mahjong playing was positively correlated with beneficial outcomes such as improved cognitive functioning, lower psychological distress, and better eye-hand coordination. These correlations may be attributable to the fact that mahjong is a mentally demanding and cognitively stimulating game (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014). Players are required to utilise multiple cognitive and social resources during the game, and it therefore offers older adults opportunities to exercise their mental abilities. However, the evidence from these studies was mainly correlational, revealing only the association between mahjong playing and the specific outcomes. They did not explain how mahjong playing led to the beneficial outcomes. Correlational research is generally limited because it provides little insight into causality in relationships. Some of the studies did not find a positive association between mahjong playing and specific outcomes (Ho & Chan, 2005; Yang et al., 2022). These findings may be due to differences in the frequency of participation in the activity and the inclusion of young older adults. One of these studies measured participation in mahjong with a 9-point scale rather than a dichotomous or trichotomous classification, which may have caused higher variability in the DV and made it more difficult to obtain a significant result (Ho & Chan, 2005). In another of these studies, recruiting young older adults, aged 60 to 69 years, may have limited the variation in the outcome, possibly resulting in a lack of statistical significance (Yang et al., 2022). Therefore, high-quality RCTs that manipulate variables that may affect the outcomes are necessary to complement the findings of the cross-sectional studies.

Another group of studies adopted a longitudinal design to investigate the long-term benefits by following up on the behaviour of older adults who played mahjong. These studies captured changes over time to elucidate the relationship between the habit of mahjong playing and the trajectories of cognitive impairments, patterns of loneliness, and risk of functional disability. Rather than merely using a dichotomous classification of whether one played mahjong or not, examining the frequency of playing enhanced the understanding of how optimal behavioural outcomes could be achieved. For instance, Xue (2020) found that compared with older adults who never played mahjong, those who played mahjong at least once a month exhibited the largest improvements, whereas Mao et al. (2020) found that playing mahjong, whether frequently or infrequently, helped to reduce the risk of cognitive impairment. These inconsistent findings on the optimal playing frequency warrant further investigation. In addition, Wang et al. (2022) studied the change of playing frequency from 2002 to 2014 on the prevention of cognitive impairment and found that playing more could decrease the risk while playing less may increase the risk to develop cognitive impairment. The results may suggest a lifelong practice of mahjong playing may also help to prevent cognitive decline. The results coincided with another cross-sectional study that more than one year of mahjong experience may also help to prevent MCI (Ding et al., 2022). It seems that a lifelong practice or a lifetime familiarity with mahjong may help to prevent cognitive decline. However, since only two studies on this issue were found, more studies are needed to reach a reliable conclusion.

The studies that examined the relationship between mahjong playing and disease prevalence also reported promising results showing that mahjong playing was associated with fewer cognitive-related disorders and lower depression and functional impairment. The results also demonstrated mahjong playing was a protective factor against those clinical conditions. However, it is possible that the conditions were caused by other co-varying factors such as bodily dysfunction and ageing rather than mahjong playing per se. Further investigation through controlled studies is necessary to confirm the relationships reported in these studies.

The three groups of quantitative observational studies predominantly examined the relationship between mahjong playing and cognitive outcomes measured using tests such as the MMSE, MoCA, and short-term memory tests. Only a few of the studies investigated psychological and daily functions such as loneliness, psychological well-being, and IADL. Preliminary but limited evidence on the benefits of mahjong playing was found in relation to psychological distress (Ross & Zhang, 2008) and loneliness (Liu, 2015; Teh & Tey, 2019). More studies are necessary to explore the relationship between mahjong playing and psychological and daily functions. A limited number of studies have focused on the effect of mahjong playing across different demographic groups (i.e., age, gender, education, and the years of mahjong playing); more studies are, therefore, needed to understand these potential confounding variables. Future studies should also control these possible confounding factors. The grouping of mahjong with card games and chess in many of the studies may have also had a confounding effect on the findings regarding the benefits of mahjong playing. Understandably, the studies combined these activities due to their similar nature (i.e., they are all cognitively and socially stimulating). Nonetheless, future research should explore mahjong playing as an independent activity and control the covariates to enable clear and concrete conclusions.

5.4.3 Effectiveness of Mahjong Interventions

The six intervention studies supported the idea that mahjong playing improves cognitive and psychological functioning. Regardless of clinical condition, the mahjong interventions enhanced general cognitive performance and short-term memory and alleviated depressive symptoms in older adults (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014; Cheng et al., 2012; Lu et al., 2015; Zhang et al., 2020). However, only four of the studies were RCTs with standardised study protocols. Because an RCT is the gold standard for evaluating the effectiveness of an intervention, it should be given the highest consideration in the literature. The computed effect sizes of the statistically significant improvements in these studies ranged from small to large, and no apparent pattern could be observed in these effect sizes. The wide range of effect sizes may have reflected the fact that the studies used diverse outcome measures, such as the MMSE, MoCA, and the CDR, to assess general cognitive ability. The Digit Span and the Digit Sequencing Tasks were only used in two studies (Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014). The relationship between mahjong playing and scores on the Forward Digit Span and Forward Digit Sequencing Tasks were significant and exhibited medium effect sizes. However, the relationship between mahjong playing and scores on the Backward Digit Span and Backward Digit Sequencing Tasks were not significant and exhibited negligible effect sizes. Because a mahjong player is required to sort and group the mahjong tiles in consecutive order, the game may enhance the short-term memorisation of numerical units. The Backward Digit Span and Backward Digit Sequencing Tasks may measure not just short-term memory but also higher-order cognitive abilities such as working memory. Owing to the diversity of the outcomes used in the studies and the limited amount of evidence that has resulted from them, more studies are needed to clarify and evaluate the effects of mahjong interventions.

By providing emerging evidence of the effects of mahjong interventions, the reviewed studies opened discussion of the mechanisms underlying these effects. Some of the intervention studies defined mahjong as a mentally demanding and cognitively stimulating game and postulated that the cognitive component of mahjong playing may promote cognitive and psychological functioning (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014). They reported that mahjong playing resulted in greater improvements in cognitive and psychological functioning than less demanding activities such as Tai Chi and handicrafts (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014). Those intervention studies that defined mahjong as a general or social leisure activity also reported similar findings by comparing mahjong playing with a passive control condition (i.e., no intervention; Lu et al., 2015; Zhang et al., 2020). In contrast, the observational studies only indicated a positive relationship between mahjong playing and cognitive, psychological, and functional abilities. It is still not clear which component (i.e., cognitive or social component) contributed to the positive effects of mahjong playing and what the underlying mechanisms are. Therefore, future research could examine the mechanisms underlying the effects of mahjong playing by separating the cognitive and social components and investigating the neural underpinnings of those effects. It would be valuable to clarify whether the positive effects of mahjong playing are due to its nature of being a general leisure activity, an intellectual leisure activity, or a social leisure activity. Future research could also develop the theoretical background on the effects of mahjong playing to foster discussion of whether a cognitively stimulating activity or a socially interactive activity better mitigates age-related decline in older adults. Because ageing is associated with brain degeneration and can be measured in neuroimaging studies (Yeung & Chan, 2021), incorporating neural evidence such as structural and functional brain changes in studies on the effects of mahjong playing may also result in valuable contributions to the ageing literature.

Another possible direction could be focusing on the difference between experienced players and novices. The RCTs included in this review recruited participants with MCI or dementia who have already acquired mahjong skills but have not played mahjong regularly in the past three to six months (Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014; Cheng et al., 2012; Zhang et al., 2020). The mahjong skills were acquired many years ago, and it is difficult to separate the effect of familiarity or mahjong playing itself. To better understand the effects of mahjong playing on cognitive abilities in older adults and isolate the effect of familiarity, future studies may investigate the performance between the experienced mahjong player and the newly acquired player.

5.4.4 Other Directions for Future Work

We propose four additional broad directions that future work could pursue to better understand the benefits of mahjong playing: incorporating diverse outcomes of higher-order functioning, investigating the generalisability of the research findings, examining long-term effects, and studying different populations. The first research direction refers to the further examination of the relationship between mahjong playing and various aspects of higher-order cognitive functioning such as EF and decision-making. In the reviewed studies, the investigation of the relationship between mahjong playing and general cognitive abilities such as short-term memory and attention was superficial. The MMSE and MoCA were the two major outcomes used in the literature. Although the intervention studies evaluated functioning in specific cognitive domains using tests such as the Digit Span, Corsi Block-Tapping, and Chinese Auditory Verbal Learning Tests, the effects of mahjong playing on higher-order cognitive functioning (e.g., EF and decision making) remain unknown. Because mahjong playing requires players to remember the game rules and flexibly devise and implement strategies, it might promote working memory and the inhibition and switching aspects of EF.

Another potential research direction is to explore whether the findings on the benefits of mahjong playing are generalisable to wider outcomes such as life satisfaction and quality of life. According to a practical handbook for mahjong interventions in Hong Kong (Yan Chi Hospital Social Services Department et al., 2005), the principal objective of a mahjong intervention is to boost happiness and self-confidence among older adults. This objective is consistent with one of the qualitative findings in this scoping review: mahjong playing stimulated a sense of youthfulness and accomplishment and enhanced self-confidence. Future research may extend the scope of this body of research from cognitive, psychological, and functional impact to a broader range of outcomes.

There were also differences in the long-term effects of mahjong playing on cognitive and psychological outcomes. A long-term effect of the activity on cognitive functioning was observed during a one-month follow-up (Cheng et al., 2006) and a six-month follow-up (Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014). However, its effect on alleviating depressive symptoms was not sustained after three months (Cheng et al., 2012). Due to the limited number of studies, it is difficult to conclude what the long-term effects of mahjong playing actually are. Future studies should not only investigate the long-term effects of mahjong playing but also compare the differences in these effects between different domains of outcomes.

The literature on mahjong playing has hitherto focused on clinical populations such as older adults with dementia, MCI, or depression instead of healthy populations. Because healthy older adults also experience declines in EF across their lifespan (Ferguson et al., 2021), investigating the effects of mahjong playing on healthy older adults could be valuable to develop methods of preventing or slowing age-related declines. Theories on active ageing (Fernandez-Mayoralas et al., 2015) and active participation in leisure activities (Mao et al., 2020) have suggested that the risk of impairment can be reduced and age-related trajectories can be slowed. RCTs are necessary to examine whether mahjong playing could potentially slow age-related declines.

5.4.5 Conclusions

The strengths of mahjong as a potential intervention are its cultural popularity and ease of implementation in Asian cultures. It is a simple activity to implement in the community and could minimise age-related decline. Considering that it is a popular activity in Asian societies, this scoping review included both the Western and Asian literature, and it therefore did not overlook the evidence in the Asian literature. It also covered a broad range of study designs and outcomes, and provided a comprehensive overview of the literature on mahjong by highlighting which aspects of the topic necessitate further examination and what types of study designs are required. In light of the convincing evidence on cognitive outcomes, mahjong also presents a unique opportunity to explore the cognitive reserve in older adults. A limitation of this review is that it focused on cognitive, psychological, and daily functions, and studies that only examined physical outcomes such as hypertension and mortality were excluded. Other culturally specific physical activities, such as Tai Chi and Qigong, were also found to improve not only cognitive functions (i.e., language abilities, executive function, short-term memory and long-term delayed recall; Liu et al., 2025), but also sleep efficiency (Siu et al., 2021), perceived stress (Yu et al., 2014), and health-related quality of life (Lee et al., 2009; 2010). Although the prevalence rate of these culturally specific activities (i.e., mahjong playing [27%], Tai Chi [15%], Baduanjin [7%], Qi gong [5%], and Luktungkuen [1%]) were lower than the common leisure activity (i.e., watching television [70%] and slow walking [68%]) in Study 1, these activities may help to facilitate a higher adherence rate of the activity. In the Tai Chi interventions, the average adherence to Tai Chi is 84.6% (Lee et al., 2009; 2010; Siu et al., 2021; Yu et al., 2014). In addition, as mahjong playing has been categorised as an intellectual and social activity while Chinese mind body exercise has been categorised as a physical activity, both forms of activity may play a complementary role in promoting the functions of older adults. Literature has reported comparable effects of mahjong playing and Tai Chi on cognition (Cheng et al., 2014). It may suggest that older adults with physical limitations could benefit from mahjong playing, or older adults who cannot perform prolonged sedentary activity could benefit from Tai Chi. Future research may focus on exploring the complementary effect of these culturally specific activities.

In conclusion, this scoping review summarised the positive effects associated with mahjong playing reported in the literature, and the findings supported the idea that the activity benefits older adults. The empirical evidence showed that the activity, which is popular and culturally important in Asian countries, has the potential to ameliorate age-related cognitive, psychological, and functional declines. Considering that most of the studies adopted a correlational research design, more studies adopting other approaches, especially RCTs, are necessary to advance our understanding of the theoretical mechanisms underlying the effects of mahjong playing.

Chapter 6

Study 3: Relationships Between Mahjong Playing and EF: Behavioural and Neural Evidence in Younger and Older Adults

6.1 Introduction

In the literature, not many studies have been conducted to examine the beneficial effects of mahjong playing on EF. Nevertheless, both the survey study (Study 1) and the scoping review (Study 2) supported a positive relationship between mahjong playing and EF. Specifically, Study 1 showed that a longer duration of mahjong playing predicted better EF in older adults. In Study 2, the scoping review identified and reported one intervention study (i.e., Zhang et al., 2020) which showed that a 12-week mahjong intervention could improve EF in older adults with MCI. The findings of these studies suggested that mahjong playing and EF are related, notwithstanding the paucity of research on this topic. Further empirical investigation is, therefore, warranted to understand the underlying mechanisms of the observed benefits of mahjong playing.

6.1.1 Mahjong Playing and EF

As a leisure activity, mahjong playing is considered to involve higher-level cognitive processes, particularly, EF (Cheng et al., 2006; Zhang et al., 2020). EF has the factor structure of one "common EF" at the unity level and two specific factors at the diversity level: (i) updating,[14] and (ii) switching (Miyake & Friedman, 2012; see section 3.1.4.1 for the definition of EF and section 3.3.2.1 for a detailed explanation on the relationship between mahjong playing and EF). Take updating of EF as an example, mahjong players have to retain information about what tiles have been

[14] Updating is also known as working memory and it is used interchangeably with working memory in the literature. In this chapter, "updating" was used when referring to the specific sub-component of EF. When describing the load of working memory or the version of the mahjong game, "working memory" was used. See Footnote 2 in Chapter 3.

collected from the pool and what tiles have been discarded by the other players to estimate the probability of collecting the targeted tiles. Regarding the switching of EF, the players need to concurrently update their tile set by deciding which tile to keep/discard in order to maximise winning probability.

However, as mentioned in Study 2, the underlying functional and neural mechanisms of how mahjong playing facilitates better EF in older adults remain unclarified. Researchers have postulated that the benefits of mahjong playing in older adults were due to the cognitive stimulation rendered by the challenging and complex game rules (Cheng et al., 2006). From a neural perspective, Fujimori et al. (2015) also demonstrated that engaging in mahjong playing may foster brain activities, suggesting that it might contribute to the accumulation of cognitive reserve in older adults. It is reasonable to suggest that the cognitive component of mahjong playing actively contributes to the maintenance and enhancement of the cognitive processes of older adults. Therefore, it is important to separate the cognitive component from the social component of mahjong playing,[15] and investigate how it relates to cognitive functions (i.e., EF in this study).

While previous research had found that mahjong playing can benefit EF of older adults with dementia or MCI (Cheng, Chow, Song, Yu, Chan, et al., 2014; Zhang et al., 2020), few studies have investigated its impacts on healthy older adults. Moreover, these two studies reported mixed findings. Cheng, Chow, Song, Yu, Chan, et al. (2014) found no significant improvement in EF after a mahjong intervention, while Zhang et al. (2020) reported an improvement in EF in their mahjong training group. Therefore, it is important to broaden the scope of the research from clinical

[15] Mahjong playing is classified as both an intellectual and social leisure activity. Previous studies implemented the mahjong intervention on a group basis (Cheng et al., 2014; Zhang et al., 2020), and the results could not separate whether the cognitive or the social component contributed to the benefits of mahjong playing.

populations to include healthy older adults, and investigate if there is a relationship between mahjong playing and EF in healthy older adults.

In the literature, few studies have been conducted to study the neurological basis and brain activations associated with mahjong playing. In one such study, Fujimori et al. (2015) used fNIRS and found that, compared with a solitaire version of the mahjong game, a real-life version of the mahjong game significantly increased the cortical activation of older adults. This supported the claim that mahjong playing increased brain activation (for details, please refer back to section 3.3.2.3). However, because a real-life version of the mahjong game was adopted, the study did not separate the cognitive and social components of mahjong playing. Moreover, the analyses of the study focused on comparing the differences between the virtual gaming environment and the real-world gaming environment. Therefore, it remains unclear if the neural activations are directly related to the cognitive component of mahjong playing. More empirical studies are needed to examine whether the cognitive component of mahjong playing could lead to activation of the brain (viz., brain exercise).

6.1.1.1 Mahjong Playing and the Updating-Specific Component of EF. It is reasonable to expect that the cognitive component of mahjong playing involves the updating-specific factor of EF. According to Miyake and Friedman (2012), this factor is responsible for the constant monitoring and rapid manipulation of working memory contents. One typical measure of the updating-specific factor is the *n*-back Task (Miyake & Friedman, 2012), in which *n* is a prespecified integer that represents the working memory load (Owen et al., 2005). For example, in a 2-back task, the participants are required to respond to a stimulus that is the same as the one presented in two previous trials. The task involves online monitoring, updating and manipulating of information (Owen et al., 2005). With a greater *n* in the *n*-back Task, the difficulty level will increase and a greater working memory load is required.

One feature of the mahjong game is that it involves 144 tiles, and the players will receive a novel set of tiles in every new round of the game (Cheng et al., 2006). The 144 tiles highlight the flexibility to manipulate the tiles and form stimuli with different levels of cognitive demand. For example, if players have built a flexible hand, there may be multiple winning options towards the end of the game,[16] thereby increasing the probability of winning. This increased probability of winning also represents a higher working memory load, as the players need to retain and manipulate more information in their minds.[17] In this connection, the winning probability of the mahjong game operationalises the working memory load of the updating task, and it is similar to the working memory load measured in the *n*-back Task.

6.1.1.2 Mahjong Playing and Switching-Specific Component of EF. The cognitive component of mahjong playing is also considered to involve the switching-specific factor of EF, which is defined as the ability to switch flexibly between tasks or mental sets (Miyake & Friedman, 2012). One typical measure of the switching-specific factor of EF is the Color-Shape Task, in which the participants are required to follow a cue that instructs them to classify the stimulus according to the colour or the shape (Miyake & Friedman, 2012).[18] Theoretically, switching tasks are considered to measure the cost related to task-set reconfiguration (i.e., the control processes that are responsible for the detachment of the previous stimulus and the attachment of the

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[16] It is common for the mahjong players to wait for a certain tile to complete their collection in their hand and win the game.

[17] For instance, players who have three options to complete their collection would require a higher working memory load than the players who have only one option to complete their collection.

[18] Apart from the Color-Shape Task, the literature also included similar switching paradigms such as letter-numbers, picture-symbol, and category-switch (Sambol et al., 2023).

current stimulus) and interference (i.e., the cost induced by resource competition between the previous and current stimulus; Ye & Damian, 2022). Global cost (i.e., the difference in performance between the pure and mixed task blocks)[19] is often measured as one of the outcomes of the tasks. It reflects the global control mechanisms such as monitoring, maintaining, and resolving the interference among the two task sets. A higher global cost suggests greater efforts and cognitive resources, thus representing a poorer performance of switching (Steffener et al., 2016; Ye & Damian, 2022).

Mahjong players often need to make choices about which tile to keep and which to discard to maximise winning probability (Ho & Chan, 2005).[20] Accepting the newly received tile from the pool and discarding one tile from the current hand may switch the original target tiles from one set to another, thereby allowing more options to complete the collection and win the game.[21] The ability to notice an opportunity to switch the tile and maximise the winning probability represents the switching of EF, as the players need to interrupt the current activity, shift to a new target, and alternate between the options.[22] This feature highlights the similarity between the mahjong game and the Color-Shape Task, in which the participant is required to flexibly switch to another set of classification rules. Hence, the mahjong game is considered to resemble the switching ability measured in the Color-Shape Task or other similar task-

[19] The task commonly includes one pure block and one mixed block. The pure block does not involve switching and only presents a single task cue (i.e., either the colour or the shape cue; Hartanto & Yang, 2020). Whereas the mixed block measures switching by presenting two cues either in a repeat or alternate order.

[20] At every turn of the game, players would receive a tile randomly from the pool and are required to discard one tile, either from their current hand or the newly received one.

[21] Each base tile has four copies in one tile set (See Chapter 3 for an example set of mahjong base tiles). Note that players could not get back the tiles that have been discarded in the pool, switching to another set of target tiles may sometimes increase the winning probabilities.

[22] For example, upon receiving an additional tile from the pool and assuming it could help to increase the winning probability, a player with better switching skills will interrupt the current target tile and flexibly switch to a new option.

switching paradigms.[23]

6.1.2 Cognitive Ageing, EF and fNIRS

Incorporating neuroimaging techniques could better elucidate the neural mechanisms of how mahjong playing provides cognitive benefits to older adults. fNIRS, a non-invasive neuroimaging tool using near-infrared light within 650-950 nm wavelength, has been used to measure the optical absorption changes during mahjong playing in previous research (Fujimori et al., 2015; Pinti et al., 2020). Specifically, it measures the concentration of oxygenated haemoglobin ([oxy-Hb]), deoxygenated haemoglobin ([deoxy-Hb]) and total haemoglobin ([total-Hb]) with a pair of light emitter and detector optodes (Scholkmann et al., 2014). The main advantages of using NIRS include low cost, being portable, having substantial tolerance to motion artefacts and without strict testing environment restrictions, as compared with other neuroimaging techniques such as electroencephalogram (EEG) and functional magnetic resonance imaging (fMRI; Ferrari & Quaresima, 2012; Lloyd-Fox et al., 2010; Tak & Ye, 2014). Studies have found that the optical measures were correlated with the Blood Oxygenation Level Dependent (BOLD) signal acquired from fMRI, and the positive association was especially stronger with [oxy-Hb] (Pinti et al., 2020; Strangman et al., 2002). With a multi-channel system and a higher sampling rate, NIRS has a better temporal resolution than fMRI (Ferrari & Quaresima, 2012). Researchers have also established standard protocols for designing, measuring, analysing and reporting the NIRS studies (Yücel et al., 2021). In sum, NIRS is capable of measuring cortical activation simultaneously during an ecologically valid

[23] Ideally, the mahjong game should include pure and mixed blocks with similar characteristics. For instance, the pure block could present trials that do not involve switching, while the mixed block could present both trials that require (i) switching the target tile to maximise the winning probability and (ii) no switching. Once the two blocks of the mahjong game have been defined, the global cost could be calculated in the same way as the Color-Shape Task.

setting (Hoshi, 2005; Yeung & Chan, 2021).

Extensive research has supported the positive relationship between the activation of cerebral oxygenation in the PFC and EF tasks across the lifespan, such as young children (Moriguchi & Hiraki, 2009, 2013), adults (Hashimoto et al., 2007; Koike et al., 2002; Shibuya-Tayoshi et al., 2007; Yasumura et al., 2014), and older adults (Bierre et al., 2017; Heilbronner & Münte, 2013; Kahlaoui et al., 2012; Kawai & Nakata, 2022; Suhr & Chelberg, 2013; Vermeij et al., 2012).

6.1.2.1 Ageing, Updating and fNIRS. A study related to the updating of EF (as measured by the *n*-back Task) observed bilateral activations in older adults and a slight right-hemispheric dominance in younger adults (Vermeij et al., 2012). It was noted that behavioural performance was poorer in higher working memory load conditions in older adults but not younger adults; it was therefore suggested that older adults might attempt to compensate for the observed age-related decline in behavioural performance (Vermeij et al., 2012). This bilateral activation compensation mechanism explains one strategy for older adults to mitigate age-related declines, and it also offers evidence to support the HAROLD model (i.e., the more spreading of brain activation pattern [dedifferentiation and less lateralisation] is observed in older adults when they are attempting to compensate or improve behavioural performance; Cabeza, 2002).

6.1.2.2 Ageing, Switching and fNIRS. For the switching component of EF, Mekari et al. (2019) found that the cerebral oxygenation in the left PFC was a significant mediator of the relationship between cardiorespiratory fitness and EF, in which the fitter older adults had higher cerebral oxygenation level and resulted in better EF performance (i.e., switching ability as measured by the Trail Making Test B [TMT-B]). Ohsugi et al. (2013) also found that greater activation in the PFC was associated with fewer errors in TMT-B in older adults, which implied that older adults with better cognitive performance were able to recruit additional neural resources to compensate for the age-related decline in the behavioural test. This pattern of elevated activation explains another strategy for older adults to compensate for the age-related declines, and it also provides supporting evidence to the CRUNCH (i.e., older adults employing overactivation to make up for the decreased neural efficiency and to reach age-equivalent behavioural performance with younger adults; Reuter-Lorenz & Cappell, 2008).

These reviewed studies underscored the characteristics of neural compensation in older adults, such that the over-recruitment of the PFC activity, compared with younger adults, is beneficial for older adults to compensate for the age-related declines in behavioural performance (Cabeza, 2002). It is also in line with the concept of compensatory scaffolding proposed in the STAC (Park & Reuter-Lorenz, 2009), in which older adults would show an increment of prefrontal activation to account for the compensation. Nevertheless, some evidence suggests that there is no significant relationship between cerebral oxygenation in the dorsolateral prefrontal cortex (dlPFC) and EF (i.e., switching ability as measured by the TMT-B; Suhr & Chelberg, 2013). Reuter-Lorenz and Park (2014) proposed that these "youth-like" brain patterns, characterised by minimal overaction, may be associated with more successful ageing. However, it should be noted that the sample size of the study was limited to 22 older adults (Suhr & Chelberg, 2013). The researchers also encouraged that more studies are needed to investigate the relationship between cerebral oxygenation in the dlPFC and EF in older adults.

In summary, regarding the advantages of NIRS and the promising neural results from the previous research, it is believed that adopting the NIRS as a neuroimaging tool concurrently during the mahjong games would facilitate the understanding of the neural underpinnings of mahjong playing. If there is an increased activation of cerebral oxygenation during the mahjong game, it provides neural evidence to support the claim that “mahjong playing increases usage of cognitive resources”. Additionally, if overactivation or bilateral activations are observed among older adults, it suggests that “mahjong playing facilitates the deployment of more effective compensatory processes in older adults”.

6.1.3 Aims and Hypotheses

This study developed two versions of computerised mahjong games (i.e., working memory and switching) and aimed to examine the relationship between mahjong playing and the updating and switching factors of EF. The primary objective was to fill the research gap concerning the relationship between mahjong playing and EF in the literature, and to clarify the neural mechanism of mahjong playing behind the observed benefits in older adults.

It addressed six research questions: (i) Are the behavioural outcomes consistent and as expected for the manipulations of updating and switching in the newly developed mahjong games? (ii) Are the patterns and levels prefrontal activations as expected for the manipulations of updating and switching in the newly developed mahjong games? (iii) Are there age differences in the behavioural outcomes for the mahjong games? (iv) Are there age differences in prefrontal activations during the mahjong games? (v) What is the relationship between the behavioural performances of the newly developed mahjong games and the commonly used updating and switching tasks in the literature? (vi) What is the relationship between the neural activations during the mahjong games and the behavioural measures of the commonly used updating and switching tasks?

Six hypotheses were proposed accordingly. First, as the mahjong games were similar to the updating and switching tasks, it was hypothesised that the high working memory load and mixed block would show poorer accuracy and longer reaction time than the low working memory load and pure block in the mahjong games.

Second, as undertaking the mahjong playing may increase the utilisation of cognitive resources, it was hypothesised that the high working memory load and mixed block would show greater prefrontal activation than the low working memory load and pure block in the mahjong games.

Third, given a clear age-related working memory and switching decline observed in the literature (Bopp & Verhaeghen, 2020; Idowu & Szameitat, 2023; Vasta et al., 2017), it was hypothesised that older adults would show poorer accuracy and longer reaction time than younger adults in all behavioural measures, including the mahjong game and the commonly used EF tasks.

Fourth, as EF tasks mainly involved activations in the dlPFC (Nejati et al., 2018; Salehinejad et al., 2021) and age-related compensatory activation is commonly observed in the literature (Cabeza, 2002; Reuter-Lorenz & Cappell, 2008), it was hypothesised that older adults would show greater prefrontal activation than younger adults in all neural measures.

Fifth, in light of the similarities between mahjong playing and EF, positive associations were expected between the behavioural measures of the mahjong games and the commonly used updating and switching measures (including computerised EF tasks and neuropsychological EF tests).

Lastly, as a greater activation in PFC was found to be associated with better EF in previous studies (Mekari et al., 2019; Ohsugi et al., 2013), positive associations were expected between the prefrontal activations during the mahjong games and improved behavioural performance on the commonly used updating and switching measure (including computerised EF tasks and neuropsychological EF tests).

6.2 Method

6.2.1 Study Designs

This study adopted cross-sectional, correlational, and mixed (within- and between-subjects) designs.

6.2.2 Participants

This study recruited 84 participants, including 41 younger and 43 older adults with self-reported basic mahjong skills. These participants were then screened using the following exclusion criteria: (i) a history of traumatic brain injury, neurological or psychiatric disorders, (ii) current use of psychotropic medication, (iii) a score less than 22 on the Hong Kong Montreal Cognitive Assessment (HK-MoCA),[24] (iv) a severe level of the subscale scores of DASS-21 (i.e., depression score ≥ 21, anxiety score ≥ 15 and stress score ≥ 26), (v) severe visual or hearing impairment, or (vi) playing mahjong more than once a week.[25] Twelve participants were excluded, due to technical difficulties with the NIRS recording (n = 4), and a severe level of the total score of DASS-21 (n = 8). The final sample size comprised 36 younger adults (14 males, 34 right-handed, aged between 18 and 25 years, M_{age} = 21.19 years, SD = 2 years) and 36 older adults (16 males, 34 right-handed, aged between 62 and 76 years, M_{age} = 68.08 years, SD = 3.61 years). Participants received a reimbursement of HKD100 for travel expenses upon completion of the study. Written informed consent was obtained from each participant before the screening and experiment. Ethical approval was obtained from the Human Subjects Ethics Sub-Committee at the Hong

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[24] One point was added if the participants received less than 12 years of education.
[25] To minimise the effect of accomplished mahjong experience.

Kong Polytechnic University (HSEARS20211004005).

6.2.3 Materials

Each participant was administered a total of six tasks, comprising three updating tasks (viz., computerised mahjong working memory game, *n*-back Task and Digit Span Test) and three switching tasks (viz., computerised mahjong switching game, Color-Shape Task and Color Trails Test [CTT]).

6.2.3.1 Computerised Mahjong Games. Two computerised mahjong games were developed to assess the updating and switching components of EF. The two games were designed based on the concepts of updating and switching outlined in the literature (Miyake & Friedman, 2012; Owen et al., 2005; Ye & Damian, 2022). During development, advice was sought from experts in EF and neuroscience (D.H.K.S, B.K.H.C, and M.K.Y) to ensure that the design was consistent with the two constructs of EF and compatible with neuroimaging data collection. Multiple rounds of pilot testing and refinement on each version were conducted before the launch of the main study. All items of the computerised mahjong game were also cross-checked with an expert in psychological testing (D.H.K.S) and a researcher who is knowledgeable in mahjong playing (D.H.K.S).

6.2.3.1.1 Computerised Mahjong Working Memory Game. The computerised mahjong working memory game was designed to assess the updating component of EF. Two levels of working memory load, viz., 1-tile-to-win and 3-tile-to-win, were developed by manipulating the winning probabilities of the stimuli. Particularly, the 1-tile-to-win item represented the low working memory load condition, while the 3-tile-to-win item represented the high working memory load condition. The game included six task blocks in total, in which each condition was comprised of three task blocks and each task block included six test items. Each task block lasted for 63 s, and the order of the two conditions was randomised. Before and after each task block, a rest block with a fixation cross was shown to the participants and lasted for 27 s to 33 s. The jittering interval was given to reduce the anticipatory effects of the block onset (Yeung & Han, 2023). The duration was also sufficient for the hemodynamic response to restore to the baseline level before the start of the next block (Yeung et al., 2021b). Participants were instructed to relax and focus on the fixation cross during the rest block. This version of the computerised mahjong game took around 9.5 min to 10 min to complete.

Thirty-six test items were developed for the computerised mahjong working memory game, and each working memory load condition consisted of 18 test items. Each test item was started by a 500 ms fixation cross that informed the upcoming stimulus, and then a set of tiles was presented for 5,000 ms as the stimulus. During the stimulus presentation, participants were instructed to work out which tile(s) could complete the collection. Afterward, the stimulus offset and an additional tile would be shown for another 5,000 ms. Participants were required to decide if the said tile could complete the collection or not. They were instructed to press the left button of a computer mouse with their index finger if the given tile could complete the collection. Alternatively, pressing the right button if the given tile could not complete the collection. To prevent all yes or all no responses, half of the trials included a given tile that could complete the collection, while the other half included a given tile that could not. The sequence of the test items was also randomised for each participant. If the participants generated a response of less than 5,000 ms, a blank screen was displayed for the remaining time to ensure uniform duration across all trials.

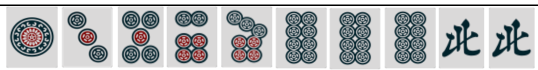
All stimuli and instructions were presented using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA, USA). Behavioural responses (i.e., accuracy and reaction time) were recorded by a desktop computer (Lenovo ThinkCentre M93p).

Figure 6.1 shows two example test items and the winning mechanisms of the low and high working memory load conditions, experimental paradigms of the block design and the schematic presentation of one trial of the computerised mahjong working memory game.

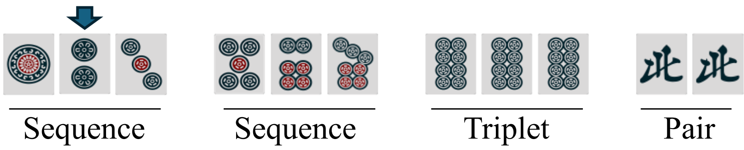
Figure 6.1

Example Items, Winning Mechanisms, Experimental Paradigm and Schematic Presentation of the Computerised Mahjong Working Memory Game

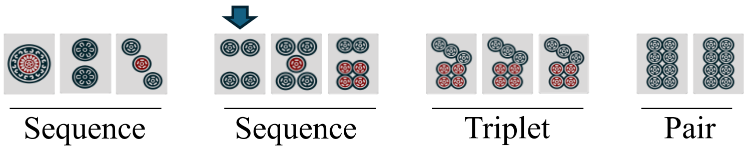
(a)

Condition	Stimulus	Given tile	Other winning options
1-tile-to-win			N/A
3-tile-to-win			

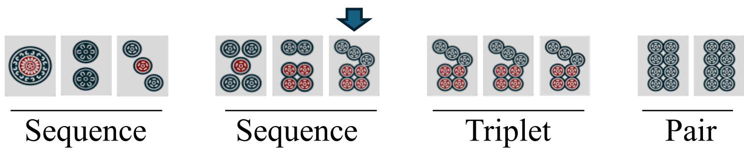
(b)

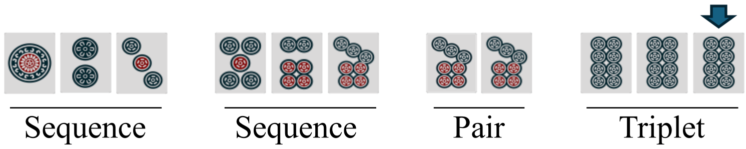


(ci)

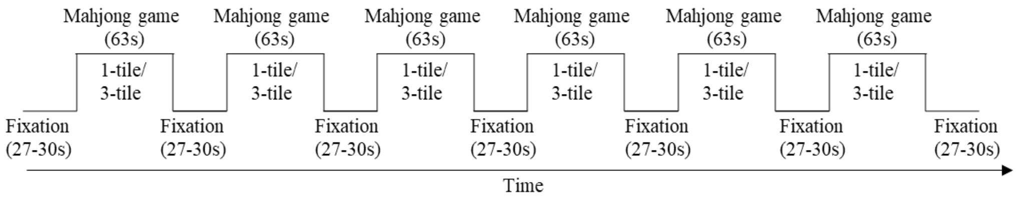


(cii)

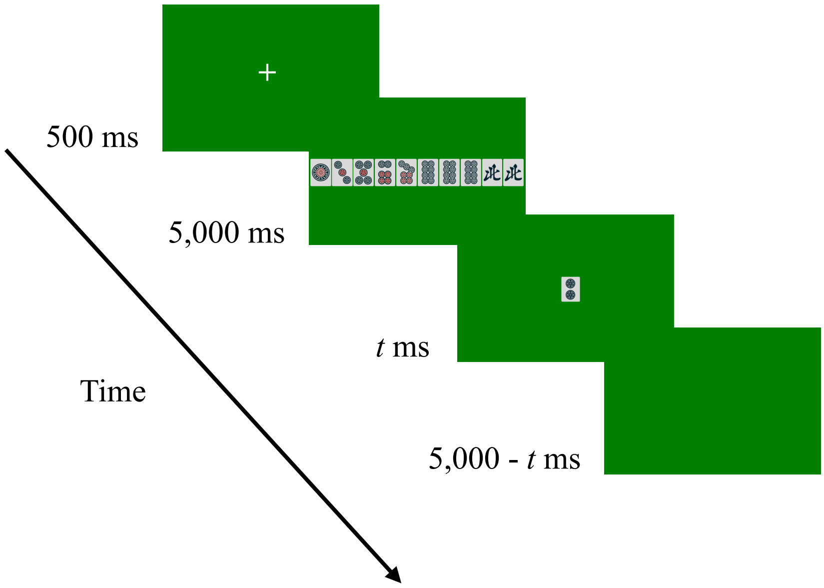




(ciii)



(d)



(e)

Note. (a) shows two example items of the computerised mahjong working memory game, with 1-tile-to-win representing the low working memory load condition and 3-tile-to-win representing the high working memory load condition.[26] (b) shows the winning mechanism of the example of a low working memory load condition. Only one option (i.e., circle two, as indicated by the blue arrow) could complete the tile set and win the game. (c) shows the winning mechanism of the example of a high working memory load condition, which includes three options: (i) circle four, (ii) circle seven and (iii) circle eight (as indicated by the blue arrows) to complete the tile set and win the game. (d) shows the experimental paradigm of the block designs, and

[26] Note that a winning hand should consist of one pair and four sets of triplets or sequences; and the stimulus depicts the mahjong hand on the verge of victory.

(e) illustrates the schematic presentations of one trial of the computerised mahjong working memory game.

6.2.3.1.2 Computerised Mahjong Switching Game. The computerised mahjong switching game was designed to assess the switching component of EF and has a similar design as the computerised mahjong working memory game. Two conditions, viz., pure and mixed blocks, were designed to measure the global cost of the computerised mahjong switching game.[27] The game included six task blocks in total, in which each pure and mixed condition comprised three task blocks and each task block included six test items. Each task block lasted for 63 s, and the order of the pure and mixed conditions was randomised. Before and after each task block, a rest block with a fixation cross was shown to the participants and lasted for 27 s to 33 s. Participants were instructed to relax and focus on the fixation cross during the rest block. This version of the computerised mahjong game took around 9.5 min to 10 min to complete.

Forty-five test items, including 27 no-switch trials and 18 switch trials were developed for the computerised mahjong switching game. Similar to the design of the Color-Shape Task (Vasta et al., 2017), the pure block only presented the no-switch trials, while the mixed block presented 50% no-switch trials and 50% switch trials. As a result, although 18 switch trials were developed, only 9 of them were randomly selected by the E-Prime and presented in the game. It may also help to ensure that the switching version is comparable with the working memory version. Therefore, 36 test items in total, including 27 no-switch trials and 9 switch trials, were presented to the

[27] Switching cost was not computed in this study because the game employed a block design. The calculation of the switching cost did not consider the pure block as it referred to the difference between the repeat and switch trials within the mixed block (Steffener et al., 2016; Ye & Damian, 2022).

participants in the computerised mahjong switching game.

Different from the working memory version, the winning probability of the stimuli remained the same (i.e., 1-tile-to-win) in the switching version. The two types of trials, viz., no-switch and switch trials, were developed by manipulating the winning probability after considering an additional tile presented alongside the original set of stimuli. Specifically, the no-switch trial required no switching ability and accepting the additional tile would decrease the winning probability from 1-tile-to-win to 0-tile. In contrast, the switch trial required the switching ability and accepting the additional tile would increase the winning probability from 1-tile-to-win to 2-tile-to-win. The switch trial was scrupulously designed such that the participants needed to utilise the additional tile to form a new winning configuration under the interference of the original winning option.

Each trial was started with a 500 ms fixation cross that informed the upcoming stimulus, and then a set of tiles would be presented for 5,000 ms as the stimulus. During the stimulus presentation, participants were instructed to work out which tile(s) could complete the collection. Afterward, an additional tile was presented beneath the set of tiles for another 5,000 ms. Participants were required to decide if keeping the new tile or discarding one of the tiles in the set could increase the winning probability of the tile set. They were instructed to press the left button of a computer mouse with their index finger if switching to the new tile could increase the winning probability. Alternatively, pressing the right button if switching to the new tile does not increase the winning probability. The sequence of the test items was also randomised for each participant. If the participants generated a response of less than 5,000 ms, a blank screen was displayed for the remaining time to ensure uniform duration across all trials.

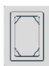
All stimuli and instructions were presented using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA, USA). Behavioural responses (i.e., accuracy and reaction time) were recorded by a desktop computer (Lenovo ThinkCentre M93p).

Figure 6.2 shows two example test items and the winning mechanisms of the no-switch and switch trials, experimental paradigms of the block design and the schematic presentation of one trial of the computerised mahjong switching game.

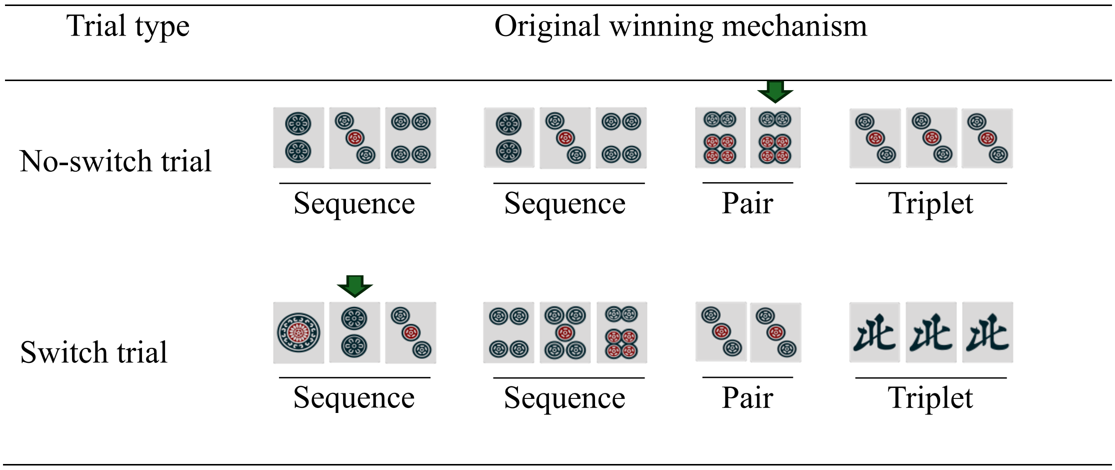
Figure 6.2

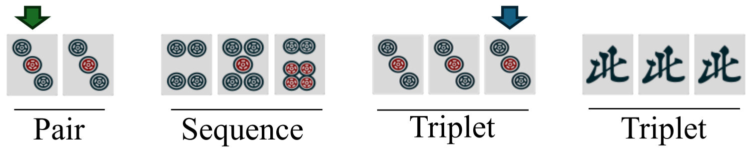
Example Items, Winning Mechanisms, Experimental Paradigm and Schematic Presentation of the Computerised Mahjong Switching Games

(a)

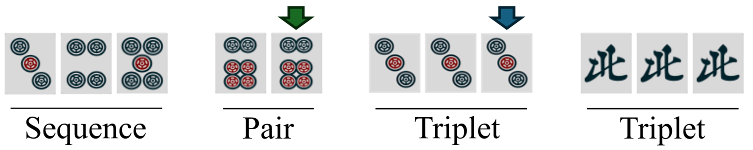
Trial type	Stimulus questions	Given tile	Winning options	
			Original	Switch to
No-switch				N/A
Switch				

(b)

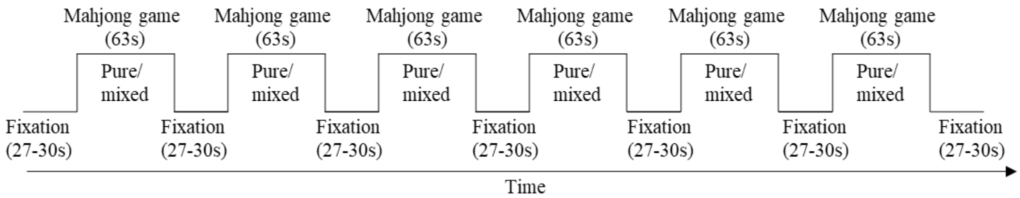

Trial type
Original winning mechanism
No-switch trial
Sequence
Sequence
Pair
Triplet
Switch trial
Sequence
Sequence
Pair
Triplet


Pair
Sequence
Triplet
Triplet

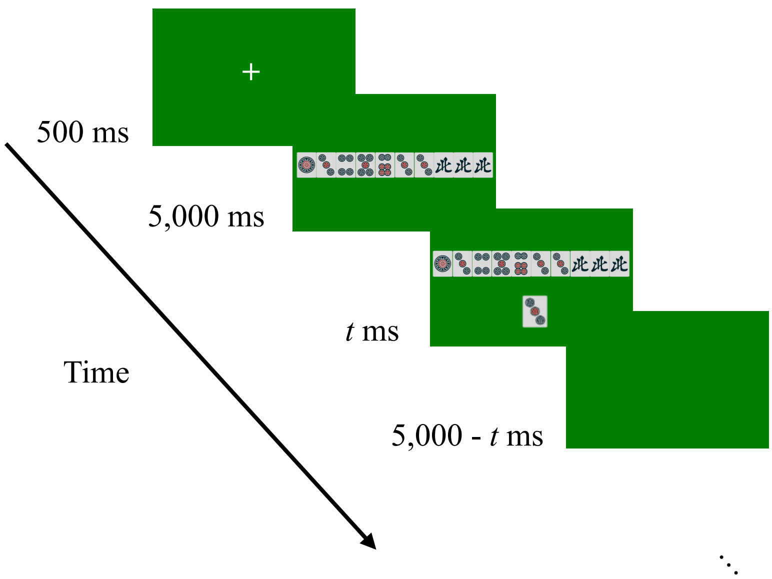
(ci)


Sequence
Pair
Triplet
Triplet

(cii)


Mahjong game (63s)
Pure/ mixed
Fixation (27-30s)
Time

(d)


+
500 ms
5,000 ms
t ms
Time
5,000 - t ms

(e)

Note. (a) shows the examples of a no-switch trial and a switch trial from the computerised mahjong switching game.[28] (b) illustrates the original winning mechanisms (i.e., the original winning option has been indicated by the green arrow) of the example no-switch and switch trials before switching. The example no-switch trial requires circle six to complete the tile set and switching to the new tile (i.e., the blank tile) does not increase the winning probability of the tile set. Alternatively, the example switch trial requires circle two to complete the tile set. Switching to keep the new tile (i.e., the circle nine) and discarding one of the tiles in the set (i.e., the circle one) could increase the winning probability. (c) illustrates the winning mechanism after switching (i.e., accepting the circle nine, as indicated by the blue arrow), with two winning options: (i) circle three and (ii) circle six (as indicated by the green arrows) to complete the tile set. (d) shows the experimental paradigm of the block designs and (e) illustrates the schematic presentations of one trial of the computerised mahjong switching game.

6.2.3.2 Computerised EF Tasks. Two computerised EF tasks, the *n*-back Task (Yeung et al., 2021b) and the Color-Shape Task (Vasta et al., 2017) were selected to assess the updating and switching of EF.

6.2.3.2.1 N-back Task. The *n*-back Task was adapted and revised based on Yeung et al. (2021b) to measure the updating component of EF. It included a working memory condition (i.e., 2-back) and a control condition (i.e., 0-back).

The task included four task blocks in total, in which each condition was presented twice and lasted for 47 s. The order of the conditions was also randomised.

[28] Note that a winning hand should consist of one pair and four sets of triplets or sequences, both the repeat and switch trials originally only have one option to complete the tile set and win the game.

Before and after each task block, a rest block with a fixation cross was shown to the participants and lasted for 27 s to 33 s. Participants were instructed to relax and focus on the fixation cross during the rest block. The *n*-back Task took around 6 min to complete.

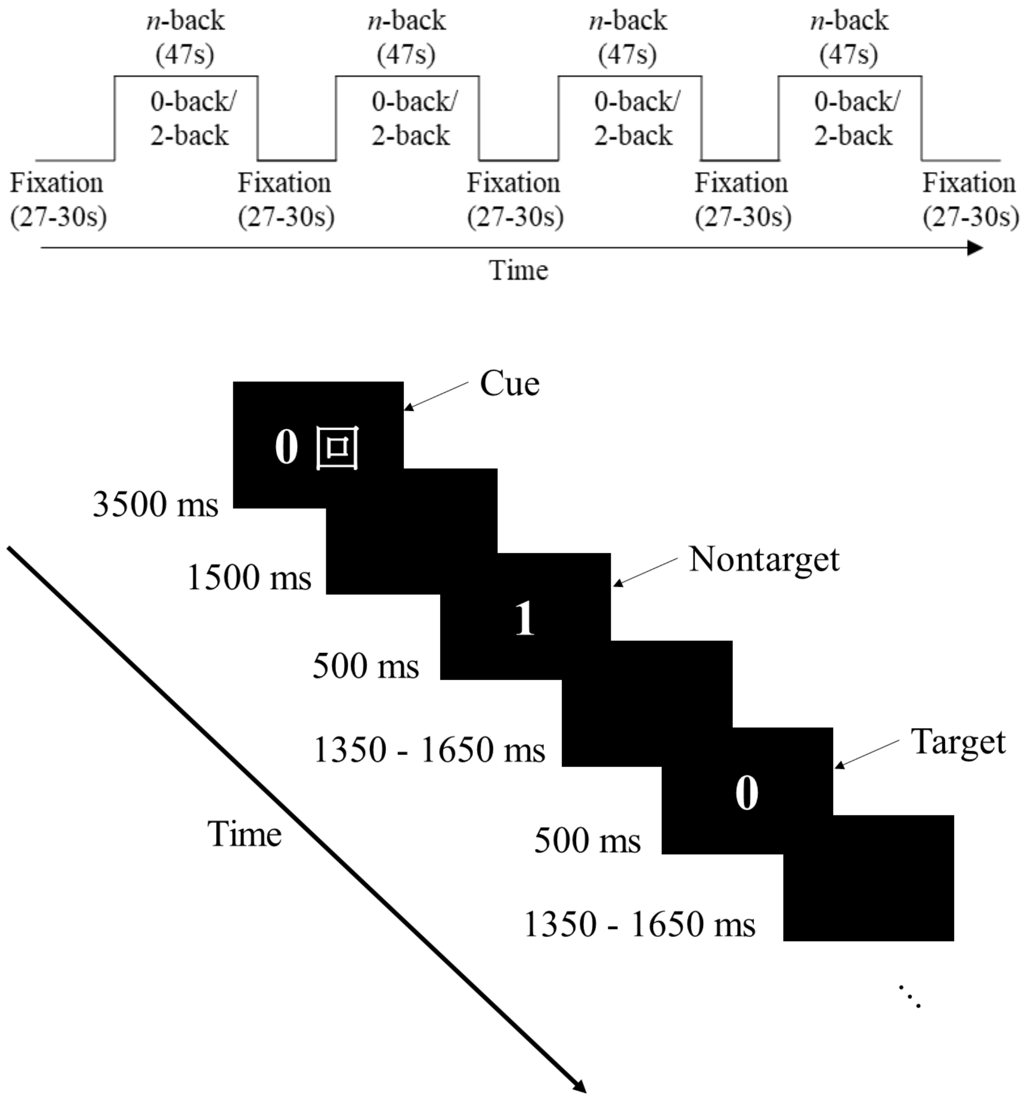
Each condition randomly presented 21 trials, including seven target trials and 14 nontarget trials. The target trials referred to the digit “0” in the 0-back task or the same digit that had been presented in two trials before in the 2-back task. The nontarget trials referred to the trials that need rejection. Each condition started with a 3,500 ms cue (i.e., 0-back /2-back) and a 1,500 ms blank screen. Twenty-one single-digit stimuli were then presented, in which one digit lasted for 500 ms and was separated by an interstimulus interval jittered from 1,350 ms to 1,650 ms. In the 0-back task, participants were required to press the left button of a mouse with the index finger when the digit “0” appeared. Otherwise, they were instructed to press the right button when other digits appeared. In the 2-back task, participants were asked to press the left button when the current digit was the same as the one presented in the two trials before. Or else, press the right button when they were not the same.

All stimuli and instructions were presented using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA, USA). Behavioural responses (i.e., accuracy and reaction time) were recorded by a desktop computer (Lenovo ThinkCentre M93p).

Figure 6.3 illustrates the experimental paradigms of the block design and the schematic presentation of the *n*-back Task.

Figure 6.3

Experimental Paradigm and Schematic Presentation of the N-back Task



(a)

(b)

Note. The (a) experimental paradigm of the block designs and the (b) schematic presentations of one nontarget and one target trial from the *n*-back Task.

6.2.3.2.2 Color-Shape Task. The Color-Shape Task was adapted and revised based on Vasta et al. (2017) that measured the global cost of switching. It comprised three conditions, namely pure blocks cued with colour, pure blocks cued with shape and mixed blocks cued with colour and shape in a pseudorandom order. The task included eight task blocks in total, including two pure blocks cued with colour, two pure blocks cued with shape and four mixed blocks. Each condition lasted for 49.5 s, and the order of the blocks was also randomised. Before and after each task block, a rest block with a fixation cross was shown to the participants and lasted for 27 s to 33 s. Participants were instructed to relax and focus on the fixation cross during the rest block. The Color-Shape Task took around 11 min to complete.

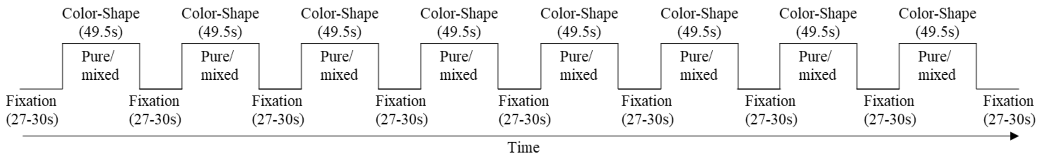
Each condition randomly presented 11 trials. In the pure block, either colour or shape was cued within the same condition. In the mixed block, it evenly presented two types of trials, including repeat and switch trials. A repeat trial referred to the two consecutive trials presented with a repeated cue (i.e., colour-colour/ shape-shape), while a switch trial referred to the two consecutive trials presented with an alternated cue (i.e., colour-shape/ shape-colour). Each trial started with a blank screen presented for 1,000 ms and followed by a cue (i.e., colour/shape) displayed for 1,000 ms. The stimulus was then presented for 1,000 ms. The interstimulus interval was 1,500 ms. In the trial cued with colour, participants were required to press the left button of a mouse with the index finger for a blue figure and the right button for a red figure. Similarly, in the trial cued with shape, participants were required to press the left button for a circle and the right button for a square.

All stimuli and instructions were presented using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA, USA). Behavioural responses (i.e., accuracy and reaction time) were recorded by a desktop computer (Lenovo ThinkCentre M93p).

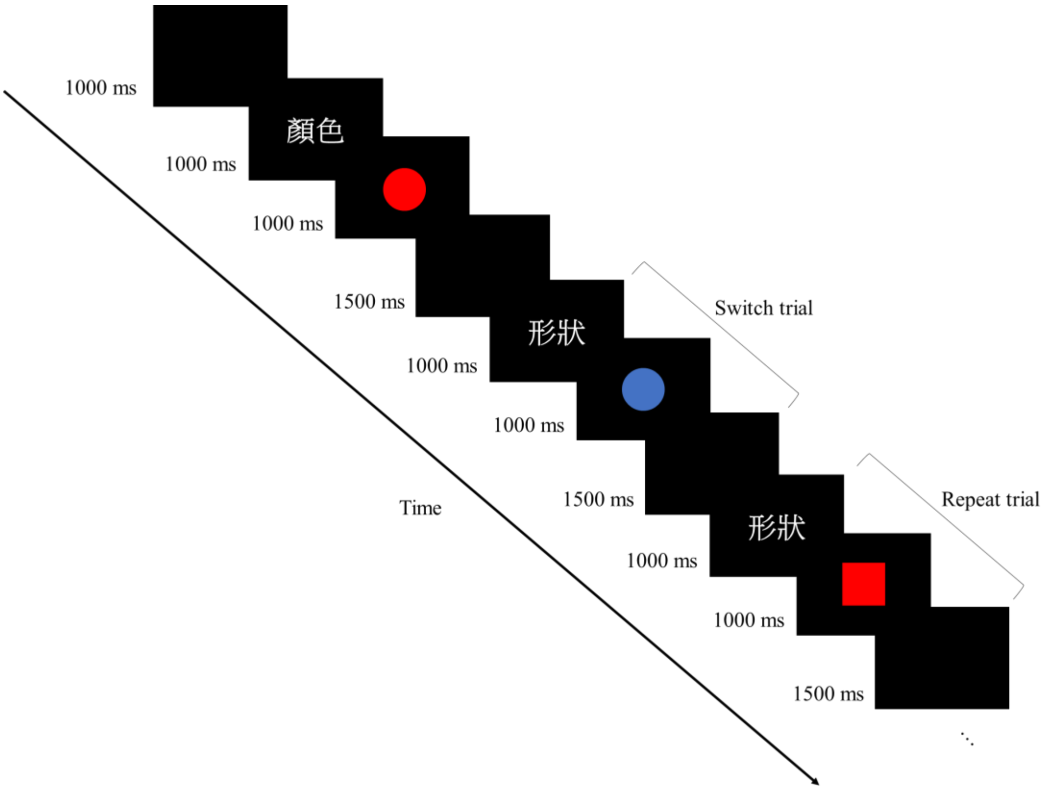
Figure 6.4 illustrates the experimental paradigms of the block design and the schematic presentation of the Color-Shape Task.

Figure 6.4

Experimental Paradigm and Schematic Presentation of the Color-Shape Task



(a)



(b)

Note. The (a) experimental paradigm of the block designs and the (b) schematic presentations of one switch and one repeat trial from the mixed block of the Color-Shape Task.

6.2.3.3 Neuropsychological Tests. Two common neuropsychological tests were chosen and administered to measure the updating and switching components of EF. The selected tests involved only digits, colours or numbers, which made it easier for use with older population with less educational background.

6.2.3.3.1 The Digit Span Test – Cantonese Version. It was administrated by verbally presenting a sequence of digits to the participants with one digit per second (Lee & Wang, 2010). Both forward and backward conditions were assessed, in which the forward condition was considered as a short-term memory recall task, while the backward condition was considered as an updating task (Wells et al., 2018). The participants were required to verbally repeat the sequence in the forward condition and verbally report the reverse order in the backward condition. The test was terminated after two attempts of failure in the sequence with equal digit length. The longest span was recorded as the DV. The test showed good internal consistency (Cronbach's $\alpha = 0.85$; Liu & Murao, 2025). Discriminant validity was established by successfully identifying major cognitive disorders (includes delirium, dementia and cognitive impairment not otherwise specified), as evidenced by a sensitivity of 0.77 and specificity of 0.78 using the optimal cutoff below 3 (J. L. M. Leung et al., 2011).

6.2.3.3.2 The Chinese version of the CTT. This test was administered by paper-and-pencil assessment forms. CTT-1 and CTT-2 were used to assess the attention and switching ability, respectively (Lee & Wang, 2010). In CTT-1, participants were instructed to connect the circles numbered 1 to 25 in ascending order. In CTT-2, in addition to the original instruction in CTT-1, participants were instructed to connect the circles with alternate colours. Completion times used in the CTT-1 and CTT-2 were measured. An interference index was calculated for the DV by subtracting the completion time in CTT-1 from CTT-2 and dividing the results by the completion time in CTT-1 (Wong et al., 2017). Both CTT-1 and CTT-2 showed good reliability (intra-class correlation [ICC] of CTT-1 = 0.77, ICC of CTT-2 = 0.90; Feeney et al., 2016). Convergent validity was supported by the significant positive correlation between the CTT and TMT (D'Elia et al., 2015).

6.2.3.4 fNIRS measurement. Prefrontal hemodynamic changes (i.e., relative changes of [oxy-Hb] and [deoxy-Hb]) were recorded using an 8-channel compact system (TechEN Inc., Milford, United States) during the computerised mahjong working memory game, *n*-back Task, computerised mahjong switching game, and Color-Shape Task. The prefrontal hemodynamic changes during neuropsychological tests were not measured, as fNIRS measurement is more compatible with the computerised tasks and the neuropsychological tests are assessed with verbal instructions and paper-and-pencil forms.

Near-infrared light of 690 and 830 nm with a sampling rate of 75 Hz were used for measurement. The amount of absorbed near-infrared light was calculated based on the modified Beer-Lambert Law (Huppert et al., 2009). fNIRS data was acquired and recorded on a Laptop (HP G7 15.6”) via a Wi-Fi connection. Automatic markers were generated from the stimulus presentation desktop to the fNIRS system during the block onsets. Previous literature suggested that the dlPFC was involved during the EF tasks (Nejati et al., 2018). Specifically, F3 and F4 from the international 10/20 system were selected as the region of interest (ROI) in this study, which corresponded to Brodmann areas (BA) 8, 9 and 46 (Herwig et al., 2003; Homan et al., 1987). The emitters and detectors were arranged in two 3 × 2 arrays, with the central detectors on each side localising and anchoring on F3 and F4 by the Beam F3 system (Beam et al., 2009). The distance between pairs of emitter and detector probes was 3 cm, which could measure a depth of 2.5 to 3 cm (Huppert et al., 2009; Okada et al., 1997). To provide additional spatial information, probe registration was performed using AltasViewer to estimate the Montreal Neurological Institute (MNI) coordinates for the channel locations (Yeung et al., 2021b). The MNI coordinates of each channel were then imported to the stand-alone spatial registration function in the Statistical Parametric Mapping for Near-infrared Spectroscopy (NIRS-SPM) to obtain the anatomical locations of channels (Yeung, 2022). Figure 6.5 visualises the probe placement of the fNIRS measurement, and Table 6.1 summarises the MNI coordinates and the anatomical labels of the channels.

To ensure the data quality before data acquisition, gain values were adjusted until the raw light intensity fell between the value of 3,000 to 25,000, as suggested by the manufacturer (i.e., TechEN). Participants were instructed to maintain a stationary posture for at least 10 s preceding the data recording. Recording only started when a clear pulsation was observed on the measurement channels.

Table 6.1

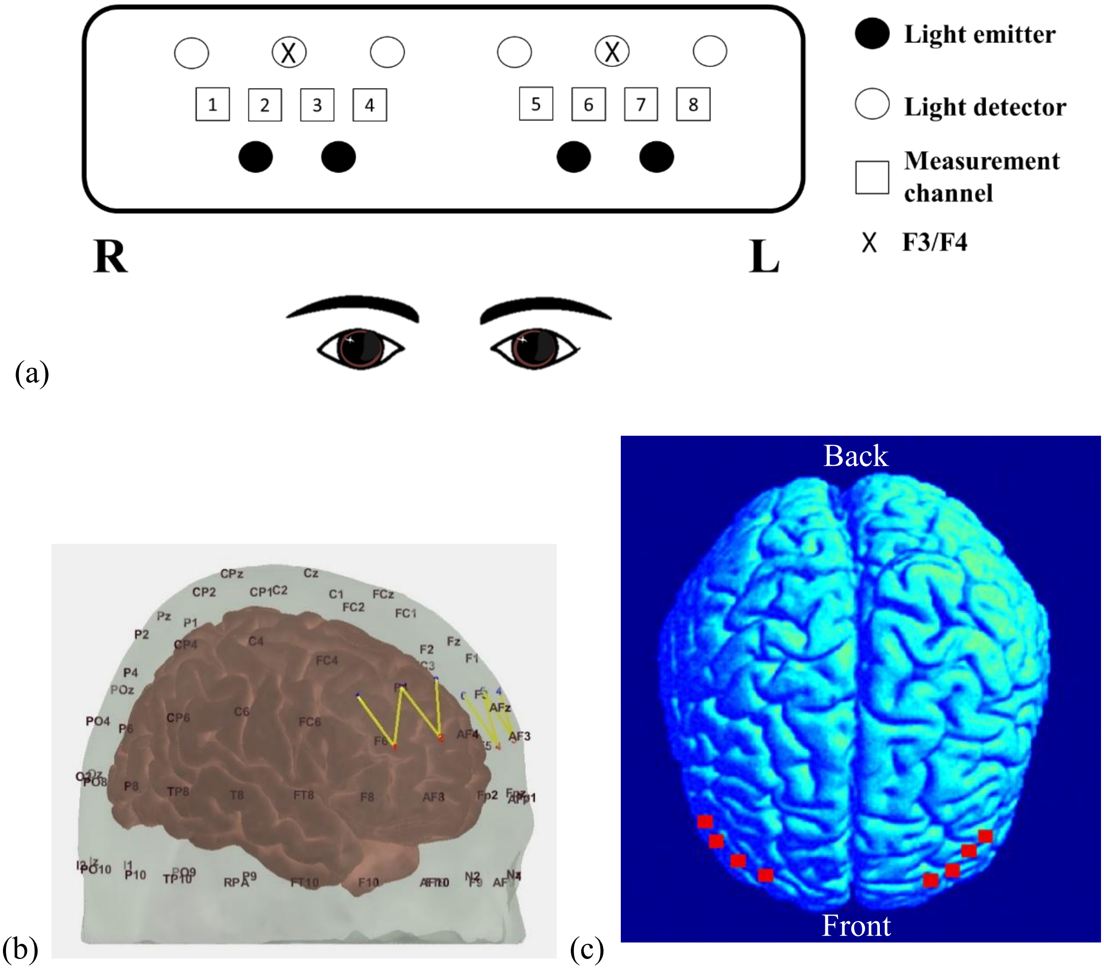
MNI coordinates, Anatomical Labels and Probabilistic Values for the Measurement Channels

	MNI coordinates (x, y, z)	Brodmann area (Talairach Daemon)	Probabilistic values
Channel 1	53, 35, 25	9-dlPFC	.018
		45-pars triangularis Broca's area	.036
		46-dlPFC	.945
Channel 2	52, 45, 28	9-dlPFC	.029
		10-Frontopolar area	.155
		46-dlPFC	.816
Channel 3	39, 49, 26	9-dlPFC	.208
		10-Frontopolar area	.624
		46-dlPFC	.168
Channel 4	31, 55, 27	9-dlPFC	.286
		10-Frontopolar area	.714
Channel 5	-27, 58, 27	9-dlPFC	.212
		10-Frontopolar area	.788
Channel 6	-31, 49, 23	9-dlPFC	.015
		10-Frontopolar area	.985
Channel 7	-39, 46, 24	9-dlPFC	.073
		10-Frontopolar area	.446
		46-dlPFC	.482
Channel 8	-45, 40, 25	9-dlPFC	.004
		10-Frontopolar area	.079
		46-dlPFC	.917

Note. MNI = Montreal Neurological Institute; dlPFC = dorsolateral prefrontal cortex.

Figure 6.5

Probe Arrangement, Placement and Spatial Registration



Note. Figures show (a) the probe placement (b) the probe registration in AltasViewer (c) the spatial registration in NIRS-SPM.

6.2.3.5 fNIRS Data Preprocessing. The HomER3 package, Quality Testing of Near Infrared Scans (QT-NIRS), and custom scripts on MATLAB R2022b (The MathWorks, Inc., Natick, MA) were used to preprocess fNIRS data.

Raw light intensity data were first converted to optical density (OD) changes. To remove the physiological noises and drifts, the low bandpass filter and high bandpass filter were set to 0.5 Hz and 0.005 Hz, respectively. The OD was then converted to the [oxy-Hb] and [deoxy-Hb] according to the modified Beer-Lambert Law (Huppert et al., 2009). Motion artefacts were corrected by a correlation-based signal improvement (CBSI) filter (Cui et al., 2010). Next, the hemodynamic response function (HRF) lasted from 5 s before block onset to 27 s after the task block was extracted. The task block duration for the mahjong working memory game, mahjong switching game, *n*-back Task, and Color-Shape Task were 63 s, 63 s, 47 s, and 49.5 s, respectively. HRF from each condition during each task were averaged for [oxy-Hb]. The 5 s cue period of the *n*-back Task was excluded from the calculation.

Since the changes of [oxy-Hb] and [deoxy-Hb] were mirror images of each other after CBSI correction, this study investigated [oxy-Hb] only (Yeung et al., 2021b). Preprocessed changes of [oxy-Hb] of each subject were then exported from HomER3 to MATLAB and SPSS for visualisation and statistical analysis.

Post-hoc evaluation of the data quality was conducted using the QT-NIRS function on MATLAB, which is also named Placing Headgear Optodes Efficiently Before Experimentation (PHOEBE) in the literature (Pollonini et al., 2016). To differentiate the excellent and unfit signals at a post-hoc stage, the Scalp Coupling Index (SCI), Power Matrix Threshold (PSP), Butterworth filter and window time were set to 0.7, 0.1, 0.8 Hz to 1.95 Hz, and 2 s, respectively (Elgendi, 2016; Hocke et al., 2018). Channels were excluded from the subsequent analyses if they reported a quality lower than 80% during the recording. Participants were also excluded from the statistical analyses if they showed less than four channels accepted by the PHOEBE.

6.2.4 Procedures

Eligible participants were invited individually to the laboratory at the Hong Kong Polytechnic University to take part in the study. The experiment took place in a quiet, dimly lit room. All participants were administered the computerised mahjong working memory game, computerised mahjong switching game, *n*-back Task, Color-

Shape Task, Digit Span Test and CTT. The order of the two computerised mahjong games was counterbalanced. Demographic variables and information related to mahjong playing were collected via a background questionnaire (see Appendix C) before data collection. The whole experiment lasted approximately 1.75 to 2 hr.

Before the start of each computerised task and neuropsychological test, all participants received sufficient rounds (i.e., no more than three times) of practice to familiarise themselves with the task instructions. The set of mahjong used in the game and a simple introduction to the mahjong game rules were also shown to the participants. The experimenter (Z.C.K.T) ensured the participants started the tasks without further questions.

6.2.5 Data Analysis

Statistical analyses were performed using SPSS (version 26) with a level of significance of 5%. The normality of the data was assessed using the criteria of skewness > 3 and kurtosis > 10. Univariate outliers with a z-score higher than 2.5 SD were screened out. Two-tailed *p* values were reported for *t*-tests. For bivariate outliers, it was defined by Cook's distance greater than 1 (Yeung et al., 2021a; Yeung et al., 2019, 2020).

6.2.5.1 Covariates. Years of experience in mahjong playing was chosen as a covariate in this study due to its theoretical relevance to the outcome measures. It was because longer years of experience in mahjong playing may have an impact on behavioural and neural performance. Since the year of education was highly related to the age difference in the Chinese context, and it was common for older Chinese adults to have a lower level of education compared with younger Chinese adults (Luo et al., 2015), therefore, years of education was not selected as the covariate.

The proposed covariate was included in the analyses related to the two mahjong games at the first stage to check its significance on the results. Only if the covariate was significant would it be included in the final analyses. The covariate has been mean-centred before conducting the analysis of covariance (ANCOVA). If a significant covariate was found, it was tested with and without outliers.

6.2.5.2 Outlier Treatment. Analyses were conducted, including and excluding outliers. If the results remained the same, the results with original statistics (viz., including outliers) were reported. Or else, if the results changed after removing the outliers, the results without outliers (viz., excluding outliers) were presented.

6.2.5.3 Behavioural Data. Analyses of behavioural data were separated into accuracy and reaction time. Only corrected trials were counted in the calculation of reaction time. Reaction time data below 150 ms or exceeding 2.5 *SD*s of the subjects' mean were excluded (Yeung & Han, 2023).

For the computerised mahjong working memory game, to examine the effect of the manipulation and the age differences, two 2 (working memory load: 1-tile-to-win, 3-tile-to-win) × 2 (age group: younger adults, older adults) mixed ANOVAs or mixed ANCOVAs were conducted on accuracy and reaction time.

For the computerised mahjong switching game, two 2 (global switching cost: pure block, mixed block) × 2 (age group: younger adults, older adults) mixed ANOVAs or mixed ANCOVAs were conducted on accuracy and reaction time.

For the *n*-back Task, two 2 (working memory load: 0-back, 2-back) × 2 (age group: younger adults, older adults) mixed ANOVAs were conducted on accuracy and reaction time.

For the Color-Shape Task, two 2 (global switching cost: pure block, mixed block) × 2 (age group: younger adults, older adults) mixed ANOVAs were conducted on accuracy and reaction time.

6.2.5.4 Neural Data. Mixed ANOVAs or mixed ANCOVAs were conducted to examine the effect of the manipulation and the age difference of [oxy-Hb] during the computerised mahjong games and the computerised EF tasks. Since there were eight channels, eight mixed ANOVAs or mixed ANCOVAs were conducted on each computerised task.

6.2.5.5 Associations of the Behavioural Performances between Computerised Mahjong Games and EF Tests. Correlational analyses were performed to explore the relationships between (i) the working memory game and the two updating measures (i.e., *n*-back Task and Backward Digit Span Test) and (ii) the switching game and the two switching measures (i.e., Color-Shape Task and CTT).

6.2.5.5.1 Updating Measures. The difference scores between the two conditions for the working memory game and *n*-back Task were first computed, in which the accuracy and reaction time recorded in the low working memory load condition were subtracted from those recorded in the high working memory load condition.[29] The composite difference scores represented the working memory load measured in the working memory game and the *n*-back Task, with a larger difference representing poorer behavioural performance.

Twelve Pearson's correlation analyses were then performed separately for younger and older adults to explore the relationships of the behavioural outcomes (i.e., accuracy, reaction time and span length) between the working memory game, *n*-back Task, and Backward Digit Span Test.

6.2.5.5.2 Switching Measures. The difference scores between the two conditions

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[29] For the working memory game, accuracies and reaction times in the 1-tile-to-win condition were subtracted from the 3-tile-to-win condition. For the *n*-back Task, accuracies and reaction times in the 0-back task were subtracted from the 2-back task.

for the switching game and Color-Shape Task were first computed, in which the accuracy and reaction time recorded in the pure block were subtracted from those recorded in the mixed block. The composite difference scores represented the global costs of switching measured in the switching game and the Color-Shape Task, with a larger difference representing poorer behavioural performance.

Twelve Pearson's correlation analyses were then performed separately for younger and older adults to explore the relationships of the behavioural outcomes (i.e., accuracy, reaction time and completion time) between the switching game, Color-Shape Task, and interference index of CTT.

6.2.5.6 Associations between Neural Activations of Computerised Mahjong Games and Behavioural Performances of EF Tests. Correlational analyses were performed to explore the relationships between (i) activations of the working memory game and behavioural performances of the two updating measures (i.e., *n*-back Task and Backward Digit Span Test) and (ii) activations of the switching game and behavioural performances of the two switching measures (i.e., Color-Shape Task and CTT). For an exploratory purpose, the changes of [oxy-Hb] were averaged across the four channels on the right dlPFC and the four channels on the left dlPFC in each task.

6.2.5.6.1 Activations of Working Memory Game and Updating Measures. The changes of [oxy-Hb] measured during the working memory game in 1-tile-to-win and 3-tile-to-win conditions were first averaged across the four channels on the right dlPFC (i.e., channels 1 to 4) and the four channels on the left dlPFC (i.e., channels 5 to 8). Then, difference scores were calculated separately for the right and left dlPFC by subtracting the averaged [oxy-Hb] in 1-tile-to-win condition from 3-tile-to-win condition. A larger difference represented an increased activation with a greater working memory load, indicating neural inefficiency.

Twelve Pearson's correlations were conducted separately for (i) younger and older adults and (ii) for the averaged [oxy-Hb] in the right and left dlPFC. It aimed at exploring the relationships between (i) activations of the working memory game and behavioural accuracy of the *n*-back Task, (ii) activations of the working memory game and behavioural reaction time of the *n*-back Task, and (iii) activations of the working memory game and the span length of Backward Digit Span Test.

6.2.5.6.2 Activations of Switching Game and Switching Measures. The changes of [oxy-Hb] measured during the switching game in pure and mixed blocks were first averaged across the four channels on the right dlPFC (i.e., channels 1 to 4) and the four channels on the left dlPFC (i.e., channels 5 to 8). Then, difference scores were calculated separately for the right and left dlPFC by subtracting the averaged [oxy-Hb] in the pure block from the mixed block. A larger difference represented an increased neural activation with a greater global cost of switching, indicating neural inefficiency.

Twelve Pearson's correlations were conducted separately for (i) younger and older adults and (ii) for the averaged [oxy-Hb] in the right and left dlPFC. It aimed at exploring the relationships between (i) activations of the switching game and behavioural accuracy of the Color-Shape Task, (ii) activations of the switching game and behavioural reaction time of the Color-Shape Task, and (iii) activations of the switching game and the interference index of CTT.

6.3 Results

6.3.1 Demographics Characteristics and Cognitive Profile of the Younger and Older Adults

Table 6.2 summarises the demographic characteristics, mahjong-related variables, psychological variables and EF scores as measured by the neuropsychological tests of the younger and older adults.

The two groups did not significantly differ in gender ratio, HK-MoCA scores, number of times of mahjong playing per year, duration of mahjong playing each time, DASS-21 anxiety and stress scores, and handedness as calculated as a Laterality Quotient, all $ps > .05$. Compared with younger adults, older adults were significantly older, had fewer years of education, reported less frequency but more experience in mahjong playing, and had lower DASS-21 depression scores, all $ps < .05$.

Independent sample *t*-tests were conducted to evaluate group differences in the EF component scores as measured by neuropsychological tests. All older adults showed significantly poorer performance than younger adults on the Forward Digit Span Test, Backward Digit Span Test, CTT-1, and CTT-2 (see Table 6.2).

Table 6.2

Demographics, Mahjong-Related Variables, Psychological Variables and EF Scores (Updating and Switching) as Measured by Neuropsychological Tests

	Younger (n = 36)	Older (n = 36)		
	M (*SD*)/ Frequency	*M* (*SD*)/ Frequency	*t*-value/ χ^2	*p*-value
(A) Demographics and other variables				
Age	21.19 (2)	68.08 (3.61)	-68.15	< .001
Gender	M = 14, F = 22	M = 16, F = 20	0.23	.811
Years of Education	15 (1.82)	11.75 (3.43)	5.03	< .001
HK-MoCA	27.58 (1.73)	27.14 (2.36)	.91	.365
Mahjong (times per year)	9.11 (10.68)	6.33 (9.98)	1.14	.258
Mahjong (frequency)	Never = 0 Yearly = 27 Monthly = 9	Never = 12 Yearly = 16 Monthly = 8	14.87	< .001
Mahjong (duration each time: hour)	2.93 (2.18)	2.42 (2.48)	.93	.354
Mahjong (years of experience)	4.83 (2.71)	32.53 (19.47)	-8.45	< .001
DASS-21 (Depression)	4.83 (4.86)	2.5 (3.56)	2.32	.023
DASS-21 (Anxiety)	5 (3.59)	3.56 (2.83)	1.89	.062
DASS-21 (Stress)	6.28 (5.96)	5.39 (4.92)	.69	.492
DASS-21 (Total)	16.11 (12.17)	11.44 (9.64)	1.80	.076
Handedness[#]	88.24 (46.47)	95.94 (17.38)	-.93	.354
(B) Neuropsychological assessment				
Forward Digit Span	9.17 (1.03)	8.36 (1.36)	2.84	.006
Backward Digit Span	6.22 (1.51)	5.33 (2.04)	2.10	.040
CTT – 1 (s)	29.61 (6.50)	50.53 (20.74)	-5.77	< .001
CTT – 2 (s)	61.50 (16.35)	97.33 (32.31)	-5.94	< .001

Note. HK-MoCA = Hong Kong Montreal Cognitive Assessment; DASS-21 = Depression Anxiety and Stress Scale-21; CTT = Color Trails Test.

represented the distribution was not normal, as indicated by skewness and kurtosis.

6.3.2 Behavioural Data

6.3.2.1 Computerised Mahjong Games.

6.3.2.1.1 Computerised Mahjong Working Memory Game. Table 6.3 summarises the performances of the younger and older groups on the computerised mahjong working memory game.

Table 6.3

Descriptive Statistics of the Behavioural Measures of the Computerised Mahjong Working Memory Game for Two Groups of Participants

	Younger (*n* = 36) ***M* (*SD*)**	**Older (*n* = 36)** ***M* (*SD*)**
one-tile-to-win accuracy (% correct)	95.7 (5.06)	90.5 (8.74)
one-tile-to-win reaction time (ms)	920.80 (321.25)	1,090.35 (199.27)
three-tile-to-win accuracy (% correct)	83.4 (13.37)	82.8 (15.09)
three-tile-to-win reaction time (ms)	1,334.16 (451.85)	1,403.95 (359.55)

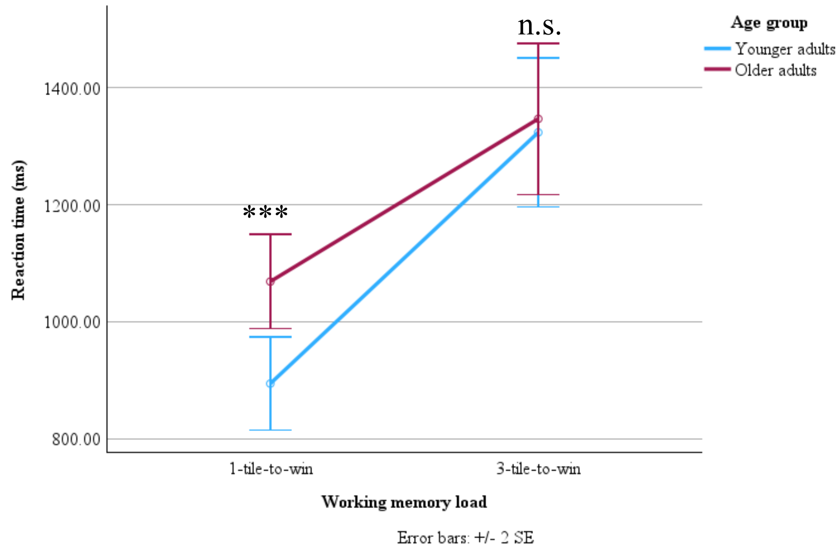
Years of mahjong playing was not a significant covariate for the two mixed ANOVAs. Therefore, two 2 (working memory load: 1-tile-to-win, 3-tile-to-win) × 2 (age group: younger, older) mixed ANOVAs, rather than mixed ANCOVAs, were conducted with accuracy and reaction time as DVs.

In terms of accuracy, there was a significant main effect for working memory load, $F(1, 70) = 45.22$, $p < .001$, $\eta_p^2 = .39$ (i.e., large effect size), indicating that accuracy in the 3-tile-to-win condition ($M = 83.08\%$, $SD = 14.16\%$) was significantly poorer than the 1-tile-to-win condition ($M = 93.11\%$, $SD = 7.57\%$). No significant main effect for age groups, $F(1, 70) = 1.83$, $p = .181$, $\eta_p^2 = .03$ (i.e., small effect size) and no significant interaction effect were found, $F(1, 70) = 2.39$, $p = .127$, $\eta_p^2 = .03$ (i.e., small effect size).

In terms of reaction time, the two-way interaction effect became significant after three univariate outliers were removed (i.e., one younger adult and two older adults). As mentioned previously, statistics without outliers were reported given this situation. The two main effects on the working memory load and age difference remained the same upon the removal of outliers. There was a significant main effect for working memory load, $F(1, 67) = 122.56$, $p < .001$, $\eta_p^2 = .65$ (i.e., large effect size), indicating that the reaction time in 3-tile-to-win condition ($M = 1{,}334.45$ ms, $SD = 373.43$ ms) was significantly longer than the 1-tile-to-win condition (*M* = 979.76 ms, *SD* = 249.7 ms). No significant main effect for age group was found, $F(1, 67) = 2.08$, $p = .154$, $\eta_p^2 = .03$ (i.e., small effect size). The two-way interaction effect was significant, $F(1, 67) = 5.60$, $p = .021$, $\eta_p^2 = .08$ (i.e., moderate effect size). Simple main effect analysis (independent sample *t*-tests with Bonferroni correction) was conducted to understand the source of the interaction. Significant age difference was found only in the 1-tile-to-win, $t(57.26) = -3.08$, $p = .003$, $d = -.74$ (i.e., moderate effect size), with older adults (*M* = 1,068.21 ms, *SD* = 175.79 ms) spending a longer reaction time than younger adults (*M* = 893.83 ms, *SD* = 281.57 ms). No significant age difference was found in the 3-tile-to-win condition, $t(56.23) = -.26$, $p = .798$, $d = -.06$ (i.e., negligible effect size). Figure 6.6 illustrates this interaction effect.

Figure 6.6

The Interaction Effect Between Age Group and Working Memory Load for the Computerised Mahjong Working Memory Game, with Reaction Time as DV



*** $p < .001$. n.s. $p > .05$.

6.3.2.1.2 Computerised Mahjong Switching Game. Table 6.4 summarises the performances of the two groups of participants on the computerised mahjong switching game.

Table 6.4

Descriptive Statistics of the Behavioural Measures of the Computerised Mahjong Switching Game for Two Groups of Participants

	Younger (*n* = 36) **M (SD)**	**Older (*n* = 36)** **M (SD)**
Pure block accuracy (% correct)	96.9 (4.21)	97.8 (4.67)
Pure block reaction time (ms)	1,026.46 (450.61)	1,026.56 (236.36)
Mixed block accuracy (% correct)	82.4 (11.53)	81 (15.96)
Mixed block reaction time (ms)	1,626.68 (465.14)	1,547.28 (426.74)

Years of mahjong playing was not a significant covariate for the two mixed ANOVAs. Therefore, two 2 (global switching cost: pure block, mixed block) × 2 (age group: younger, older) mixed ANOVAs, rather than mixed ANCOVAs, were conducted with accuracy and reaction time as DVs.

In terms of accuracy, there was a significant main effect for global switching cost, $F(1, 70) = 99.80$, $p < .001$, $\eta_p^2 = .59$ (i.e., large effect size), indicating that the accuracy in the mixed block ($M = 81.68\%$, $SD = 13.84\%$) was significantly poorer than that in the pure block ($M = 97.35\%$, $SD = 4.44\%$). No significant main effect was found for the age group, $F(1, 70) = .02$, $p = .882$, $\eta_p^2 = .00$ (i.e., negligible effect size), and no significant interaction effect was found, $F(1, 70) = .53$, $p = .470$, $\eta_p^2 = .01$ (i.e., small effect size).

In terms of reaction time, there was a significant main effect for global switching cost, $F(1, 70) = 209.85$, $p < .001$, $\eta_p^2 = .75$ (i.e., large effect size), indicating that the reaction time in the mixed block ($M = 1{,}586.98$ ms, $SD = 444.99$ ms) significantly longer than that in the pure block ($M = 1{,}026.51$ ms, $SD = 357.26$ ms). No significant main effect for age groups, $F(1, 70) = .21$, $p = .651$, $\eta_p^2 = .00$ (i.e., negligible effect size) and no significant interaction effect was reported, $F(1, 70) = 1.06$, $p = .308$, $\eta_p^2 = .01$ (i.e., small effect size).

6.3.2.2 Computerised EF Tasks.

6.3.2.2.1 N-back Task. Table 6.5 summarises the performances of young and older adults on the *n*-back Task.

Table 6.5

Descriptive Statistics of the Behavioural Measures of the N-back Task for Two Groups of Participants

	Younger (*n* = 36) *M* (*SD*)	**Older (*n* = 36)** *M* (*SD*)
zero-back accuracy (% correct) #	97.9 (2.72)	97.8 (6.25)
zero-back reaction time (ms)	385.48 (56.43)	486.97 (72.92)
two-back accuracy (% correct)	90.5 (5.07)	81.9 (13.25)
two-back reaction time (ms)	570.03 (146.20)	710.09 (139.81)

represented the distribution was not normally indicated by skewness and kurtosis.

Two 2 (working memory load: 0-back, 2-back) × 2 (age group: younger, older) mixed ANOVAs were conducted with accuracy and reaction time as DVs.

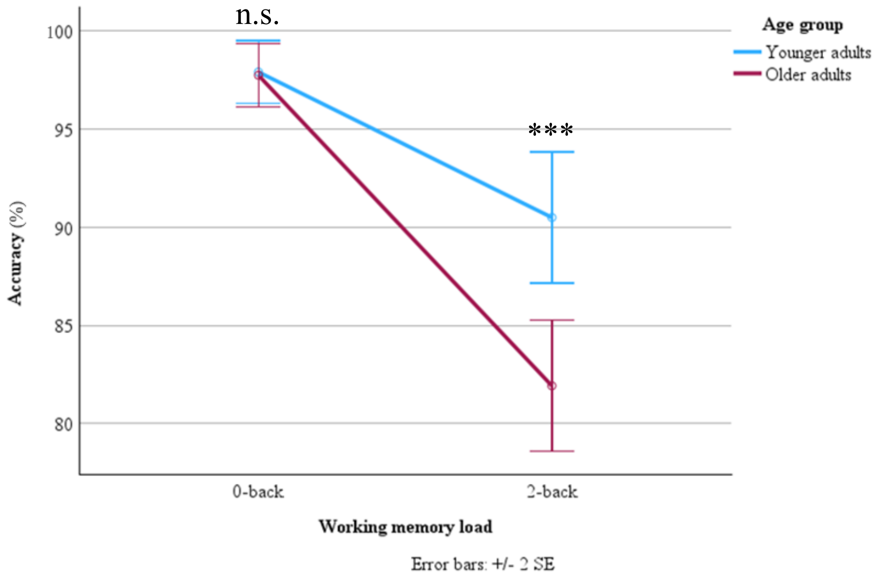
In terms of accuracy, there was a significant main effect for the working memory load, $F(1, 70) = 77.54$, $p < .001$, $\eta_p^2 = .53$ (i.e., large effect size), indicating that the accuracy in the 2-back condition (M = 86.21%, SD = 10.86%) was significantly poorer than that in the 0-back condition (M = 97.83%, SD = 4.79%). There was a significant main effect for the age group, $F(1, 70) = 11.27$, $p = .001$, $\eta_p^2 = .14$ (i.e., large effect size), indicating that the older adults (M = 89.83%, pooled SD = 10.36%) had a significantly poorer accuracy than younger adults (M = 94.21%, pooled SD = 4.07%). The interaction effect was also significant, $F(1, 70) = 10.16$, $p = .002$, η_p^2

= .13 (i.e., moderate effect size). Simple main effect analysis (independent sample *t*-tests with Bonferroni correction) was conducted to understand the source of the interaction. Age difference was found for the 2-back condition, $t(45.05) = 3.63$, $p < .001$, $d = .86$ (i.e., large effect size), with older adults ($M = 81.92\%$, $SD = 13.25\%$) performed less accurately than younger adults ($M = 90.5\%$, $SD = 5.07\%$). No significant age difference was found for the 0-back condition, $t(70) = .15$, $p = .884$, $d = .04$ (i.e., negligible effect size). Figure 6.7 illustrates the interaction effect.

In terms of reaction time, there was a significant main effect for the working memory load, $F(1, 70) = 199.40$, $p < .001$, $\eta_p^2 = .74$ (i.e., large effect size), indicating that the reaction time in the 2-back condition ($M = 640.06$ ms, $SD = 158.57$ ms) was significantly longer than that in the 0-back condition ($M = 436.23$ ms, $SD = 82.48$ ms). There was also a significant main effect for age, $F(1, 70) = 30.51$, $p < .001$, $\eta_p^2 = .30$ (i.e., large effect size), indicating that the older adults ($M = 598.53$ ms, $SD = 111.5$ ms) had a significantly longer reaction time than younger adults ($M = 477.76$ ms, $SD = 110.81$ ms). No significant interaction effect was reported, $F(1, 70) = 1.79$, $p = .186$, $\eta_p^2 = .03$ (i.e., small effect size).

Figure 6.7

The Interaction Effect between Age Group and Working Memory Load for the N-Back Task, with Accuracy as DV



*** $p < .001$. n.s. $p > .05$.

6.3.2.2.2 Color-Shape Task. Table 6.6 presents the descriptive statistics of the Color-Shape Task.

Table 6.6

Descriptive Statistics of the Behavioural Measures of the Color-Shape Task

	Younger (*n* = 36) ***M* (*SD*)**	**Older (*n* = 36)** ***M* (*SD*)**
Pure block accuracy (% correct) #	96.6 (8.51)	95 (4.75)
Pure block reaction time (ms)	490.94 (116.39)	616.82 (145.57)
Mixed block accuracy (% correct)	93.9 (9.17)	92.8 (7.43)
Mixed block reaction time (ms)	583.56 (187.44)	725.37 (185.12)

represented the distribution was not normally indicated by skewness and kurtosis.

Two 2 (global switching cost: pure block, mixed block) × 2 (age group: younger, older) mixed ANOVAs were conducted, with accuracy and reaction time as DVs.

In terms of accuracy, the main effect for the age group became significant after four univariate outliers were removed (i.e., two younger adults and two older adults). As mentioned previously, statistics without outliers were reported given this situation. The main effect for global switching cost and the two-way interaction remained the same upon the removal of outliers. There was a significant main effect for global switching cost, $F(1, 66) = 8.48$, $p = .005$, $\eta_p^2 = .11$ (i.e., moderate effect size), indicating that the accuracy in the mixed block ($M = 94.85\%$, $SD = 5.51\%$) was significantly poorer than that in the pure block ($M = 96.81\%$, $SD = 3.99\%$). There was a significant main effect for the age group, $F(1, 66) = 8.16$, $p = .006$, $\eta_p^2 = .11$ (i.e., moderate effect size), indicating that the older adults ($M = 94.54\%$, $SD = 5.32\%$) had a significantly lower accuracy than younger adults ($M = 97.13\%$, $SD = 3.86\%$). No significant interaction effect was reported, $F(1, 66) = 1.40$, $p = .241$, $\eta_p^2 = .02$ (i.e., negligible effect size).

In terms of reaction time, there was a significant main effect for global switching cost, $F(1, 70) = 84.30$, $p < .001$, $\eta_p^2 = .55$ (i.e., large effect size), indicating that the reaction time in the mixed block ($M = 654.47$ ms, $SD = 198.27$ ms) was significantly longer than that in the pure block ($M = 553.88$ ms, $SD = 145.4$ ms). There was a significant main effect for age, $F(1, 70) = 13.51$, $p < .001$, $\eta_p^2 = .16$ (i.e., large effect size), indicating that the older adults ($M = 671.10$ ms, $SD = 166.53$ ms) had a significantly longer reaction time than that of the younger adults ($M = 537.25$ ms, $SD = 156.02$ ms). No significant interaction effect was found, $F(1, 70) = .53$, $p = .470$, $\eta_p^2 = .01$ (i.e., small effect size).

6.3.3 Neural Data

6.3.3.1 Computerised Mahjong Games.

6.3.3.1.1 Computerised Mahjong Working Memory Game. Figure 6.8 presents the time courses of the [oxy-Hb] changes during the computerised mahjong working memory game. Years of mahjong playing was not a significant covariate across the eight mixed ANOVAs. Therefore, eight 2 (working memory load: 1-tile-to-win, 3-tile-to-win) × 2 (age group: younger, older) mixed ANOVAs, rather than mixed ANCOVAs, were conducted with [oxy-Hb] as DV for the eight fNIRS channels. Table 6.7 summarises the statistics from the mixed ANOVAs on the eight channels after removing outliers.

After removing univariate outliers,[30] all channels displayed a significant main effect for working memory load, whereby a significant increase of [oxy-Hb] was found for the higher load condition, *p*s $< .05$ (see Table 6.7). Four channels showed a significant main effect for the age group, whereby older adults showed significantly higher activations than younger adults, *p*s $< .05$ (see Table 6.7). No significant interaction effect was found, *p*s $> .05$ (see Table 6.7).

[30] The following number of univariate outliers were removed: Ch 1 ($n = 3$; one younger adult and two older adults), Ch 2 ($n = 5$; two younger adults and three older adults), Ch 3 ($n = 3$; one younger adult and two older adults), Ch 4 ($n = 3$; one younger adult and two older adults), Ch 5 ($n = 4$; one younger adult and three older adults), Ch 6 ($n = 2$; one younger adult and one older adult), Ch 7 ($n = 3$; three older adults), and Ch 8 ($n = 4$; one younger adult and three older adults).

Figure 6.8

Time Courses of [oxy-Hb] Changes in the Eight Channels during the Computerised Mahjong Working Memory Game

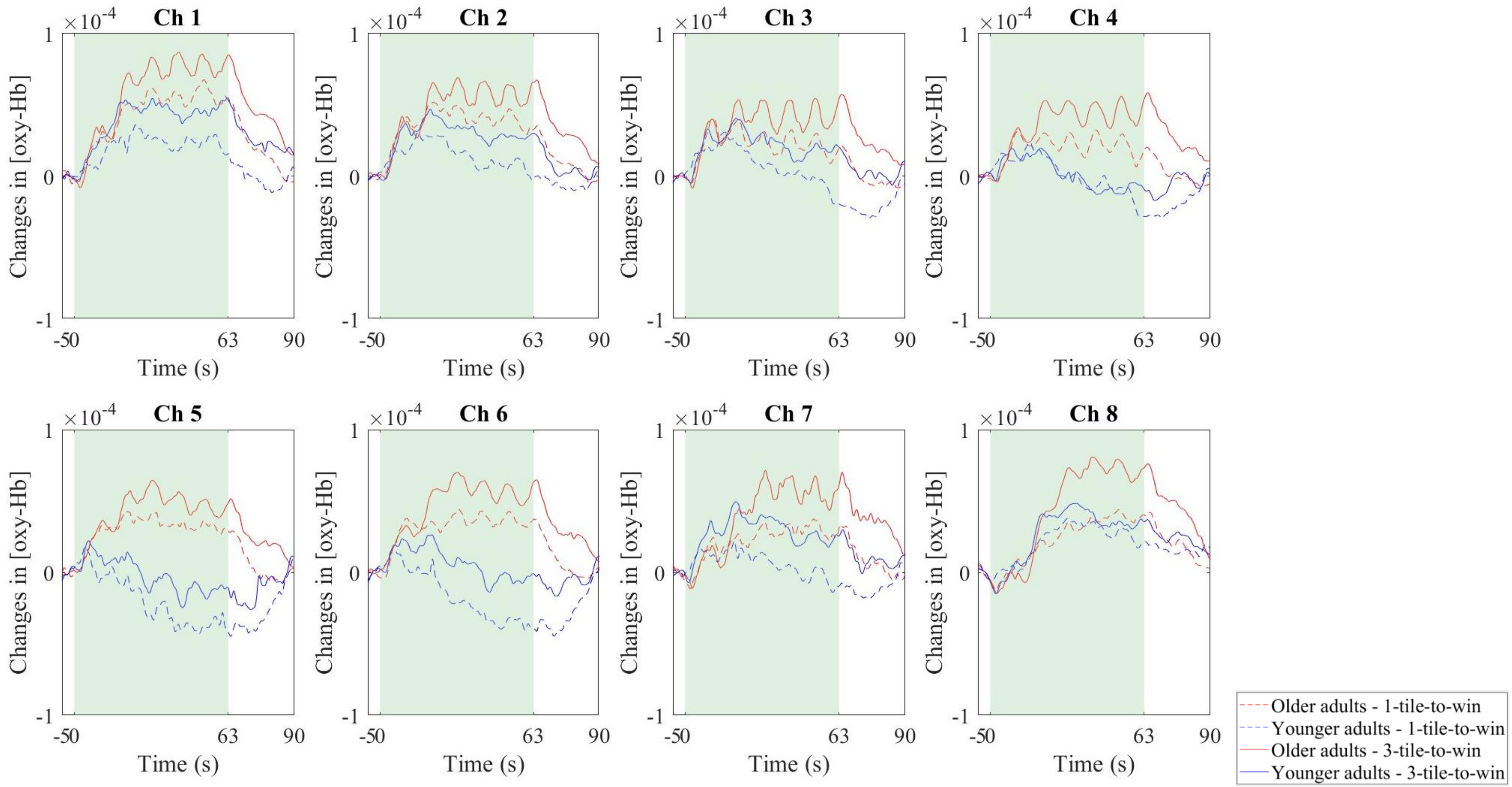


Table 6.7

Results for Mixed ANOVAs of the Computerised Mahjong Working Memory Game After Removing Outliers

	Main effect for working memory load				Main effect for age				Interaction effect			
	df	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2
Ch 1	1, 50	7.67**	.008	.13	1, 50	1.73	.194	.03	1, 50	0.39	.537	.01
Ch 2	1, 57	7.24**	.009	.11	1, 57	6.71*	.012	.11	1, 57	0.07	.795	.00
Ch 3	1, 56	8.82**	.004	.14	1, 56	1.02	.316	.02	1, 56	0.15	.697	.00
Ch 4	1, 52	4.80*	.033	.08	1, 52	5.01*	.029	.09	1, 52	1.28	.262	.02
Ch 5	1, 53	5.14*	.027	.09	1, 53	10.67**	.002	.17	1, 53	0.37	.546	.01
Ch 6	1, 61	6.46*	.014	.10	1, 61	10.29**	.002	.14	1, 61	1.87	.177	.03
Ch 7	1, 61	9.35**	.003	.13	1, 61	0.68	.414	.01	1, 61	0.75	.390	.01
Ch 8	1, 57	7.37**	.009	.11	1, 57	0.09	.770	.00	1, 57	1.19	.279	.02

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

6.3.3.1.2 Computerised Mahjong Switching Game. Figure 6.9 presents the time courses of the [oxy-Hb] changes during the computerised mahjong switching game. Years of mahjong playing was not a significant covariate across the eight mixed ANOVAs, so ANCOVAs were not conducted. Eight 2 (global switching cost: pure block, mixed block) × 2 (age group: younger, older) mixed ANOVAs were conducted for the eight fNIRS channels with [oxy-Hb] as DV. Table 6.8 summarises the statistics from the mixed ANOVAs on the eight channels after removing outliers.

After removing outliers,[31] all channels reported no significant main effect for global switching cost, *p*s > .05 (see Table 6.8). Five channels reported a significant main effect for age group, whereby older adults showed a significant increase in [oxy-Hb] than younger adults, *p*s < .05 (see Table 6.8). A significant 2-way interaction was found for Ch 5, $F(1, 55) = 4.08$, $p = .048$, $\eta_p^2 = .07$ (i.e., moderate effect size). A simple main effect analysis (independent sample *t*-tests with Bonferroni correction) was conducted to understand the source of the interaction. Significant age difference was found only in the mixed block condition, $t(55) = -2.73$, $p = .008$, $d = -.72$ (i.e., moderate effect size), with older adults showing a greater increase of [oxy-Hb] than younger adults. No significant age difference was found in the pure block, $t(43.53) = -1.24$, $p = .222$, $d = -.33$ (i.e., small effect size). Figure 6.10 illustrates the interaction effect.

[31] The following number of univariate outliers were removed: Ch 1 (*n* = 2; one younger adult and one older adult), Ch 2 (*n* = 2; one younger adult and one older adult), Ch 4 (*n* = 2; one younger adult and one older adult), Ch 5 (*n* = 2; one younger adult and one older adult), Ch 6 (*n* = 3; one younger adult and two older adults), Ch 7 (*n* = 5; two younger adults and three older adults), and Ch 8 (*n* = 3; one younger adult and two older adults). No univariate outliers were identified on Ch 3.

Figure 6.9

Time Courses of [oxy-Hb] Changes in the Eight Channels during the Computerised Mahjong Switching Game

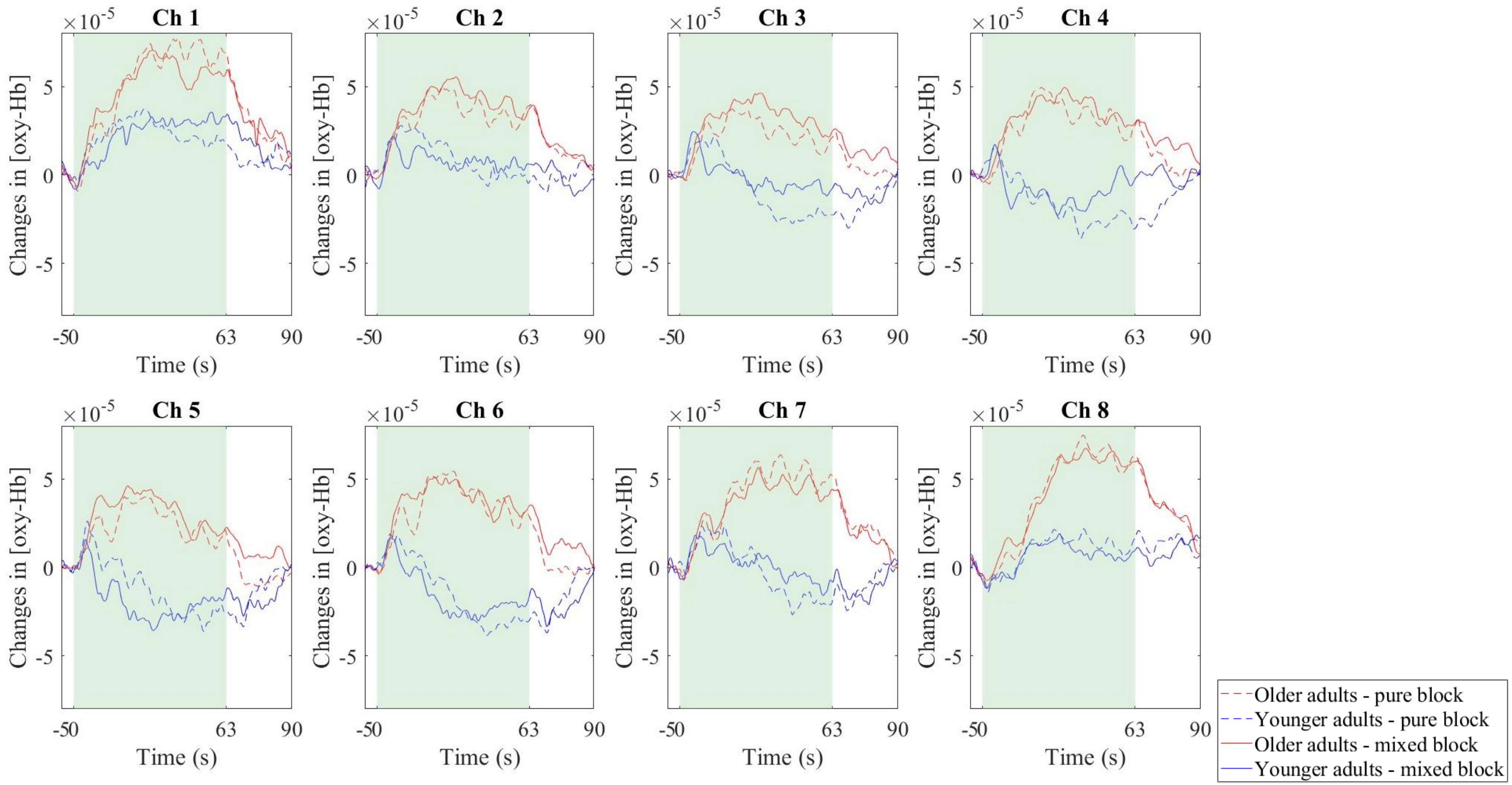


Table 6.8

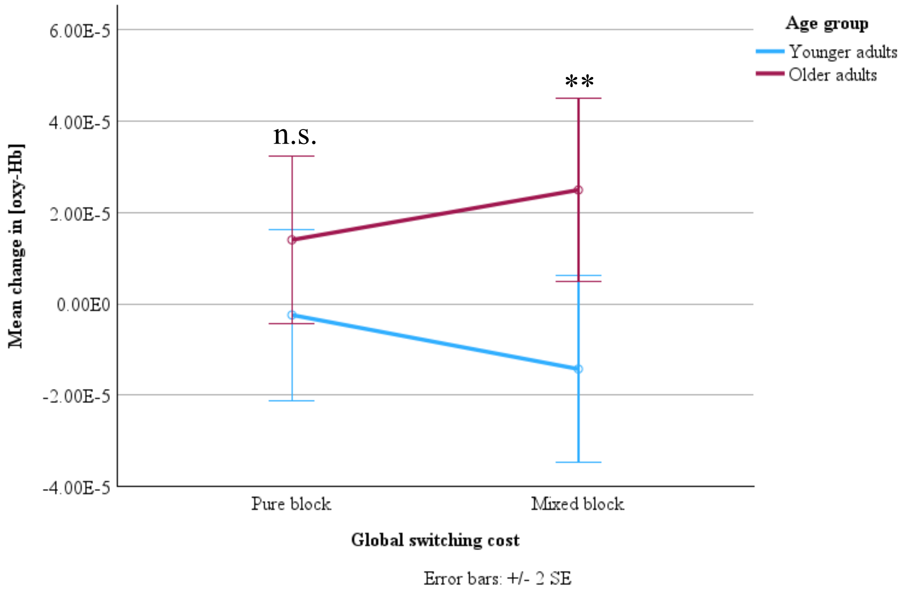
Mixed ANOVAs of the Computerised Mahjong Switching Game After Removing Outliers

	Main effect on global switching cost				Main effect on age				Interaction effect			
	df	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2
Ch 1	1, 49	0.01	.941	.00	1, 49	1.34	.253	.03	1, 49	0.12	.734	.00
Ch 2	1, 60	0.19	.668	.00	1, 60	3.92	.052	.06	1, 60	1.03	.313	.02
Ch 3	1, 60	1.46	.231	.02	1, 60	6.93*	.011	.10	1, 60	0.04	.837	.00
Ch 4	1, 54	1.72	.196	.03	1, 54	7.59**	.008	.12	1, 54	0.00	.975	.00
Ch 5	1, 55	0.01	.936	.00	1, 55	4.92*	.031	.08	1, 55	4.08*	.048	.07
Ch 6	1, 61	0.00	.958	.00	1, 61	6.46*	.014	.10	1, 61	1.01	.318	.02
Ch 7	1, 58	0.10	.756	.00	1, 58	7.03*	.010	.11	1, 58	0.10	.757	.00
Ch 8	1, 58	0.05	.825	.00	1, 58	3.32	.073	.05	1, 58	0.00	.976	.00

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

Figure 6.10

The Interaction Effect for [oxy-Hb] Found in Ch 5 of the Computerised Mahjong Switching Game



** $p < .01$. n.s. $p > .05$.

6.3.3.2 Computerised EF Tasks.

6.3.3.2.1 N-back Task. Figure 6.11 presents the time courses of the [oxy-Hb] changes during the *n*-back Task. Eight 2 (working memory load: 0-back, 2-back) × 2 (age group: younger, older) mixed ANOVAs were conducted with [oxy-Hb] as DV for the eight fNIRS channels. Table 6.9 summarises the statistics of the mixed ANOVAs for the eight channels after removing outliers.

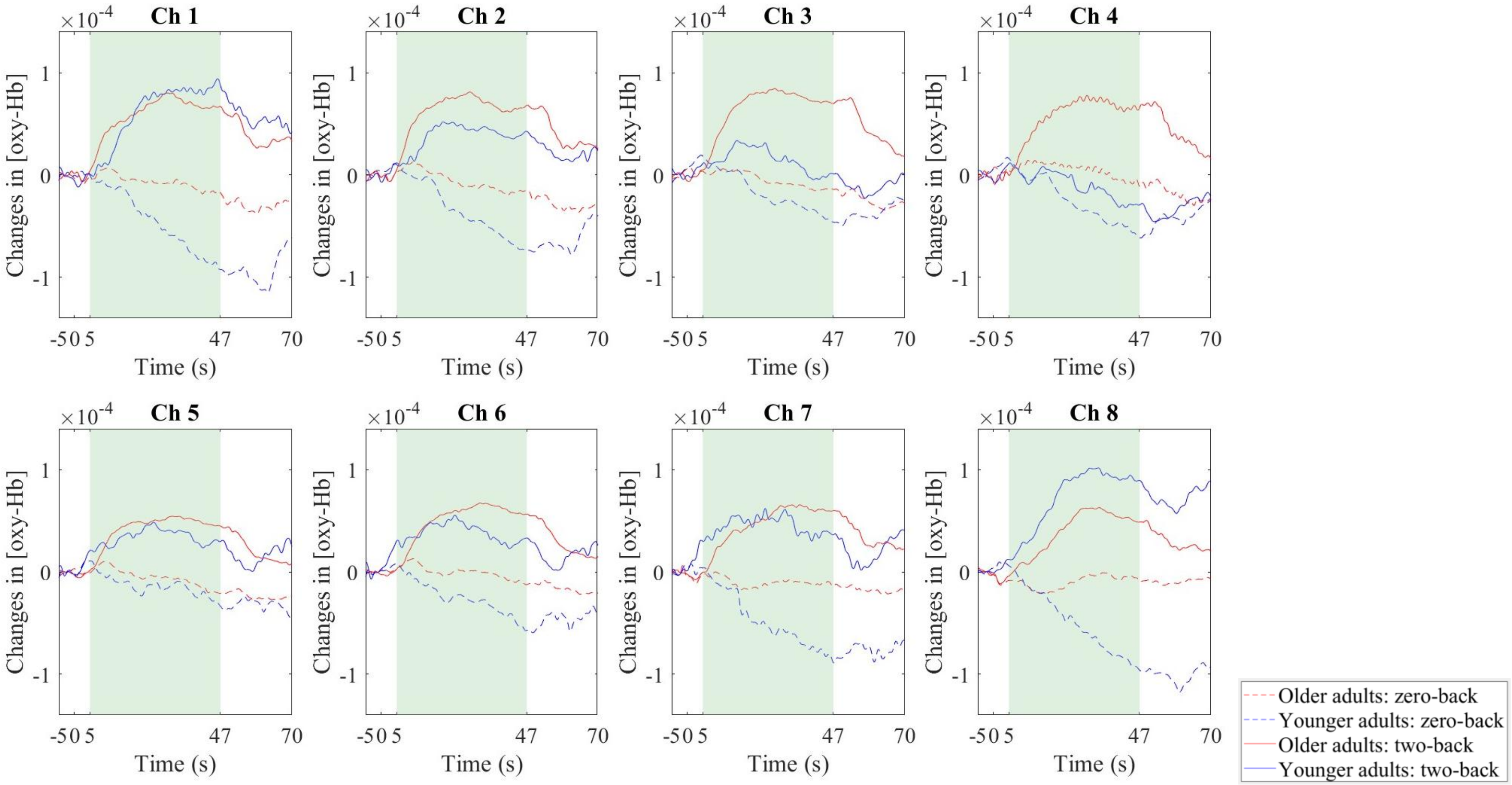
After removing outliers,[32] all channels displayed significant main effects for the working memory load, *p*s < .05 (see Table 6.9). The activation during the 2-back condition was significantly higher than that of the 0-back condition. Two channels on

[32] The following number of univariate outliers were removed: Ch 1 ($n = 4$; two younger adults and two older adults), Ch 2 ($n = 4$; three younger adults and one older adult), Ch 3 ($n = 3$; two younger adults and one older adult), Ch 4 ($n = 2$; two younger adults), Ch 5 ($n = 2$; one younger adult and one older adult), Ch 6 ($n = 4$; two younger adults and two older adults), Ch 7 ($n = 4$; two younger adults and two older adults), and Ch 8 ($n = 1$; one younger adults).

the right dlPFC reported significant main effect for age group, including Ch 3, $F(1, 52) = 7.26$, $p = .009$, $\eta_p^2 = .12$ (i.e., moderate effect size) and Ch 4, $F(1, 52) = 13.46$, $p = .001$, $\eta_p^2 = .21$ (i.e., large effect size). Older adults were found to have significantly higher activations than younger adults in these two channels. A significant 2-way interaction was found in Ch 3, $F(1, 52) = 7.25$, $p = .010$, $\eta_p^2 = .12$ (i.e., moderate effect size). Simple main effect analysis (independent sample *t*-tests with Bonferroni correction) was conducted to understand the source of the interaction. Results suggested no significant age group difference in the 0-back task, $t(52) = -.46$, $p = .651$, $d = -.12$ (i.e., negligible effect size), but older adults were found to have a significantly higher level of [oxy-Hb] in the 2-back task than younger adults, $t(52) = -3.38$, $p = .001$, $d = -.92$ (i.e., large effect size). Figure 6.12 illustrates the interaction effect.

Figure 6.11

Time Courses of [oxy-Hb] Changes in the Eight Channels during the N-back Task



Note. The *n*-back Task started at 0s with the instruction and cue lasted for 5 s and ended at 47 s.

Table 6.9

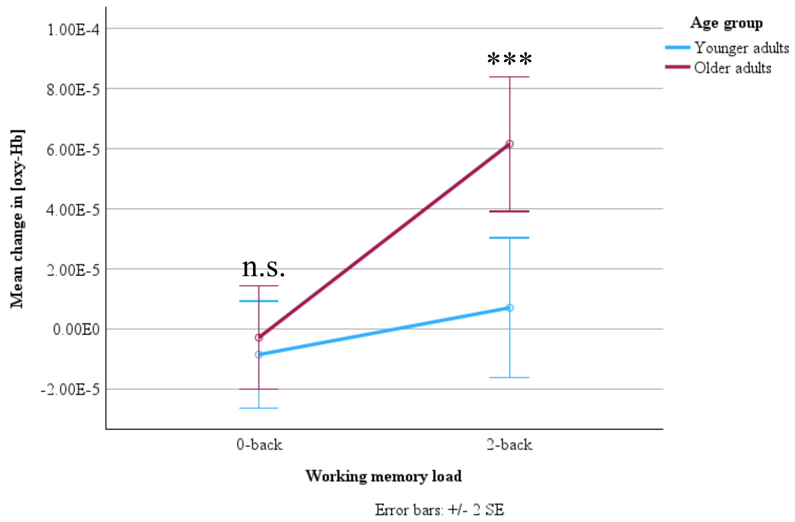
Results of Mixed ANOVAs of the N-back Task After Removing Outliers

	Main effect on working memory load				Main effect on age				Interaction effect			
	df	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2
Ch 1	1, 49	41.77***	<.001	0.49	1, 49	0.97	.331	.02	1, 49	0.03	.861	.00
Ch 2	1, 54	61.04***	<.001	0.53	1, 54	2.45	.123	.04	1, 54	0.42	.522	.01
Ch 3	1, 52	19.42***	<.001	0.27	1, 52	7.26**	.009	.12	1, 52	7.25*	.010	.12
Ch 4	1, 52	9.15**	.004	0.15	1, 52	13.46**	.001	.21	1, 52	2.05	.158	.04
Ch 5	1, 53	22.59***	<.001	0.30	1, 53	0.10	.756	.00	1, 53	0.29	.593	.01
Ch 6	1, 53	24.95***	<.001	0.32	1, 53	2.31	.135	.04	1, 53	0.57	.455	.01
Ch 7	1, 53	26.45***	<.001	0.33	1, 53	0.82	.370	.02	1, 53	0.76	.389	.01
Ch 8	1, 58	31.64***	<.001	0.35	1, 58	0.38	.538	.01	1, 58	3.99	.050	.06

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

Figure 6.12

The Interaction Effect for [oxy-Hb] in Ch 3 of the N-back Task



*** $p < .001$. n.s. $p > .05$.

6.3.3.2.2 Color-Shape Task. Figure 6.14 presents the time courses of the [oxy-Hb] changes during the Color-Shape Task. Eight 2 (global switching cost: pure block, mixed block) × 2 (age group: younger, older) mixed ANOVAs were conducted with [oxy-Hb] as DV for the eight fNIRS channels. Table 6.10 summarises the statistics from the mixed ANOVAs for the eight channels after removing outliers.

After removing outliers,[33] all four channels on the left side showed significant main effects for global switching cost, *p*s < .05 (see Table 6.10). Results revealed that the activations in the mixed block condition were significantly higher than that in the pure block condition. Six channels exhibited significant main effects for age group, whereby older adults showed significantly higher activations than younger adults, *p*s < 0.05 (see Table 6.10). No significant 2-way interaction was found, *p*s > .05.

[33] The following number of univariate outliers were removed: Ch 1 (*n* = 4; two younger adults and two older adults), Ch 2 (*n* = 4; two younger adults and two older adults), Ch 3 (*n* = 2; one younger adult and one older adult), Ch 4 (*n* = 2; two older adults), Ch 5 (*n* = 1; one younger adults), Ch 6 (*n* = 3; one younger adult and two older adults), Ch 7 (*n* = 1; one older adults), and Ch 8 (*n* = 3; one younger adult and two older adults).

Figure 6.13

Time Courses of [oxy-Hb] Changes in the Eight Channels during the Color-Shape Task

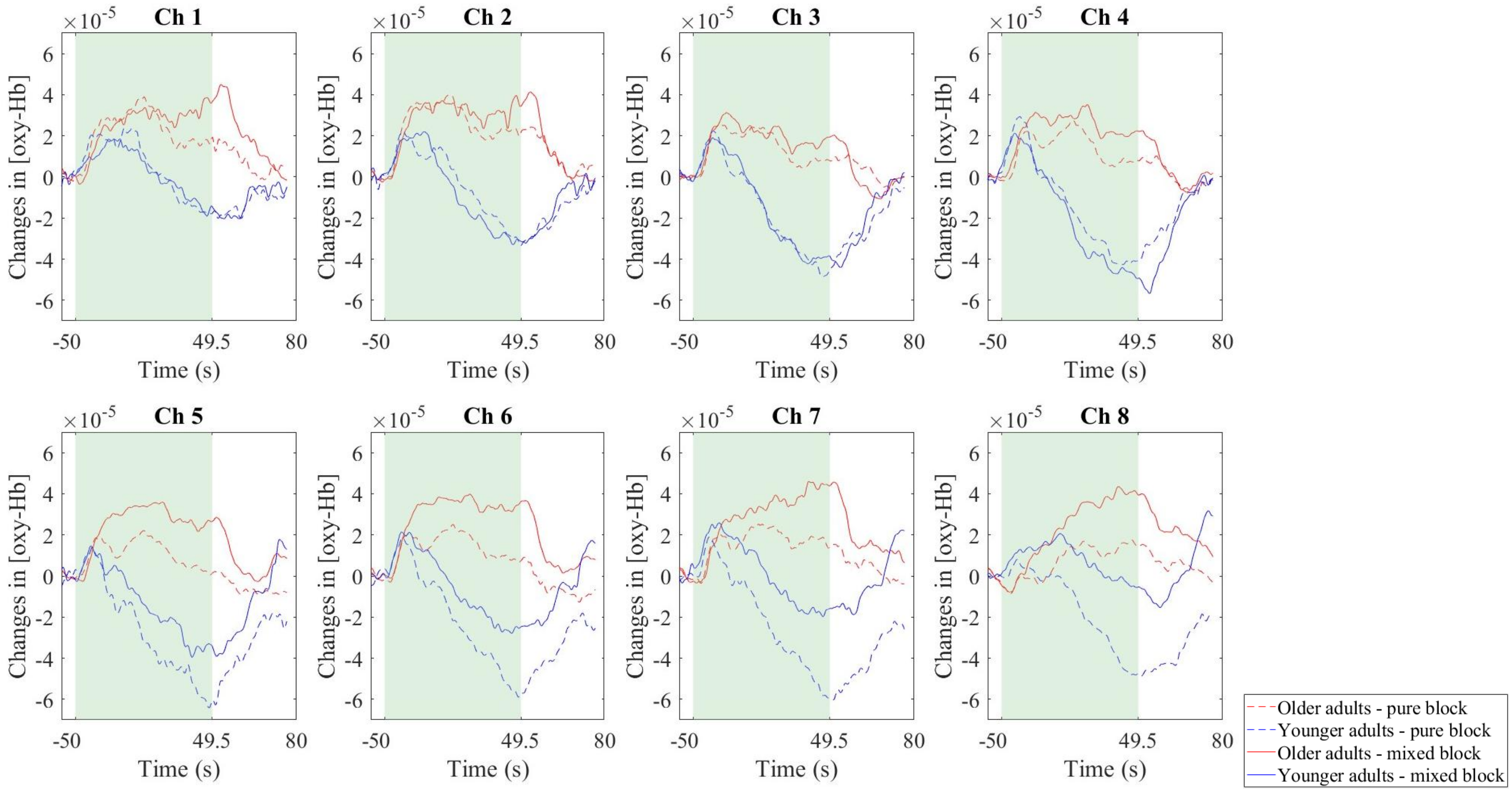


Table 6.10

Mixed ANOVAs of the Color-Shape Task After Removing Outliers

	Main effect on global switching cost				Main effect on age				Interaction effect			
	df	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2
Ch 1	1, 45	0.18	.673	.00	1, 45	2.03	.161	.04	1, 45	0.27	.607	.01
Ch 2	1, 54	0.15	.698	.00	1, 54	7.24**	.009	.12	1, 54	0.00	.999	.00
Ch 3	1, 51	0.02	.876	.00	1, 51	5.95*	.018	.10	1, 51	0.01	.936	.00
Ch 4	1, 48	0.04	.833	.00	1, 48	8.48**	.005	.15	1, 48	1.01	.320	.02
Ch 5	1, 53	7.66**	.008	.13	1, 53	18.88***	<.001	.26	1, 53	0.01	.935	.00
Ch 6	1, 55	6.57*	.013	.11	1, 55	7.41**	.009	.12	1, 55	0.05	.820	.00
Ch 7	1, 55	7.16*	.010	.12	1, 55	7.89**	.007	.13	1, 55	0.91	.343	.02
Ch 8	1, 53	4.69*	.035	.08	1, 53	3.38	.072	.06	1, 53	0.05	.832	.00

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

6.3.4 Relationships between Behavioural Outcomes in the Computerised Mahjong Games, Computerised EF Tasks and Neuropsychological Tests

Pearson's correlations were calculated to examine the relationships between the behavioural outcomes of (i) the working memory game and updating measures, as well as (ii) the switching game and switching measures. Given the age differences found before, the analyses were conducted separately for younger and older populations. No bivariate outliers were detected in the correlational analyses.

6.3.4.1 Updating Measures. Twelve Pearson's correlation analyses were performed to explore the relationships of the behavioural outcomes (i.e., accuracy, reaction time and span length) between the working memory game, *n*-back Task, and Backward Digit Span Test. Table 6.11 summarises Pearson's coefficients of the working memory game and updating measures after excluding the univariate outliers.

The reaction times of the computerised working memory game and *n*-back Task were found to have a significant positive correlation in younger adults, $r = .46$, $p = .007$. No other significant relationships were reported, ps > .05 (see Table 6.11).

Table 6.11

Correlation Coefficients Between Behavioural Outcomes in Working Memory Game, n-back Task and Backward Digit Span Test

	Computerised mahjong working memory game	
	Accuracy	Reaction time
(A) *n*-back (accuracy)		
Younger adults	.21	.27
Older adults	.09	.33
(B) *n* -back (reaction time)		
Younger adults	-.10	.46**
Older adults	.31	.04
(D) Backward Digit Span Test		
Younger adults	.15	.10
Older adults	.27	.11

* $p < .05$. ** $p < .01$.

6.3.4.2 Switching Measures. Twelve Pearson's correlation analyses were performed to explore the relationships of the behavioural outcomes (i.e., accuracy, reaction time and completion time) between the switching game, Color-Shape Task, and the interference index of CTT. Table 6.12 summarises Pearson's coefficients of the switching game and switching measures after excluding the univariate outliers.

No significant relationships were found, all *p*s > .05 (see Table 6.12).

Table 6.12

Correlation Coefficients between Behavioural Outcomes in Switching Game, Color-Shape Task and Color Trails Test

	Computerised mahjong switching game	
	Accuracy	Reaction time
(A) Color-Shape Task (accuracy)		
Younger adults	-.03	-.06
Older adults	.22	.02
(B) Color-Shape Task (reaction time)		
Younger adults	.06	.30
Older adults	-.07	-.11
(C) Color Trails Test (interference index)		
Younger adults	.10	.05
Older adults	.06	.08

6.3.5 Relationships between Neural Activation during the Mahjong Games and Behavioural Performance in the EF Tasks

All channels of [oxy-Hb] from all tests reported skewness < 3 and kurtosis < 10 after removing univariate outliers, which indicated that the neural data were normally distributed. Pearson's correlations were calculated to explore the relationships between the neural activations during the mahjong games and the behavioural measures of the EF tasks/tests. Given the age differences found before, the analyses were conducted separately for younger and older populations.

6.3.5.1 Updating Measures. Twelve Pearson's correlations were conducted to explore the relationships between the [oxy-Hb] measured during the working memory game and the behavioural measures of the *n*-back Task and Backward Digit Span Test. Table 6.13 summarises the Pearson's coefficients after excluding the univariate and bivariate outliers, if necessary.

The [oxy-Hb] measured during the working memory game was positively correlated with the accuracy of the *n*-back Task in younger adults in the left dlPFC, *r*

= .43, p = .014. In addition, the [oxy-Hb] measured during the working memory game was also negatively correlated with the span length of the Backward Digit Span Test in younger adults in the right dlPFC, r = -.36, p = .038. No other significant relationships were found, ps > .05 (see Table 6.13).

Table 6.13

Correlation Coefficients between [oxy-Hb] in the Working Memory Game and the Behavioural Measures of the n-Back Task and the Backward Digit Span Tests

	Computerised mahjong working memory game	
	[oxy-Hb] in the left dlPFC	[oxy-Hb] in the right dlPFC
(A) *n*-back (accuracy)		
Younger adults	.43*	.07
Older adults	.33	-.03
(B) *n* -back (reaction time)		
Younger adults	-.12	.10
Older adults	-.04	.07
(C) Backward Digit Span Test		
Younger adults	-.22	-.36*
Older adults	.05	.07

* p < .05.

6.3.5.2 Switching Measures. Twelve Pearson's correlations were conducted to explore the relationships between the [oxy-Hb] measured during the switching game and the behavioural measures of the Color-Shape Task and CTT interference index. Figure 6.14 summarises the Pearson's coefficients after excluding the univariate and bivariate outliers, if necessary.

The [oxy-Hb] measured during the switching game were found to have significant negative associations with the CTT interference index in older adults in the left dlPFC, r = -.53, p = .001 and the right dlPFC, r = -.35, p = .046. In addition, the [oxy-Hb] measured during the switching game were also found to have a significant positive association with the CTT interference index in younger adults in the left dlPFC, *r* = .41, *p* = .017. No other significant relationships were found, *p*s > .05 (see Table 6.14).

Table 6.14

Correlation Coefficients between [oxy-Hb] in Computerised Mahjong Switching Game, Color-Shape Task and Color Trails Test

	Computerised mahjong switching game	
	[oxy-Hb] in the left dlPFC	[oxy-Hb] in the right dlPFC
(A) Color-Shape Task (accuracy)		
Younger adults	.06	-.10
Older adults	.01	.03
(B) Color-Shape Task (reaction time)		
Younger adults	.03	.15
Older adults	-.03	-.24
(C) Color Trails Test (interference index)		
Younger adults	.41*	.15
Older adults	-.53**	-.35*

* *p* < .05, ** *p* < .01.

6.3.6 Summary of Significant Findings

Tables 6.15-17 summarise the significant findings regarding the (i) mahjong game manipulations, (ii) age-related differences, and (c) associations between mahjong playing and EF.

Table 6.15

A Summary of Significant Findings Regarding Task Manipulations

	Findings on DVs		
	Accuracy	Reaction time	[oxy-Hb]
(A) Updating measures			
Computerised mahjong working memory game	High load < Low load†	High load < Low load†	High load < Low load (in 8 channels)@†
N-back Task	High load < Low load†	High load < Low load†	High load < Low load (in 8 channels)†
(B) Switching measures			
Computerised mahjong switching game	Mixed block < Pure block†	Mixed block < Pure block†	Mixed block ≈ Pure block
Color-Shape Task	Mixed block < Pure block@	Mixed block < Pure block†	Mixed block < Pure block (in 4 channels)@

Note. Symbol < represents "performed poorer than" (i.e., poorer accuracy, longer reaction time and greater activation). Symbol ≈ represents "performed comparably with". DV = dependent variables; [oxy-Hb] = concentration of oxygenated haemoglobin; WM = working memory.

@ moderate effect sizes. † large effect sizes.

Table 6.16

A Summary of Significant Findings Regarding Age-Related Differences

	Findings on DVs		
	Accuracy/ Span length	Reaction time / Completion time	[oxy-Hb]
(A) Updating measures			
Computerised mahjong working memory game	Older ≈ Younger	Older ≈ Younger#	Older < Younger (in 4 channels) @†
N-back Task	Older < Younger†#	Older < Younger†	Older < Younger (in 2 channels) @†#
Backward Digit Span Test	Older < Younger	-	-
(B) Switching measures			
Computerised mahjong switching game	Older ≈ Younger	Older ≈ Younger	Older < Younger (in 5 channels)@ #
Color-Shape Task	Older < Younger@	Older < Younger†	Older < Younger (in 6 channels)@†
CTT-2	-	Older < Younger	-

Note. Symbol < represents "performed poorer than" (i.e., poorer accuracy, longer span, longer reaction time/completion time and greater activation). Symbol ≈ represents "performed comparably with". DV = dependent variables; [oxy-Hb] = concentration of oxygenated haemoglobin; CTT = Color Trails Test.

@ moderate effect sizes. † large effect sizes.

Significant interaction effect was found, in which older adults exhibited poorer behavioural performed/greater prefrontal activation than younger adults in 1-tile-to-win condition in the working memory game, 2-back task and mixed block of switching game.

Table 6.17

A Summary of Significant Findings Regarding Associations between Mahjong Playing and EF

Mahjong games	EF tasks	Findings
(A) Updating		
Working memory game (reaction time)	*N*-back Task (reaction time)	A positive association was reported in younger adults.
Working memory game [oxy-Hb]	*N*-back Task (accuracy)	A positive association was reported in younger adults in the left dlPFC.
	Backward Digit Span	A negative association was reported in younger adults in the right dlPFC.
(B) Switching		
Switching game [oxy-Hb]	CTT interference index	• Negative associations were reported in older adults in the right and left dlPFC. • A positive association was reported in younger adults in the left dlPFC.

Note. EF = executive functions; CTT = Color Trails Test; [oxy-Hb] = concentration of oxygenated haemoglobin; dlPFC = dorsolateral prefrontal cortex.

6.4 Discussion

This study designed two computerised mahjong games to investigate the relationship between mahjong playing and the updating and switching components of EF in younger and older adults. The results obtained partially supported the six hypotheses. First, the manipulations for the two EF components (viz., updating and switching) of the two mahjong games were found to be significant. In both the working memory and the switching games, high working memory load and mixed block resulted in poorer accuracy and longer reaction time compared to low working memory load and pure block. Second, in the two mahjong games, only the high working memory load exhibited higher prefrontal activation compared to the low working memory load, while the mixed block and pure block exhibited a similar level of prefrontal activation. Third, unexpectedly, age differences were not found for the behavioural accuracy and reaction time measures of the two games.[34] Fourth, significant age differences in neural activations were found for the two computerised mahjong games, specifically older adults showed higher levels of prefrontal activation during the games than younger adults. Fifth, in terms of the correlations between the behavioural measures of the computerised mahjong games and the EF tasks/tests, only the reaction times in both working memory game and *n*-back Task were positively and significantly correlated in young participants. There was no significant association between the switching game and the switching measures. Lastly, neural activations during the two computerised mahjong games were found to be significantly correlated with behavioural performance of EF tasks/tests. Specifically, an increased activation

[34] Note that there was a significant interaction effect observed in the reaction time of the working memory game, indicating that older adults performed poorer than younger adults only in the low working memory load condition, rather than the high working memory load condition. Findings will be discussed in the section 6.4.2.1.

during the working memory game was significantly and positively correlated with better performance in the *n*-back Task in younger adults. An age difference was also observed, indicating that increased activation was associated with better updating and switching abilities in older adults. In contrast, in younger adults, an increased activation during the mahjong games were found to significantly correlated with poorer performance in the neuropsychological EF task.

6.4.1 Manipulations of the Mahjong Games Regarding the Updating- and Switching-Specific Components of EF

The results fully supported the first hypothesis but only partially supported the second hypothesis: (i) behavioural performances in the high working memory load and the mixed block conditions were found to be poorer than those in the low working memory load and pure block conditions respectively; (ii) higher prefrontal activation was found in the high working memory load compared to the low working memory load, but no significant difference in prefrontal activation was observed between the mixed block and pure block. Findings are discussed in terms of (i) behavioural outcomes and (ii) prefrontal activation.

6.4.1.1 Behavioural Outcomes. The working memory and switching games showed significant main effects regarding the manipulations of working memory load and the global cost of switching. The findings were in line with the results observed in the conventional EF tasks measuring updating (i.e., *n*-back Task) and switching (i.e., Color-Shape Task) in this study.

Both the working memory game and *n*-back Task demonstrated a less accurate and longer reaction time performance in the high working memory load conditions (i.e., 3-tile-to-win and 2-back) than low working memory load conditions (i.e., 1-tile-to-win and 0-back). Consistent with the literature, a higher working memory load would attenuate behavioural performance (Bopp & Verhaeghen, 2020). It is because a higher working memory load would increase the cognitive load of the task, which also requires the individual to hold and manipulate more information in their mind. Therefore, it may lead to difficulties in executing tasks efficiently, further resulting in poorer behavioural performances such as decreased accuracy and slower reaction time. In this connection, it is possible to suggest that manipulating the winning probability in the mahjong hand could utilise cognitive resources in different levels of cognitive demand.

Similarly, both the switching game and Color-Shape Task revealed a less accurate and longer reaction time performance in the mixed blocks than in pure blocks. Consistent with the literature, a greater global cost of switching would hinder behavioural performance (Wasylyshyn et al., 2011; Ye & Damian, 2022), as it requires greater cognitive efforts to alternate between the tasks (i.e., detach the previous stimulus, attach to the newly stimulus, and resolve the interference among the two stimuli; Ye & Damian, 2022). Regarding this, it showed that the ability to notice an opportunity to switch the tile and maximise the winning probability in the mahjong game is related to switching.

6.4.1.2 Prefrontal Activation. The neural findings provide further and stronger corroborating evidence to support the behavioural evidence, such that it strengthens the claim that mahjong playing requires brain resources in the areas associated with EF. The findings were partially consistent with the neural results observed in the conventional EF tasks measuring updating (i.e., *n*-back Task) and switching (i.e., Color-Shape Task) in this study.

The computerised mahjong working memory game showed an increase in hemodynamic tissue oxygenation in all channels when the working memory load was high. It suggests that the utilisation of the brain resources increased when the working memory load was high. In accordance with the literature, a higher working memory load would increase the utilisation of neural resources (Han et al., 2022). This is because additional cognitive resources are required to hold and manipulate more information in mind. The results further suggested that manipulating the winning probability in the mahjong hand could also utilise neural resources in different levels of cognitive demand.

Unexpectedly, the switching game did not show a significant increase in hemodynamic tissue oxygenation related to the global cost of switching. The results were inconsistent with the neural results observed in the Color-Shape Task in this study and in the literature. Vasta et al. (2017) showed that the prefrontal activation measured in the mixed block was greater than in the pure block, suggesting a greater global cost of switching. The discrepancy may be due to the nature that the mixed block involved both switch and no-switch trials and the comparison between mixed and pure blocks was not sufficient to reach statistical significance. It is suggested to look at the switching cost, defined by the difference between the switch and repeat (i.e., no-switch in this game) trials for further investigation of the task manipulation (Eckart et al., 2023). Although the neural results did not report a significant effect on the global switching cost, there was an observable increase from rest to the task block and a notable decrease in prefrontal activation from task to the rest block. It is suggested that the switching game may still exert some neural activations related to the dlPFC, which is an important area supporting EF (Diamond, 2013; MacPherson et al., 2002; Miyake & Friedman, 2012; Nejati et al., 2018; Salehinejad et al., 2021).

In summary, the task manipulations related to updating and switching in the mahjong games suggested that mahjong playing may involve EF. In particular, manipulating the winning probabilities in the mahjong hand may be related to updating, while noticing an opportunity to switch the tile for maximising winning probability may be related to switching.

6.4.2 Age Differences Observed in the Mahjong Games

The results obtained partially supported the third hypothesis while fully supported the fourth hypothesis: (iii) the computerised mahjong games showed no significant age difference for behavioural accuracy and reaction time, but (iv) it was found that older adults exhibited higher prefrontal activation than younger adults during both games. Findings are discussed in terms of the age difference in (i) behavioural outcomes and (ii) prefrontal activation.

6.4.2.1 Behavioural Outcomes. The working memory and switching games showed no significant age difference between younger and older adults. The findings were inconsistent with the results observed in the conventional EF tasks measuring updating (i.e., *n*-back Task and Backward Digit Span Test) and switching (i.e., Color-Shape Task and CTT-2) in this study.

While the working memory game shows no age difference in behavioural outcomes, both the *n*-back Task and Backward Digit Span Test exhibited poorer behavioural performance in older adults compared to younger adults. The results were inconsistent with the findings of a meta-analysis that summarised 401 articles and suggested that older adults have poorer performance on the updating tasks than younger adults (Hedge's $g = 0.8$ [i.e., large effect size]; Maldonado et al., 2020). One possible reason to explain the inconsistency could be related to the maintenance of updating ability as induced by mahjong playing. Although the covariate (i.e., years of mahjong experience) did not have an impact on the results,[35] older adults reported longer years of mahjong playing than younger adults. It is suggested that these experiences related to mahjong playing might have contributed to the accumulation of cognitive reserve in older adults, enabling them to achieve comparable behavioural performance to younger adults. While the neural results showed significant age differences, it is also possible that the older adults recruited overactivation to compensate for the behavioural performance. The results would be discussed in section 6.4.2.2. In addition, it is noted that the age differences in both accuracy and reaction time were shown in the expected direction, in which older adults showed less accurate, $F(1, 70) = 1.83$, $p = .181$, and slower reaction time, $F(1, 67) = 2.08$, $p = .154$, than younger adults. Therefore, another reason for not observing a significant age difference could be due to insufficient power to detect a significant main effect for age.

As expected, one interesting finding referred to the significant interaction effect observed in the computerised mahjong working memory game: older adults showed longer reaction time than younger adults in the low working memory load condition instead of the high working memory load condition. It could be attributed to the fact that even though the stimuli were easier in the low working memory load condition, they still exert some working memory load, thereby differentiating the younger and older adults. According to the processing-speed theory, older adults need more time to process complicated cognitive tasks, resulting in slower operational speed compared to younger adults (Salthouse, 1996). Furthermore, since the significant interaction effect was observed in reaction time but not in accuracy, the results could also be

[35] It may be because a statistical test may not be an appropriate method to control for the mahjong experience in this case. Alternatively, the two populations were homogeneous regarding the familiarity of mahjong playing, as the current study has excluded frequent players.

attributed to a potential speed-accuracy tradeoff. In other words, older adults spent longer reaction time to ensure a higher level of response accuracy in the low working memory load condition (Larson & Hawkins, 2023).

Unexpectedly, the switching game reported comparable behavioural performance between the younger and older adults, which is different from the results observed in the switching measures (i.e., Color-Shape Task and CTT-2) in this study. Literature suggested that older adults have poorer performance on the switching tasks than younger adults (Hedge's $g = 1.4$ [i.e., large effect size]; Maldonado et al., 2020). One possible reason for the absence of significant age difference may reflect the fact that the participants are more familiar with the mahjong game than the Color-Shape Task, especially for older adults. Therefore, cognitive reserve regarding mahjong playing may have been accumulated and helped the older adults to achieve comparable performance with younger adults.

6.4.2.2 Prefrontal Activation. As expected, both working memory and switching games showed that older adults exhibited greater prefrontal activation than younger adults. The findings are consistent with the results observed in the conventional EF tasks measuring updating (i.e., *n*-back Task and Backward Digit Span Test) and switching (i.e., Color-Shape Task and CTT-2) in this study.

Both the working memory game and *n*-back Task showed that older adults exhibited greater prefrontal activation than younger adults, suggesting a lower neural efficiency in older adults (Reuter-Lorenz & Cappell, 2008). Consistent with the literature, studies have demonstrated similar findings in that older adults recruited more prefrontal regions during the *n*-back Task than younger adults (Hyodo et al., 2024; Vermeij et al., 2012). It is suggested that the working memory game could capture age-related difference in updating of EF (i.e., older adults would recruit more neural resources during the working memory game, similar to the *n*-back Task).

Both the mahjong switching game and Color-Shape Task showed that older adults exhibited greater prefrontal activation than younger adults, suggesting a lower neural efficiency in older adults (Reuter-Lorenz & Cappell, 2008). Consistent with the results of previous studies (Bierre et al., 2017; Ohsugi et al., 2013; Smith et al., 2004), it indicated that the hemodynamic tissue oxygenation was increased in older adults but decreased in younger adults. Likewise, one channel displayed a significant interaction effect, revealing an increased level of [oxy-Hb] in older adults in the mixed block instead of the pure block. Alongside the findings in the Color-Shape Task, the results suggested that the switching game could capture age-related differences in switching of EF (i.e., older adults would recruit more neural resources during the switching game, similar to the Color-Shape Task) even though there was no age difference behaviourally.

6.4.2.3 Neural Compensation for Behavioural Performance. It is more interesting to discuss why significant age differences were observed in the neural measures, but most of the behavioural measures showed negligible age differences. One possible direction to explain the results refers to the compensatory mechanism of neural efficiency, which enabled older adults to achieve behavioural performance comparable to that of younger adults (Roberto Cabeza et al., 2018). In other words, older adults could have recruited additional brain resources in the prefrontal areas to compensate for the behavioural performance. This explanation is consistent with the compensatory processes and the CRUNCH mentioned in the hypothesis (Park & Reuter-Lorenz, 2009; Reuter-Lorenz & Cappell, 2008). In addition, given that the patterns of significant age differences in the neural measures were not found only in one hemisphere, it may also reflect that less lateralised patterns of neural activation were observed during the mahjong games. The results further supported the HAROLD model, in which older adults exhibited bilateral activations during the tasks compared with younger adults (Cabeza, 2002). However, to explicitly compare and visualise the activations between younger and older adults, further subgroup analyses are needed. In light of the encouraging findings related to the compensatory processes, it was possible to highlight the potential of using mahjong playing to build the cognitive reserve of EF in older adults. Yet, besides the compensatory processes, it would also be possible to argue that the age difference may emerge at the neural level before being observed on the behavioural measures, suggesting that neural measures are more sensitive to detect the age-related difference (Jack et al., 2018; Jack Jr et al., 2010). More longitudinal studies are needed to follow up on the developmental trend of the age-related declines in EF, its neural changes and the effectiveness of the accumulation of cognitive reserve.

Another intriguing observation is that the neural compensation appears to be specific to the mahjong games. In contrast to the results from mahjong games, the computerised EF tasks showed significant age differences in both the behavioural and neural outcomes. Note that the prefrontal area is a crucial area for EF and is sensitive to age-related declines (MacPherson et al., 2002; Nejati et al., 2018), the results suggested that the older adults were experiencing age-related declines in EF. The compensatory mechanism induced during mahjong games was then suggested that the cognitive component of mahjong playing may facilitate the cognitive benefits associated with EF, particularly in the context of mahjong playing. It is possible that the mahjong games are more ecologically valid or familiar to the older adults than the EF tasks, and it helps to accumulate the cognitive reserve more easily than the experimental tasks. A systematic review showed that ecologically valid rehabilitation involving virtual reality, computerised training, video games and robotics allowed the maintenance of cognitive reserve (Morales et al., 2023). In light of this, the findings of the present study may convey the message that mahjong playing would be a potential activity for accumulating cognitive reserve compared with the experimental tasks due to the ecologically valid settings and content. It also emphasised that future training paradigms related to cognitive reserve should consider the ecological validity of the program to maximise the benefits. Nevertheless, with limited evidence (especially since this study was conducted in a laboratory setting) and without a properly designed RCT, it would be premature to claim that mahjong playing is effective in accumulating the cognitive reserve of EF in healthy older adults. Future research, especially RCTs is recommended to extend this scope of study and clarify the impact of ecological validity and generalisability of mahjong playing.

Furthermore, the compensatory processes may interact with the level of familiarity of the items in the mahjong game. In the working memory game, a significant interaction effect was observed for the behavioural measure, where older adults exhibited longer reaction time than younger adults, specifically in the low working memory load condition rather than the high load. In contrast, this interaction effect was absent in the neural measures, where older adults engaged additional neural resources in both low- and high-load conditions compared to younger adults. This may suggest that the neural compensation was only evident in the high load condition, and the low load condition showed mixed effects.[36] Possibly, greater familiarity with the items is postulated to facilitate the accumulation of cognitive reserve and promoting neural compensation, resulting in the absence of behavioural age

[36] The compensatory processes were still in effect on the accuracy measure, but not did not apply to the reaction time performance.

difference. In the real-life setting of mahjong playing, it is common for the player to build a flexible hand (i.e., more options to complete the tile set and involve greater working memory load). Therefore, it is possible that the participants are more familiar with the high load condition, potentially facilitating the neural compensation. For the items in low load condition and with less familiarity, older adults may only compensate for the accuracy rather than reaction time. However, it is important to note that the literature often reported age differences across all levels of task load (Mattay et al., 2006; Nagel et al., 2009), with a larger difference at a higher task load. It remained uncertain why the neural compensation was observed only in a high load condition in this case but not for the low load condition. Further investigation is warranted to examine if the cognitive load would have an impact on the compensatory processes and if it is related to the issue of familiarity.

6.4.3 Relationships between Mahjong Games and EF Tasks

The results partially supported the fifth hypothesis and the sixth hypothesis: (v) only the reaction times in the computerised mahjong working memory game and *n*-back Task were positively correlated; (vi) increased neural activations during the computerised mahjong games were associated with better performance on the *n*-back Task, but poorer behavioural performance on the Backward Digit Span Test and Color Trails Test.

6.4.3.1 Associations between the Behavioural Outcomes of Mahjong Games and EF Tasks. A positive association was reported between the reaction time of the working memory game and *n*-back Task in younger adults, suggesting that the working memory game was related to the updating of EF and demonstrated similar characteristics to the conventional working memory task (Bopp & Verhaeghen, 2020). The results are consistent with the expectation and provided empirical evidence to support the operationalisation of updating in the computerised mahjong working memory game. Importantly, it showed that the manipulation of the winning probability of the mahjong hand was successful and related to the working memory load. The current correlational analyses were exploratory and offered preliminary evidence to support the empirical basis for the connection between mahjong playing and EF. It is acknowledged that the analyses were conducted with a small sample size, were dependent on age, and the significant correlation was observed in relation to reaction time rather than accuracy. Future research should consider increasing the sample size for further exploration.

Unexpectedly, no significant association was found between the switching game and the switching measures. Although the task manipulation of switching in the switching game was significant, the correlational analyses could not provide empirical evidence to support the connection between the switching game and the switching measure. Nonetheless, as mentioned in section 6.4.1.2, it is suggested to look at the switching cost, defined by the difference between the switch and repeat (i.e., no-switch in this game) trials for further investigation (Eckart et al., 2023). Note that the correlational analyses were conducted with a small sample size, the absence of significant correlation may be due to insufficient power. More research with a larger sample size should be conducted in future.

6.4.3.1 Neural Activations of Mahjong Games and Behavioural Performances in EF Tasks. In the computerised mahjong working memory game, the prefrontal activation in the left dlPFC during the working memory game was positively associated with the behavioural accuracy of *n*-back Task in younger adults; while the prefrontal activation in the right dlPFC showed a negative association with the Backward Digit Span Test in younger adults. These results were partially consistent with the hypothesis, suggesting that an increase in neural resources in the working memory game was associated with a higher accuracy in the *n*-back Task but a shorter span (i.e., poorer performance) in the Backward Digit Span Test. On the one hand, considering the behavioural performance of the working memory game was also found to be positively correlated with the behavioural performance of the *n*-back Task, these results provided a piece of corroborating evidence to support the connection between the working memory game and updating measures (i.e., *n*-back Task). Although significant correlations were not consistently observed in the two age groups, the results were encouraging to suggest that "mahjong playing was related to updating of EF and may foster brain exercise related to updating". Regarding the negative correlation between the prefrontal activation during the working memory game and the Backward Digit Span Test, it is possible that the test construct of Backward Digit Span Test has measured more than updating and considered the span length (Woods et al., 2011). It may further suggest that the working memory game is more similar to the *n*-back Task (i.e., updating component) than the Backward Digit Span Test (i.e., both updating and span length). Note that these exploratory correlational analyses were conducted on a small sample size and without multiple corrections, the results should be interpreted cautiously. Future studies with larger sample sizes are suggested to further investigate the topic.

In the switching game, the prefrontal activations in the right and left dlPFC during the switching game were negatively associated with the CTT interference index, specifically in older adults. In younger adults, only the left dlPFC showed significant positive correlation between the prefrontal activations during the switching game and the CTT interference index. It was partially in line with the hypothesis, suggesting that an increase in neural resources in the switching game was associated with less interference (i.e., better performance) in the CTT for older adults only. For younger adults, it is possible that they did not require overactivation to compensate for the age-related loss, as overactivation represents lower neural efficiency (Bierre et al., 2017; Reuter-Lorenz & Park, 2014). Therefore, an increased prefrontal activation in younger adults correlated with larger CTT interference index (i.e., poorer performance). This finding supported the concept of neural compensation in the ageing literature (Reuter-Lorenz & Cappell, 2008; Reuter-Lorenz & Park, 2014), which involves the utilisation of overactivation to compensate for behavioural performance. It also provided an empirical basis for the connection between the switching game and the switching measures, suggesting that "mahjong playing was related to switching of EF and may foster brain exercise related to switching". It is acknowledged that the correlational analyses were exploratory, with a small sample size, and significant correlations were not consistently observed in the two age groups. Future research is suggested to increase the sample size and reaffirm the results.

Overall, the findings of this study supported the relationship between mahjong playing and the updating and switching components of EF. It elucidated the neural mechanisms of mahjong playing, and its associated age differences. It is suggested that mahjong playing may foster the neural compensation in older adults, such that older adults compensated for the behavioural performances with overactivation in dlPFC.

6.4.4 Limitations and Future Directions

One limitation of the current study is that two sub-components of EF were included instead of three due to limited time and resources for the PhD project. One model of EF proposed three sub-components, including updating, switching and inhibition (Miyake et al., 2000). The current study did not investigate the inhibition component of EF. The rules of mahjong playing also involve inhibition, such as delaying to claim the win and waiting for a greater reward even though the player could win the game earlier; or inhibiting to discard a tile even though the player has received a tile that does not match the groupings of the current hand, as doing so might allow others to win. This characteristic is closely related to the delayed gratification task (Raghunathan et al., 2023). Future research is recommended to examine the relationship between mahjong playing and the inhibition component of EF. This may contribute to the development of engaging inhibition training for older adults.

As another limitation, the correlational analyses conducted between mahjong playing and EF were based on a comparatively small sample size. Noticing that the correlation is age-sensitive, the analyses have been conducted separately for the two age groups. Although the results are promising, it is suggested that future studies should increase the sample size to further corroborate the relationships between mahjong playing and EF using correlational or even regression analyses.

To investigate mahjong playing in a laboratory setting and focus on specific cognitive processes, the computerised mahjong games in this study are not exactly the same as the full game. The current study only designed two subgames based on the mahjong rules that allowed researchers to assess EF. To fully understand the benefits of mahjong playing, future research may also explore other cognitive or social domains based on other game rules. This could involve studying skills like anticipating and planning the moves several steps ahead and examining the social dynamics that emerge among mahjong players during the gameplay. Moreover, as mahjong is a multiplayer game, it also shows its potential to develop as a measurement tool to understand social cognition and human communication. Future research may also consider using hyperscanning (i.e., measuring brain activity from multiple players simultaneously when they interact with each other; focusing on the brain synchronisation during social interactions) to explore the benefits of the social component, which is the cutting-edge field in neuroscience. In addition, mahjong playing could also involve understanding the thoughts and intentions of other players, which is similar to the definition of theory of mind - understanding others' mental states (Schurz et al., 2021). Another possible research direction may consider developing theory of mind training and investigate its effectiveness.

The current study used a block design and only analysed the global switching cost instead of the switching cost for the computerised mahjong switching game and the Color-Shape Task. The switching cost compared the difference between repeat and switch trials within the mixed block and it would be useful to analyse this as a DV for the two tasks as well. However, to do so it requires extensive efforts to change the block design to an event-related design. It is suggested that future studies should explore the switching cost and assess whether it shows different outcomes as compared to the global cost.

Finally, the current study only recruited participants who acquired basic mahjong skills and did not explore the difference between experienced and novice players. Future studies could explore if similar results can be found in experienced players. Although year of mahjong experience was not found to be a significant covariate in this study, it is still important to replicate the findings in this study in experienced players. Future studies can also include new learners of the mahjong game to see if their performances on the mahjong games and EF tasks are the same as those of the novice and experienced players.

Chapter 7

General Discussion

Engaging in leisure activities, one proxy measure to accumulate cognitive reserve has been suggested to foster better functions of ageing (Cappa, 2017; Chen et al., 2019; Hotz et al., 2023; Stern et al., 2023). However, what types of leisure activities and how they facilitate cognitive, psychological and daily functions still await further elucidation. In addition, among the activities that received attention for research, the majority are linked to Western culture, with a noticeable scarcity of studies delving into culturally specific activities. Mahjong playing, one popular culturally specific activity in Asia, has been selected and examined in this thesis because of its cognitive benefits (Cheng, Chow, Song, Yu, & Lam, 2014) and facilitation of intrinsic motivation (Rahman et al., 2019). Three studies, including one large-scale cross-sectional survey (Study 1), one scoping review (Study 2), and one neuroimaging experimental study (Study 3), were conducted to investigate whether engaging in leisure activities and one culturally specific activity (i.e., mahjong playing) could facilitate better functions in older adults. Overall, the findings revealed that the recent patterns of nature and extent of leisure activity participation have changed, particularly with more older adults engaging in intellectual activities such as using computers or surfing the Internet. It also supported that engaging in leisure activities, with different domains and dosages of participation, could predict better cognitive, psychological and daily functions in older adults. Importantly, these positive associations were also observed in one culturally specific activity (i.e., mahjong playing). The findings also extended the investigation beyond examining predictions to understanding the underlying mechanism of mahjong playing, suggesting that this activity may potentially accumulate cognitive reserve to maintain age-equivalent behavioural performance.

7.1 Leisure Activity Participation: An Update on Nature and Extent

The findings of Study 1 updated the nature and extent of leisure activity participation among older adults in Hong Kong since 2013 (Zhao & Chen, 2013). Different from previous studies (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990; Zhao & Chen, 2013), this study included not only participation rate and frequency but also the duration of each activity among those engaged participants.

Although watching television remained the most popular leisure activity among older adults, the participation rate has decreased from an average of 98.9% in previous studies (Cheung et al., 2009; Chou et al., 2004; Zhao & Chen, 2013) to 70% in this study. In contrast, more older adults were found to be engaging in using the computers or surfing the Internet (53%) in this study, as compared to an average of 9.3% in previous studies (Cheung et al., 2009; Zhao & Chen, 2013). This observed trend suggested a switch from recreational activity (viz., watching television) to intellectual activity (viz., using computers or surfing the Internet) among older adults. Importantly, the findings underscored the increasing acceptance of technology among older adults and the potential for utilising the Internet and technology to enhance the functions of older adults.

Watching television was the most frequent activity in previous studies (Cheung et al., 2009; Chou et al., 2004; Zhao & Chen, 2013). Interestingly, this study revealed that some activities have also become frequent activities among older adults recently, such as keeping a pet, using computers or surfing the Internet and cooking for pleasure. According to the Active Theory (Havighurst, 1948) and the STAC-r (Reuter-Lorenz & Park, 2014), active engagement in leisure activity can help promote better functions during ageing. The results highlighted that these frequent activities have the potential to promote participation and boost the activity level of older adults.

In addition to examining participation rate and frequency, this study introduced a novel dimension by measuring the duration of each activity among the older adults. This dimension was not included in previous studies (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990; Zhao & Chen, 2013). The inclusion of measuring the duration of each activity has offered a more comprehensive understanding of the engagement patterns of various activities among older adults. Results showed that some leisure activities relating to the Chinese culture, such as mahjong playing and Chinese martial arts, were being engaged in for longer durations by older adults than other activities. The findings suggest that older adults in Hong Kong are more likely to spend a longer duration on culturally specific activities they are interested in, highlighting the potential benefits of promoting these activities to enhance their activity levels.

7.2 Leisure Activity Participation: Effective Domains and Dosages

The findings of Study 1 indicated that engaging in leisure activities could predict better functions in older adults (viz., better general cognition and EF, less loneliness, reduced levels of depression, anxiety and stress and better functional independence). Different from previous studies which only examined a few leisure activities (Gu et al., 2023; Krueger et al., 2023; Teh & Tey, 2019), this study included 48 activities and systematically classified them into four domains (viz., intellectual, social, recreational and physical activities) and three dosages (viz., diversity, frequency and duration; G. T. Y. Leung, K. F. Leung, et al., 2011). Although leisure activity participation could significantly predict functions of ageing, the directions of the predictions varied across the four domains and three dosages.

7.2.1 Domains of Activities

Consistent with the literature, engaging in intellectual, social, recreational and physical activities were positively correlated/beneficial to functions of ageing, including cognitive (Gavett et al., 2024; Hammond & Stinchcombe, 2022; Hertzog et al., 2008; Muiños & Ballesteros, 2021), psychological (Fingerman et al., 2022; Luo & Waite, 2014; Rivera-Torres et al., 2021; Yen et al., 2024) and daily functions (D'Orsi et al., 2014; Fujiwara et al., 2009; Gao et al., 2018; Gu et al., 2023). This may be because engaging in leisure activities may promote an environmental enrichment effect, which fosters the accumulation of cognitive reserve (Opdebeeck et al., 2016; Stern, 2009; Stern et al., 2023). A better cognitive reserve is suggested to better attenuate the negative effects of ageing, thus resulting in better maintenance of the functions in older adults (Cappa, 2017).

7.2.1.1 Cross-Domain Benefits. Results of Study 1 also provided evidence to support the cross-domain benefits of engaging in leisure activities. For example, engaging in intellectual activities was found to predict psychological and daily functions, while engaging in social activities was found to predict cognitive and daily functions. This observation is consistent with the existing literature, which found that participation in social and physical activities was related to cognitive performance (Hertzog et al., 2008). It is also shown that engaging in all four domains of activities (viz., intellectual, social, recreational and physical activities) could promote mental health and daily functions in older adults (Gao et al., 2018; Gu et al., 2023; Rivera-Torres et al., 2021). It is possible that engaging in multiple domains could increase the exposure to life experience (Stern, 2009), thus accumulating cognitive reserve for better functions of ageing.

Unexpectedly, some domains of activities did not significantly predict the functions (e.g., participation in physical activity did not predict the psychological functions in older adults). While this finding is inconsistent with the current literature

(Rivera-Torres et al., 2021), it is possible to suggest that the cross-domain benefits may be limited to some factors. For example, it is critical to consider social support when promoting mental health with physical activities (Sasidharan et al., 2006; Siegmund et al., 2021), as social support promotes well-being and prevents social isolation. However, Study 1 has encompassed both individual and group exercise in the domain of physical activities (e.g., swimming vs. playing ballgames or racquet sports), leading to difficulties in examining if social support serves as an essential factor in the relationship between physical activity and psychological outcomes among older adults. In addition, it is crucial to consider the intensity of physical exercise while promoting daily functions. Paterson and Warburton (2010) showed that only moderate levels of physical activity were associated with a reduced risk of functional disability, rather than light physical activity. More studies are needed to explore the critical factors that facilitate/hinder the cross-domain benefits of leisure activity participation.

7.2.2 Dosage of Participation

More importantly, the findings also revealed that varying dosages of participation could predict functions in different directions.

7.2.2.1 Optimal Dosages. Interestingly, more frequent social activity predicted poorer general cognition, functional independence and mental health, whereas longer duration of social activity was associated with better general cognition, functional independence and mental health. More diverse intellectual activities also predicted poorer EF and mental health, but more frequent intellectual activities could predict better EF and mental health. The findings were inconsistent with the current literature, as an increased dosage was not associated with better functions (Wenzel et al., 2024). It is possible that when one dimension (i.e., frequency) is negatively associated with the outcomes, another dimension (i.e., duration) may help to buffer the effect. For example, frequently engaging in social activity may cause social exhaustion in older adults, but extending the duration may be helpful to reduce the complaints and buffer the effect (Wenzel et al., 2024). One may suggest that increasing the duration may imply a better quality of engagement, as the older adult has established a stable social circle with others. Regarding EF, participating in a greater diversity of intellectual activities may introduce additional cognitive processing demands and result in cognitive fatigue among older adults when they manage activity schedules (Ren et al., 2019), but increasing the frequency of these activities may help to reduce the complaints. This may imply that regular participation is more important than diversity while promoting cognitive functions among older adults (Wong et al., 2016). However, it should be noted that this effect is only observed in social and intellectual activities. Future research is necessary to clarify and interpret this phenomenon.

Study 1 also showed that engaging in one culturally specific activity (i.e., mahjong playing) could predict cognitive, psychological and daily functions in older adults. Considering that culturally specific activities offered a greater intrinsic motivation for participation for people in that culture (Rahman et al., 2019), it is important to examine if these activities share similar benefits with culturally general activities, such as reading, playing bridge, or doing crosswords, as discussed previously in the literature (Opdebeeck et al., 2016). The following sections will discuss the findings from Study 1 to Study 3 regarding the benefits of mahjong playing in facilitating better functions of ageing.

7.3 The Culturally Specific Activity: Mahjong Playing

The current findings related to mahjong playing from Study 1 to Study 3 could be summarised into three areas: (i) updated profile of the nature and extent of participation, (ii) benefits in cognitive, psychological and daily functions, and (iii) relationship between mahjong playing and EF: an examination of behavioural manipulation and its neural basis.

7.3.1 Updated Profile of the Nature and Extent of Participation

Study 1 showed that mahjong playing is a relatively prevalent activity among older adults in Hong Kong, and those who engaged in the game played it for a relatively longer duration than other activities. Among the 48 activities, mahjong playing had a participation rate of 27% (rank = 12th among 48 activities). Among the mahjong players, they also engaged in the game almost twice a week (rank = 33rd among 48 activities), with an average of 4.06 hr each time (rank = 2nd among 48 activities). Consistent with previous studies, mahjong playing shared a similar prevalence rate as reported in previous studies (Cheung et al., 2009; Chou et al., 2004; Kwan, 1990) but did not fall within the category of common activities, such as watching television (70%; rank = 1st among 48 activities). However, it should be noted that once older adults engage in mahjong playing, they spend a longer duration on each gaming session. It is possible that mahjong playing, a culturally specific activity, offers intrinsic motivation to older adults to sustain their engagement (Rahman et al., 2019). The results also suggested that mahjong playing is an enjoyable game among older adults, possibly due to its characteristics of luck, uncertainty, and flexibility (i.e., older adults would receive a different combination of stimuli and devise different strategies in each game; Cheng et al., 2006). Therefore, it may foster excitement during the gameplay and motivate the older adults to continue their participation. This characteristic also underscored the potential of implementing mahjong playing to enhance activity levels and maintain participation in future studies, especially interventions.

7.3.2 Benefits in Cognitive, Psychological and Daily Functions

Apart from being a motivated activity among older adults, Study 1 also demonstrated that engaging in mahjong playing could predict cognitive, psychological and daily functions in older adults. However, similar to the findings related to other leisure activities, different dosages of participation could predict functions in different directions.

7.3.2.1 Dosage of Participation. More frequent mahjong playing was found to predict poorer general cognition, EF, greater loneliness, poorer mental health and functional independence, whereas a longer duration of mahjong playing was associated with better performance in these functions. These findings were inconsistent with the current literature, which showed that an increased dosage would be associated with better functions (Wenzel et al., 2024). However, this pattern of optimal dosage is similar to the findings observed in the overall leisure activity participation in Study 1, suggesting that when one dimension (i.e., frequency) is negatively associated with the outcomes, another dimension (i.e., duration) may help to buffer the effect. This observation implied that the game needs time to develop (i.e., mahjong is a slow game; Greene, 2015): the players require time to devise strategies, and they also need time to build high-quality social relationships. The findings also suggested that playing mahjong frequently may lead to negative impacts, such as addictive behaviours, ignorance of other aspects of everyday life and losing money. Therefore, regularly engaging in the game without sufficient duration may imply that older adults have limited exposure to mental exercise and high-quality social connection, resulting in limited benefits and negative impacts on the functions of ageing. In addition, as the game is cognitively demanding and shares similar characteristics with the EF tasks, it is also possible that time is required to accumulate cognitive reserve. For example, sorting and arranging the sequence of the mahjong tiles is highly similar to the working memory of EF (i.e., the ability to hold and manipulate information in the mind). Spending enough time in the game may then offer mental exercise to older adults, thereby accumulating cognitive reserve and facilitating better functions of ageing. In addition, according to the socioemotional selectivity theory, older adults would shift their goals of living from knowledge goals to emotional goals (Cartensen et al., 2003). It is possible that a longer duration of mahjong playing may provide greater emotional support to older adults, thus associating with these positive functions of ageing.

While Study 1 adopted a cross-sectional design, it provided limited insights into the causal relationship between mahjong playing and its benefits. These encouraging correlational findings warranted a further investigation into the specific benefits of mahjong playing in older adults. Therefore, a scoping review (Study 2) was undertaken to systematically summarise, synthesise and evaluate the existing evidence, as well as identify the research gaps for future research. As mahjong playing is an activity related to Chinese culture, studies across the Western and Asian databases were identified and included.

7.3.2.2 Benefits of Mahjong Playing as Identified in the Literature. The scoping review identified five primary benefits associated with mahjong playing in older adults: (i) the subjective meaning attached to mahjong playing, (ii) short-term benefits, (iii) long-term benefits, (iv) being a protective factor against clinical conditions, and (v) interventional effectiveness. These results aligned with Study 1, indicating that engaging in mahjong playing yielded benefits for cognitive, psychological and daily functions in older adults.

7.3.2.2.1 Subjective Meaning Attached to Mahjong Playing. Some qualitative interviews proposed that mahjong playing could provide subjective meaning to older adults, such as offering a sense of competency and a feeling of youthfulness and preventing social isolation (Kim, 2020; Liu, 2015; Wu & Tang, 2011). The qualitative findings are different from quantitative evidence, and it may be useful to generate new hypotheses for future research directions. Being a culturally specific activity, it provides valuable evidence to support the cultural differences in accumulating cognitive reserve via leisure activity engagement. The subjective meaning of mahjong playing also highlights that this activity has a special cultural meaning towards older adults in Asian countries, which may boost the motivation for participation and sustained engagement.

7.3.2.2.2 Short-term Benefits of Mahjong Playing. The scoping review supported the short-term benefits of mahjong playing among older adults, with findings from 13 included studies. Eleven studies revealed a positive association between mahjong playing and better cognitive, psychological and daily functions. In contrast, two studies found no significant relationships. Short-term benefits of mahjong playing included better cognitive ability (Fang & Shen, 2017; Zhou & Hu, 2020), reduced depression and psychological distress (Ren et al., 2021; Ross & Zhang, 2008) and better daily functions (Chou et al., 2004; Tsang et al., 2016). These findings suggest that mahjong playing could potentially lead to positive impacts on cognitive, psychological and daily functions in older adults. This is likely to be because mahjong playing is a mentally demanding and cognitively stimulating game, which could promote an active lifestyle and lead to better functions in older adults.

7.3.2.2.3 Long-term Benefits of Mahjong Playing. In addition, the scoping review supported the long-term benefits of mahjong playing among older adults. Out of the 16 longitudinal studies, 14 have shown the long-term effects of mahjong playing on cognitive, psychological and daily functions. For example, mahjong playing was associated with better cognitive maintenance (Xue, 2020; Yi & Kang, 2008), and relatively stable cognitive decline (Ni et al., 2020; Ye et al., 2021; Yu et al., 2021). One study also revealed that mahjong playing was positively associated with the possibility of reversion from MCI (Sha et al., 2022). These findings suggested that a sustained engagement in mahjong playing is beneficial to maintaining cognitive performance, possibly due to an accumulation of cognitive reserve. More studies are needed to reaffirm the observation, especially including not only behavioural benefits but also the neurobiology or neural basis of mahjong playing.

7.3.2.2.4 Being a Protective Factor Against Clinical Conditions. The scoping review also identified 15 studies that investigated the relationship between mahjong playing and older adults with clinical conditions. Thirteen studies reported that mahjong playing was a protective factor for older adults with cognitive impairment (Guo et al., 2020; Qiu et al., 2019; Sun et al., 2023), MCI (Wang, Cao, Deng, et al., 2017; Xue et al., 2012), dementia (Cao, Wang, et al., 2017a), AD (Shi et al., 2012), Parkinson's Disease (Juan. Wang et al., 2020), ADL impairment (Cai et al., 2020), and depression (Ayijiamali et al., 2015; Tang et al., 2021). These findings suggested that mahjong playing could potentially lead to better cognitive, psychological and daily functions in these older adults. However, the mechanism of how mahjong playing brought about these benefits in older adults remains unclear, highlighting the need for further investigations.

7.3.2.2.5 Effectiveness of Mahjong Intervention. The scoping review also evaluated the interventional effectiveness of mahjong playing in older adults. Four RCTs and two non-RCTs were included, in which they showed that mahjong intervention could improve general cognitive abilities (small to large effect sizes), performance in specific cognitive tasks (small to large effect sizes), EF (either small or large effect sizes), psychological and daily functions (medium to large effect sizes). These findings suggested that, as an intervention, mahjong playing is effective in enhancing age-related declines. Nevertheless, the intervention studies have predominantly targeted clinical populations, such as older adults with dementia, leaving the effectiveness in healthy populations largely uncertain (Cheng et al., 2006; Cheng, Chow, Song, Yu, Chan, et al., 2014; Cheng, Chow, Song, Yu, & Lam, 2014; Cheng et al., 2012). Further studies are required to examine whether participation in mahjong playing can contribute to the accumulation of cognitive reserve in healthy older adults. Moreover, these studies also did not clarify whether the cognitive or social components of mahjong playing actively contribute to its effectiveness. The neural basis of mahjong playing also remained unclear.

So far, these findings from Study 1 and Study 2 have addressed the first and the fourth research gaps as outlined in section 3.3.2 (i.e., the first: mahjong playing and EF; the fourth: mixed findings on the benefits of mahjong playing in older adults). However, as highlighted in the scoping review, the existing literature has not yet explored the (i) mechanisms of mahjong playing and (ii) its associated neural activations. Study 3 was proposed to address the remaining gaps.

7.3.3 Relationship between Mahjong Playing and EF: An Examination of Behavioural Manipulation and Its Neural Basis

Given the complexity of the game rules and the involvement of cognitive processes (Cheng et al., 2006), it was reasonable to suggest that the players need to utilise EF skills and activate the brain areas corresponding to EF during mahjong playing. Study 1 and Study 2 have demonstrated that participating in mahjong playing could predict EF and ameliorate age-related EF declines, respectively. Nevertheless, a more direct approach is required to address the remaining research gaps concerning mechanisms and neural activation. Therefore, an experimental study (Study 3) employed both behavioural and neural measures was conducted to elucidate the underlying mechanisms of how mahjong playing is related to EF in older adults.

7.3.3.1 Manipulations of the Cognitive Component of Mahjong Playing and Its Resemblance to EF Tasks. Two versions of computerised mahjong games (i.e., working memory and switching games) were developed to investigate their relationships with the updating and switching components of EF as measured by experimental tasks and neuropsychological tests. Findings supported the manipulations of the games, indicating that high working memory load in the working memory game and mixed block in the switching game revealed poorer behavioural performances when compared to low working memory load and pure block, respectively. It is primarily due to the two games were designed using the concepts of updating and switching outlined in the literature (Miyake & Friedman, 2012; Owen et al., 2005; Ye & Damian, 2022); and the games exhibited similar characteristics to the EF tasks. On the one hand, manipulating the winning probability in the working memory game could utilise cognitive resources and lead to varying levels of cognitive demand akin to the *n*-back Task (i.e., updating task). On the other hand, switching the current targeted tile to an additional tile to maximise the winning probability is similar to the Color-Shape Task (i.e., switching task).

However, it is noted that in terms of neural evidence, only the high working memory load exhibited higher prefrontal activation compared to the low working memory load in the working memory game; and no significant difference was observed between the mixed block and pure block in the switching game. While both behavioural and neural evidence showed significant manipulation effects on the working memory load, it suggested that the working memory game involves updating of EF. Unexpectedly, the neural outcomes of the switching game did not demonstrate significant manipulation effects similar to the behavioural outcomes. It may be due to the mixture of switch and no-switch trials in the mixed block, resulting in insufficient contrast between the mixed and pure blocks. Additional analyses on the switching cost (i.e., the difference between the switch and repeat/no-switch trials; Eckart et al., 2023) are warranted for further investigation. These promising findings have provided preliminary evidence to support the relationship between the cognitive component of mahjong playing and EF.

7.3.3.2 Correlations between Mahjong Playing and EF. In addition to the task manipulations, Study 3 showed that both the behavioural and neural measures of the working memory game were associated with the updating measures, while only the neural measure of the switching game was associated with the switching measures. In behavioural measures, the reaction time of the working memory game was positively correlated with the reaction time of the *n*-back Task. In neural measures, the prefrontal activations during the working memory game showed a significant correlation with the *n*-back Task, and the prefrontal activations during both games exhibited significant correlation with the performance on neuropsychological EF tests. It suggested that the working memory game was associated with the *n*-back Task, and increased activations during the mahjong games were associated with poorer neuropsychological updating and switching test performances in younger adults. Conversely, in older adults, an increased activation during the mahjong games, especially switching game, was associated with better performance in the switching measure (i.e., CTT). The findings have offered another piece of preliminary evidence to further support the relationship between mahjong playing and EF, especially neural activations were measured in the dlPFC, which is an important area supporting EF (Diamond, 2013; MacPherson et al., 2002; Miyake & Friedman, 2012; Nejati et al., 2018; Salehinejad et al., 2021). While the behavioural measures of the switching game and switching measures were not correlated, it may suggest that they are not directly related to each other. However, it is noteworthy that the correlation coefficient between the reaction time of the switching game and the reaction time of the Color-Shape Task was 0.3 in younger adults (p = .081), indicating a small to medium effect size between the two. With a limited sample size in the correlational analyses (n = 34 after removing outliers), the absence of significant correlation may be due to insufficient power. In sum, these preliminary findings regarding the correlations between mahjong playing and EF suggested similarities between the two. More studies with larger sample sizes are needed to further reaffirm the results, especially for the switching of EF.

7.3.3.3 Neural Basis of Mahjong Playing. The results were similar between the mahjong games and computerised EF tasks, except that the mahjong games displayed no significant age difference in behavioural performance. Consistent with the literature, it was found that older adults were experiencing neural inefficiency (Roberto Cabeza et al., 2018), wherein supplementary prefrontal activations are utilised to compensate for behavioural performance, resulting in an age-equivalent behavioural performance (Reuter-Lorenz & Cappell, 2008). This mechanism, known as compensation, helped to maintain age-equivalent behavioural performance in older adults, suggesting the presence of neuroplasticity. One noteworthy discussion arising from the findings could be that it remained unclear why compensation only occurred during the two mahjong games, despite the older adults showing age-related declines in EF in the computerised EF tasks (i.e., *n*-back Task and Color-Shape Task).

Regarding this variance, it is clear that the mahjong games were related to EF, but they are not exactly the same as the EF tasks/tests. The findings may suggest that mahjong may have unique characteristics or special qualities that set it apart.

As suggested by Roberto Cabeza et al. (2018), there could be an interaction between cognitive reserve and the capacity for compensation, indicating that a greater cognitive reserve could deploy a more effective compensatory process. One distinctive characteristic of mahjong playing is its requirement for effortful cognitive engagement within an enjoyable atmosphere. Unlike the *n*-back Task and Color-Shape Task, where participants have not developed fundamental skills necessary to perform them, they have acquired basic skills for playing mahjong. Therefore, older adults may have accumulated experiences and a greater cognitive reserve through mahjong playing, which enabled them to deploy a more effective compensatory process (i.e., maintain age-equivalent behavioural performance during the mahjong games but not during the EF tasks/tests). However, how mahjong playing facilitates the accumulation of cognitive reserve and consequently leads to a better compensatory process remains unclear. Four possible mechanisms are suggested: (i) enjoyment, (ii) expertise, (iii) novelty and (iv) familiarity.

7.3.3.3.1 Enjoyment. Mahjong playing is an enjoyable game among older adults. Compared to other activities, older adults are willing to spend time in the game and maintain it for a long time. As suggested by Rahman et al. (2019), these culturally specific activities offered intrinsic motivation to older adults, hence promoting a sustained engagement in the activities. In this connection, sustained engagement may have facilitated the accumulation of cognitive reserve, thus promoting a better compensatory process.

7.3.3.3.2 Expertise. While the enjoyment of the game has promoted sustained engagement, it is also possible that older adults have accumulated expertise or experience related to mahjong playing. Highlighting the characteristics of being a cognitively demanding game (Cheng et al., 2006), a sustained engagement in mahjong playing may offer mental exercise to older adults, as consistent with the qualitative findings in Study 2. Similar to chess playing, another intellectual and social leisure activity, was also found to promote better functions of ageing (Cibeira et al., 2021; Çol et al., 2022). It is suggested that the complexity of the game rules helped train the brain functions (Silver et al., 2018). These mental exercises arising from mahjong playing are proposed to facilitate the accumulation of cognitive reserve, resulting in a better compensatory process.

7.3.3.3.3 Novelty. Another feature of mahjong playing refers to the novelty, in which different combinations of stimuli are presented to the players in each game (Cheng et al., 2006). The novelty of mahjong playing may have facilitated new experiences for older adults, or it may offer the practice of cognitive flexibility to older adults during the game. In addition, this novelty may also facilitate the uncertainty and excitement of the game, which further motivates the engagement. Hence, it may foster the accumulation of cognitive reserve and promote a better compensatory process.

7.3.3.3.4 Familiarity. It is also possible that familiarity may have an impact on the accumulation of cognitive reserve.[37] Study 3 has reported an interesting interaction effect between the working memory load (low/high) and age group (younger/older), in which only the low load condition exhibited a significant age-

[37] Note that this concept of familiarity did not contradict the idea of novelty, as the two concepts could concurrently exist in the mahjong game. For example, players could build a flexible mahjong hand with more options to win and with different tiles each time, allowing the co-existence of familiarity and novelty.

related decline in EF in older adults. In other words, compensation only occurs in high load but not low load conditions. The possible explanation is related to familiarity, in which players are more likely to build a flexible hand with more options to complete the tile set (i.e., more familiar with high load than low load conditions). It may suggest that a higher level of familiarity may also facilitate the accumulation of cognitive reserve and result in a better compensatory process.

In summary, the findings suggested that mahjong playing is related to EF, and the neural basis further proposed the accumulation of cognitive reserve. However, it is believed that the mechanism of how mahjong playing accumulates cognitive reserve is more complex. The above-proposed mechanisms involve simple preliminary ideas and more research is needed, especially for the analyses with moderation and mediation. To properly confirm the idea of cognitive reserve, more longitudinal research that follows on the maintenance of cognitive performance is needed.

7.4 Contributions and Implications

This PhD project investigated whether engaging in leisure activities and one culturally specific activity, mahjong playing were related to better functions in older adults. The three studies yielded promising findings to support the claim and expanded the current state of the field.

First, this project has offered an important update on the nature and extent of leisure activity participation and found that the engagement pattern could change with time. The most recent study on leisure activity participation among older adults in Hong Kong was carried out at least 12 years ago (Zhao & Chen, 2013). During that period, older adults predominantly engaged in sedentary recreational activities, such as watching television and listening to the radio. This study revealed a shift in the engagement pattern among older adults, with more older adults engaging in using computers and surfing the Internet, while fewer older adults are participating in watching television and listening to the radio. This finding made a valuable contribution to the understanding of which activities are more common and easier to promote. For instance, the shift from recreational activity to intellectual activity suggested that some older adults were open to newly developed technologies, indicating that technology has become increasingly integrated into the daily lives of older adults. This finding highlights a potential benefit from digital literacy programs aimed at enhancing their technology skills. Future research could also investigate how technology usage might bridge the generation gap between younger and older adults, fostering communication between them and potentially preventing social isolation among older adults. For example, communication software (e.g., Zoom, Teams, and WhatsApp) could help to facilitate real-time communication between younger and older adults without geographical constraints. Wearable devices and health applications may also provide a platform for younger and older adults to share their health and physical conditions, which facilitates their social connections. Additionally, this project also introduced a novel dimension by measuring the duration of each activity among the older adults apart from the participation rate and frequency. Results showed that older adults have reported a longer duration of some culturally specific activities, such as mahjong playing and Chinese martial arts. It highlighted the significant role and enduring popularity of these activities among Hong Kong older adults.

Second, the current project has included a comprehensive investigation that not only focused on general cognition but also on EF (i.e., one higher-order cognitive function), psychological functions, and daily functions. Previous studies have placed a heavy emphasis on examining the relationship between leisure activity participation and cognitive functions (Iizuka et al., 2019; Opdebeeck et al., 2016; Rivera-Torres et al., 2021; Stern & Munn, 2010). This project has included other important functions. For example, EF is an important function for goal-directed behaviour and planning (Diamond, 2013), serving as an early indicator of age-related declines and closely related to the prefrontal lobe (West, 1996). The psychological and daily functions are also important domains to consider because they are related to a positive ageing experience (Kim & Park, 2017). The findings this study have provided a comprehensive investigation on how to promote better functions in older adults via leisure activity participation and mahjong playing. The comprehensive approach of outcome selection (i.e., including cognitive, psychological, and daily functions) also supports the “complexity of ageing” idea proposed by the Counterpart Theory (Birren, 1964). The findings also encourage cross-disciplinary collaboration among psychologists, neuropsychologist, psychiatrists, and occupational therapists to develop holistic intervention programs that target all three aspects of functions.

Third, the study also highlights and compares the roles of specific domains and dosages of leisure activity participation. Previous studies have typically focused on one or two domains of activities (Ahn et al., 2024; Liu et al., 2021; Lopez-Bueno et al., 2023; Qiu et al., 2019), with measurements often limited to frequency or a dichotomous classification of the participation (D'Orsi et al., 2014; Falk et al., 2014; Gao et al., 2018; Gu et al., 2023; Wang et al., 2021; Zhao et al., 2022). This study has systematically investigated four domains of activities (viz., intellectual, social, recreational, and physical activities) and three dosages of participation (viz., diversity, frequency, and duration). The findings suggested that engaging in leisure activity across multiple domains could offer cross-domain advantages, and varying levels of participation may predict functions in different ways. This highlights the importance of incorporating different extents of engagement in future studies. For example, more frequent but less diverse intellectual activity participation could predict reduced levels of depression, anxiety and stress in older adults. This novel finding allows practitioners to design and customise leisure activity promotion campaigns to facilitate better functions in older adults. For example, the results could provide guidelines for the Government and non-governmental organisations to promote the leisure activity participation in the specific domain of activities with the right dosage.

Fourth, this project scientifically investigated one culturally specific activity, mahjong playing and explored whether this popular activity could help to promote better functions in older adults. There is limited discussion about cultural differences in leisure activity participation, with previous studies mainly focused on culturally general activities, such as reading, playing bridge, or doing crosswords (Opdebeeck et al., 2016). As a popular activity, mahjong playing has received little research attention (unlike Tai Chi or Qigong, which are regarded as physical activities). While research in this field has just started to develop and the evidence is accumulating, the findings of this study have provided empirical evidence and contributed to the ageing literature with novel insights. Importantly, the study updated the prevalence rate of mahjong playing among older adults in Hong Kong. The last update was conducted 16 years ago (Cheung et al., 2009), and during that time, the duration of mahjong playing was not measured. This is the first study that measured the prevalence rate, frequency and duration of mahjong playing, and utilised these variables to predict the cognitive, psychological and daily functions of older adults. The statistics revealed that mahjong playing is an enjoyable leisure activity among older adults, but the prevalence rate is less than other common activities such as watching television and slow walking. It highlights the possibility of training those infrequent players and novices to actively exercise the brain and maintain activation of the neural resources during the game, further strengthening neural activation and accumulating cognitive reserve. Also, the duration of mahjong playing has been ranked second among other leisure activities. It highlighted the intrinsic motivation that the game offered to older adults for continued engagement. These findings suggested that mahjong playing could be a potential activity for promoting brain health and fostering active participation among older adults in Hong Kong. Practically, as mahjong playing allows older adults to encounter new stimuli and devise different winning strategies in each game, practitioners could develop appealing programs to sustain or enhance the participation of older adults. Future studies could also explore the development of digital health applications or gamified cognitive training utilising mahjong to enhance/maintain cognitive, psychological and daily functions among older adults.

Fifth, previous research related to mahjong playing has predominantly concentrated on general cognition (Ho & Chan, 2005; Mai et al., 2023; Mao et al., 2020; Yu et al., 2021; Zhang et al., 2023). In contrast, this study bridged a gap by extending the focus from general cognition to EF. Investigating EF provided a more detailed understanding of how mahjong playing is related to higher-order cognitive functions (Diamond, 2013). The findings clarified the relationship between mahjong playing and EF, suggesting that some mahjong playing processes were related to updating and switching components of EF. It also showed that mahjong playing was associated with an increased activation in the prefrontal area, especially in older adults. The frontal lobe hypothesis of cognitive ageing suggested that the prefrontal lobe is the first area to show deterioration in normal ageing (West, 1996). Therefore, extending the research area from general cognition to EF helps to better understand the potential cognitive benefits of mahjong playing.

Sixth, previous studies considered mahjong playing as a general leisure activity and did not examine specifically its cognitive or social characteristics in the research questions (Chou et al., 2004; Deng et al., 2018; Lee et al., 2020; Mao et al., 2020; Ren et al., 2023; Sha et al., 2022; Tang et al., 2021; S. Wang et al., 2022; Yu et al., 2021; Zhao et al., 2023). This study offered the first attempt to elucidate the functional mechanisms of mahjong playing. The current study focused on the cognitive component and examined its relationship with updating and switching of EF. Findings suggested that it was similar to the updating and switching of EF with successful manipulations in the working memory game (i.e., manipulating the winning probability in the mahjong hand) and the switching game (i.e., ability to notice an opportunity to switch the tile and maximise the winning probability). The two games also reported significant associations with the EF tasks/tests. This may contribute to the development of engaging EF training for older adults.

Seventh, this project also offered the first attempt to examine the neural correlates of the relationship between mahjong playing and EF, suggesting that the two are related but not interchangeable. The findings supported that older adults increased prefrontal activations to compensate for better behavioural performance in the games, which elucidated the neural mechanisms of mahjong playing (i.e., accumulating cognitive reserve and compensation). Specifically, older adults utilised overactivation with less lateralised patterns to compensate for behavioural performance, which supported the influential ageing models such as CRUNCH (i.e., overactivation in the prefrontal area to compensate for the age-related behavioural decline) and HAROLD (i.e., dedifferentiation of brain activation to improve behavioural performance; Cabeza, 2002; Reuter-Lorenz & Cappell, 2008). These neural findings provide support to the models of neural compensation, showing that mahjong playing may be an effective strategy to overcome the neural inefficiency associated with cognitive ageing. Hence, the current findings supported the idea that "mahjong playing may foster cognitive stimulation related to EF and facilitate the neural compensation to improve better functions of older adults".

Finally, the project provided empirical evidence to support the benefits of leisure activity participation and mahjong playing for cognitive, psychological and daily functions. According to STAC and STAC-r, life-course enrichment factors (e.g., experience and active lifestyles) are crucial to foster better effective scaffolding and maintenance of cognition (Park & Reuter-Lorenz, 2009). The current findings supported that leisure activity participation and mahjong playing are effective strategies to accumulate experience and promote active lifestyles (i.e., intellectual engagement helped to facilitate neural resource enrichment, thus, preserving the level of cognitive functions via compensation; Reuter-Lorenz & Park, 2014). They also provided extension on the counterpart theory (Birren, 1964; as summarised in section 2.2.1) and the theory of selection, optimization and compensation (Baltes, 1987; as summarised in section 2.2.2), which suggested that an increased experience would foster plasticity in ageing and promote better ageing process (Baltes, 1987; Birren, 1988). It has also extended on which type of leisure activities and what dosage of participation were effective in accumulating cognitive reserve and resulting in better functions of ageing.

7.5 Limitations and Recommendations for Future Research

This PhD project has a few limitations that future research should address. First, only EF was considered as a higher-order cognitive function in this thesis. Other higher-order cognitive functions such as prospective memory, planning, problem-solving and decision-making, were not examined in this PhD study. Future research may consider expanding the investigation into the complex cognitive functions in addition to EF. It would provide valuable insights into the literature on strategies for maintaining and mitigating age-related cognitive decline in higher-order cognitive functions.

The current project, particularly Study 1, mainly included correlational evidence, which provided limited insights into causal relationships. To better understand if leisure activity participation and mahjong playing could mitigate age-related declines, additional studies with interventions are suggested. Another critical point to consider is that this study also offered limited insights into the directions and interactions among the three types of functions (viz., cognitive, psychological and daily functions). It remains unclear whether the cognitive benefits were being derived before the psychological and functional benefits; or the other way around. Further studies are recommended to explore the dynamics of these functions, and investigate whether benefits are generalised from cognitive functions to psychological and daily functions.

Another limitation relates to the cross-sectional designs of the study. The current studies only applied cross-sectional designs and could not investigate the long-term impact of leisure activity participation. To further elucidate whether the effect could last for a longer period and whether early life participation is important, future research is suggested to apply a longitudinal design, with younger and middle-aged adults, to examine the long-term effects of leisure activity participation on cognitive maintenance. It may be one prospective avenue for future research and the investigation could be ongoing.

The research may also consider investigating other types of culturally specific activities apart from mahjong playing, such as Tai Chi and calligraphy. Given that culturally specific activities offer intrinsic motivation to older adults to sustain their participation (Rahman et al., 2019), it is valuable to examine if other types of culturally specific activities would show a similar positive effect as mahjong playing.

Besides, it is also important to compare the effects of mahjong playing on other activities, such as similar culturally specific physical activity (i.e., Tai Chi), similar intellectual activity (i.e., playing board games), another type of intellectual activity (i.e., playing musical instruments) and recreational activity (i.e., listening to music). Similar to mahjong playing, older adults who engaged in Tai Chi were found to report better cognitive functions (Liu et al., 2025), better sleep efficiency (Siu et al., 2021), lower perceived stress (Yu et al., 2014), and better health-related quality of life (Lee et al., 2009; 2010). Playing board games could help to improve global cognition, EF and well-being in older adults (Chen et al., 2022; Guardabassi et al., 2024). Music interventions for older adults could also have positive effects on psychological well-being and cognitive functions (Ma & Ma, 2023). Therefore, future studies may compare and contrast the beneficial effects across these activities and find out the active components that facilitate the benefits for older adults. Future research may also examine the effectiveness of leisure activity programs that are designed for multiple health domains (i.e., cognitive, psychological and daily functions).

7.6 Conclusion

This PhD project investigated whether leisure activity participation and mahjong playing are associated with better functioning in older adults. Findings of the project highlighted that both might be effective in accumulating cognitive reserve and promoting better functions of ageing. Importantly, it offered a comprehensive investigation of the topic of leisure activity participation, including the clarification of the effective domains of activities and dosages of engagement. It also offered a scientific investigation of understanding the benefits of mahjong playing and elucidating the underlying neural mechanism. The evidence supported prefrontal involvement during the two mahjong games, and compensation (as reflected by increased cortical activation) has occurred to facilitate an age-equivalent performance between younger and older adults. It is also possible that mahjong playing has helped to accumulate cognitive reserve, which further facilitated the compensation and resulted in better functions of ageing. Future research and practitioners may utilise this popular culturally specific activity, mahjong playing, to design more engaging interventions for older adults. In summary, it is concluded that leisure activity and mahjong playing could be potential strategies to promote better functions in older adults.

Appendices A

Study 1: Ethics Approval and Supplementary Table

Ethics Approval from the Hong Kong Polytechnic University

From: institutional.review.board@polyu.edu.hk <institutional.review.board@polyu.edu.hk>
Sent: Monday, April 22, 2024 10:24 AM
To: SHUM, David [FHSS] <david.shum@ >
Cc: Fong, Kenneth [RS] <kenneth.fong@ >; Chung, Vangie [RS] <vangie.chung@ >; YEE, Benjamin [RS] <benjamin.yee@ >; Man, Gloria [RS] <gloria.man@ >; Mok, Dennis [RS] <dennis.mok@ >
Subject: Application result (HSEARS20210302003-02)

Dear Shum Ho Keung David

Please note that the following request for changes in the application for human ethics approval has been approved:

Project Title: The Relationships Between Leisure Activity Participation and Cognitive, Psychological and Functional abilities in Older Individuals: A Survey Study
Application Number: HSEARS20210302003-02 (Click here to view the application)
Principal Investigator: Shum Ho Keung David
Department: Department of Rehabilitation Sciences
Approver / Delegate: Yee Kay Yan Benjamin

Human Subjects Ethics Application Review System
(It is a system-generated message. Please do not reply to it)

c.c. Approver / Delegates

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Table A4.1

Classification of Leisure Activities from G. T. Y. Leung, K. F. Leung, et al. (2011)

Domain(s)	Leisure activity
Intellectual	1. Reading books, newspapers, or magazines
	2. Using computer or surfing the Internet
	3. Playing board games
	4. Playing mahjong
	5. Playing card games
	6. Gambling
	7. Investment or following the stock market
	8. Participating in forums or discussions
	9. Writing
	10. Calligraphy
	11. Painting
	12. Handicraft (e.g. knitting and needlework)
	13. Playing a musical instrument
Social	1. Attending an interest class
	2. Joining a social centre
	3. Participating in volunteer work
	4. Going to museums, exhibitions, theatres or concerts
	5. Meeting relatives or friends
	6. Drama or Chinese opera performance
	7. Singing
	8. Attending religious activities
Recreational	1. Watching television
	2. Listening to the radio
	3. Listening to music
	4. Shopping
	5. Cooking for pleasure
	6. Fishing
	7. Keeping plants
	8. Keeping pets
	9. Facials or massage
Physical	1. Mind-body exercise
	• Tai chi
	• Qi gong
	• Yoga
	• Other Chinese-style mind-body exercise(s)
	2. Strenuous aerobic exercise
	• Chinese martial arts
	• Jogging or running
	• Stair climbing
	• Swimming
	• Hiking or excursions
	• Bicycling or using exercise machines
	• Playing ballgames or racquet sports
	• Callisthenics
	• Dancing
	3. Stretching and toning exercise
	• Slow walking, pebble trail walking, general stretching and toning exercise

Appendices B

Study 2: An Example Search Strategy and Supplementary Table

An Example Search Strategy in Web of Science

TS=((mahjong OR mahjongg OR mah-jongg OR "Mah Jong" OR "Pung Chow" OR "tile-based game*" OR tile-based) AND ("older adult*" OR age* OR aging OR elder* OR senior OR "older people" OR "old age*" OR geriatric OR gerontolog* OR senile OR old))

Table B5.1

Effect sizes for Intervention Studies

Study	Outcomes	Metrics extracted from the study			Converted to Cohen's *d*		
		Group	Time	Interaction	Group	Time	Interaction
Cheng et al. (2006)	MMSE	N/A	Baseline to post-test: • 2X: $d = 0.58$ • 4X: $d = 0.58$ Baseline to 1-month follow-up: • 2X: $d = 0.49$ • 4X: $d = 0.66$	N/A	N/A	N/A	N/A
	Forward Digit Span	N/A	Baseline to post-test: • 2X: $d = 1.36$ • 4X: $d = 0.98$ Baseline to 1-month follow-up: • 2X: $d = 1.33$ • 4X: $d = 1.56$	N/A	N/A	N/A	N/A
	Forward Digit Sequence	N/A	Baseline to post-test: • 2X: $d = 1.48$ • 4X: $d = 0.97$ Baseline to 1-month follow-up: • 2X: $d = 1.39$ • 4X: $d = 1.56$	N/A	N/A	N/A	N/A
	Auditory Verbal Learning Test (trial 1)	N/A	Baseline to post-test: • 2X: $d = 0.52$ • 4X: $d = 0.92$ Baseline to 1-month follow-up: • 2X: $d = 1.06$ • 4X: $d = 1.06$	N/A	N/A	N/A	N/A

Table B5.1 (*continued*)

Study	Outcomes	Metrics extracted from the study			Converted to Cohen's *d*		
		Group	Time	Interaction	Group	Time	Interaction
	Auditory Verbal Learning Test (trial 2)	N/A	Baseline to post-test: • 2X: *d* = 0.25 • 4X: *d* = 0.47 Baseline to 1-month follow-up: • 2X: *d* = 0.73 • 4X: *d* = 0.72	N/A	N/A	N/A	N/A
	Auditory Verbal Learning Test (trial 3)	N/A	Baseline to post-test: • 2X: *d* = 0.15 • 4X: *d* = 0.15 Baseline to 1-month follow-up: • 2X: *d* = 0.68 • 4X: *d* = 0.65	N/A	N/A	N/A	N/A
	Auditory Verbal Learning Test (trial 4)	N/A	Baseline to post-test: • 2X: *d* = 0.04 • 4X: *d* = 0.03 Baseline to 1-month follow-up: • 2X: *d* = 0.10 • 4X: *d* = 0.44	N/A	N/A	N/A	N/A
	Auditory Verbal Learning Test (trial 5)	N/A	Baseline to post-test: • 2X: *d* = -0.15 • 4X: *d* = 0.25 Baseline to 1-month follow-up: • 2X: *d* = 0.32 • 4X: *d* = 0.40	N/A	N/A	N/A	N/A

Table B5.1 (*continued*)

Study	Outcomes	Metrics extracted from the study			Converted to Cohen's *d*		
		Group	Time	Interaction	Group	Time	Interaction
Cheng et al. (2012)	GDS*	vs. control: *d* = -1.06 vs. Tai Chi: *d* = -0.68	*d* = -0.82		-1.06	-0.82	-0.57
Cheng et al. (2014a)	MMSE	*B* = 2.24 (0.36, 4.12)	N/A	*B* = 1.48 (0.83, 2.12)	0.40	N/A	0.77
	Forward Digit Sequence	*B* = 0.69 (0.06, 1.04)	N/A	*B* = 0.66 (0.34, 0.98)	0.48	N/A	0.69
	Backward Digit Sequence	*B* = 0.47 (-0.04, 0.98)	N/A	*B* = 0.08 (-0.19, 0.35)	0.31	N/A	0.10
	Forward Digit Span	*B* = 0.78 (0.19, 1.36)	N/A	*B* = 0.67 (0.28, 1.06)	0.45	N/A	0.58
	Backward Digit Span	*B* = 0.62 (-0.04, 1.28)	N/A	*B* = 0.19 (-0.15, 0.53)	0.32	N/A	0.19
	Verbal memory – immediate recall	*B* = 0.31 (-0.03, 0.65)	N/A	*B* = 0.13 (-0.08, 0.33)	0.31	N/A	0.21
	Verbal memory – delayed recalled	*B* = 0.21 (-0.96, 1.38)	N/A	*B* = 0.37 (-0.03, 0.77)	0.06	N/A	0.31
	Categorical Fluency	*B* = 3.46 (1.02, 5.90)	N/A	*B* = 1.13 (-0.29, 2.54)	0.48	N/A	0.27
Cheng et al. (2014b)	CDR-sum-of-box*	*B* = -0.33 (-2.75, 2.1)	N/A	*B* = -0.45 (-0.88, -0.02)	-0.04	N/A	-0.34
	CDR – cognition*	*B* = 0.43 (-1.51, 2.35)	N/A	*B* = -0.09 (-0.33, 0.15)	0.07	N/A	-0.12
	CDR – functioning*	*B* = -0.66 (-1.59, 0.28)	N/A	*B* = -0.06 (-0.30, 0.19)	-0.23	N/A	-0.08
Lu et al. (2015)	STM-immediate block span	*β* = -0.05, *SE* = 0.05	N/A	*β* = 0.3, *SE* = 0.03	-0.10	N/A	0.62
	STM-correct numbers	*β* = 0.03, *SE* = 0.25	N/A	*β* = 1.89, *SE* = 0.25	0.06	N/A	2.33
	STM-incorrect numbers*	*β* = -0.57, *SE* = 0.31	N/A	*β* = -1.02, *SE* = 0.13	-1.37	N/A	-10.04
	STM-sequencing errors of numbers*	*β* = -0.21, *SE* = 0.3	N/A	*β* = -0.51, *SE* = 0.16	-0.42	N/A	-1.17
	STM-omitted numbers*	*β* = 1.43, *SE* = 1.1	N/A	*β* = -3, *SE* = 1.25	2.77	N/A	-2.10
	Attention-average reaction time*	*β* = 0.02, *SE* = 0.43	N/A	*β* = -0.1, *SE* = 0.02	0.04	N/A	-0.20
	Attention-misidentification reaction frequency*	*β* = 1.42, *SE* = 1.47	N/A	*β* = -4.26, *SE* = 0.59	2.79	N/A	-2.04
	Attention-neglect reaction frequency*	*β* = 1.8, *SE* = 1.33	N/A	*β* = -4.23, *SE* = 0.54	2.38	N/A	-2.04
	Logical reasoning	*β* = -1.18, *SE* = 1.08	N/A	*β* = 5.27, *SE* = 0.53	-3.73	N/A	2.02
Zhang et al. (2020)	MoCA	N/A	N/A	N/A	0.44	0.81	1.26
	STT*	N/A	N/A	N/A	-0.29	-0.33	-1.43
	FAQ*	N/A	N/A	N/A	-1.01	-0.48	-1.31

Note 1. MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; GDS = Geriatric Depression Scale; CDR = Clinical Dementia Rating; STM = short-term memory; STT = Shape Trial Test; FAQ = Functional Activities Questionnaire; 4X = four times a week; 2X = two times a week; *B* = unstandardised beta, *β* =

standardised beta; SE = standard error; *d* = Cohen's *d*.

Note 2. The *d* (Group) represents the effect size between the treatment (Mahjong) and control group, *d* (Time) represents the effect size between the pretest and posttest of the treatment group, *d* (Interaction) represents the interaction between group and time. The $d > 0.2$, 0.5 and 0.8 are interpreted as small, medium and large effect sizes, respectively.

Note 3. Effect sizes were computed and estimated according to Lipsey & Wilson (2001). If the correlation *r* between the pretest and posttest scores was not reported in the article, it was assumed as 0.5 in the computation.

* Higher score represents poorer performance.

Appendices C

Study 3: Ethics Approval and Demographic Questionnaires

Ethics Approval from the Hong Kong Polytechnic University

From: institutional.review.board@polyu.edu.hk <institutional.review.board@polyu.edu.hk>
Sent: Wednesday, 9 March 2022 2:53 PM
To: SHUM, David [FHSS] <david.shum@ >
Cc: Cheng, Andy [RS] <andy.cheng@ >; Chung, Vangie [RS] <vangie.chung@ >; LO, Alexandra [RS] <alexandra.lo@ >; YEE, Benjamin [RS] <benjamin.yee@ >; Man, Gloria [RS] <gloria.man@ >; Mok, Dennis [RS] <dennis.mok@ >
Subject: Application Result (HSEARS20211004005)

Dear Shum Ho Keung David

Please note that the following application for human ethics approval has been approved:

Project Title: The Relationships Between Playing Mahjong and the Executive Functions: Evaluation of Behavioural and Neural Evidence
Application Number: HSEARS20211004005 (Click here to view the application)
Principal Investigator: Shum Ho Keung David
Department: Department of Rehabilitation Sciences
Approver / Delegate: Yee Kay Yan Benjamin

Human Subjects Ethics Application Review System
(It is a system-generated message. Please do not reply to it)

c.c. Approver / Delegates

85th THE HONG KONG POLYTECHNIC UNIVERSITY 香港理工大學

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Demographic Questionnaires

基本資料

參加者編號：________　　受訪日期：____年____月____日

此問卷共分兩部分，答案沒有對與不對。您的答案是不記名和保密，所提供的資料只供研究之用。

1. 基本資料

中文姓名：________　　性別：男／女／其它

出生日期：____年____月____日　　年齡：____歲

電話號碼：________　　電郵：________________

受教育年數（不計幼稚園）：____年　最高學歷：________

母語：廣東話／普通話／其他（請註明）：________　　流利廣東話：是／否

現在職業（或退休前職業）：________

吸煙習慣：

☐ 從來冇

☐ 冇，已戒煙（戒煙年數？____年）

☐ 有（平均每日食多少支煙？____枝）

飲酒習慣：

☐ 從來冇

☐ 冇，已戒酒（戒酒年數？____年）

☐ 有（平均每週飲多少酒？次數：____；

每次飲什麼、飲多少：

種類：______；多少杯/罐/瓶: ______；容器：______；每杯/罐/瓶多少毫升：______

種類：______；多少杯/罐/瓶: ______；容器：______；每杯/罐/瓶多少毫升：______

	慣用手（在適當的方格上加剔號）				
	只用左手	**多數用左手**	**左右手共用**	**多數用右手**	**只用右手**
寫字					
丟球					
刷牙					
使用湯匙					

你有人臉辨識困難嗎？

☐ 冇　☐ 有 (曾接受評估：☐ 冇; ☐ 有)

2. 病歷和藥物記錄

有否曾經西醫或者其他醫護人員確診以下病症，並服食相關藥物？

如無，請圈「無」；如有，請圈「有」，並填寫相關資料。

		如有，請填：					
		列明病症	有否服藥	服食年數	藥名	服食次數	每次服食份量
1. 腦損傷（中風／腦積血／腦出血／其他腦部創傷）	無 / 有						
2. 腦部疾病（腦退化症／柏金遜症／癲癇症）	無 / 有						
3. 精神病（抑鬱症／焦慮症 ／精神分裂／自閉症／注意力缺乏／過度活躍症）	無 / 有						
4. 高血脂（高膽固醇）	無 / 有						
5. 糖尿病	無 / 有						
6. 高血壓	無 / 有						
7. 心血管疾病（心臟病／冠狀動脈症候群／心絞痛）	無 / 有						
8. 肺病（肺炎／哮喘／肺結核／慢性阻塞性肺病）	無 / 有						
9. 內分泌疾病（甲狀線疾病）	無 / 有						
10. 腎病	無 / 有						
11. 癌症	無 / 有						
12. 其它慢性疾病	無 / 有						
13. 視覺改變	無 / 有						
14. 聽覺改變	無 / 有						
15. 過去三個月，有否服食其他處方或精神科藥物	無 / 有						

- **有否興趣參加本研究室未來所舉辦的研究計劃？**

☐ 有（圈出首選聯絡方式：電郵／Whatsapp／電話）

☐ 無

- 請問你有多常打麻雀？

  ☐ 過去一年有數次（請註明次數:__________）

  ☐ 每月數次（請註明次數:__________）

  ☐ 每星期

  ☐ 每星期數次（請註明次數:__________）

  ☐ 平均每日

- 請問你每次打麻雀打多久?

  ______________小時______________分鐘

- 請問你打麻雀多少年了?

  ________________年

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