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A Mobile Game for the Social and Cognitive Well-Being of the Elderly in China

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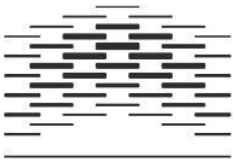

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Preface and Acknowledgement

By 2015, there were appropriately 143.86 million people aged over 65 years old in China, account for around 10.5% of Chinese population (Statistical, 2016). World Health Organization predicted the proportion of Chinese aged over 60 years old will double from 12.4% (168 million) to 28% in 2040 (402 million) (WHO, 2015a). Such tremendous increase of elderly population imposes great strain on the efforts to promote well-being of them. In this project, I would like to contribute to the social and cognitive well-being of Chinese elderly population.

Sincere gratitude is expressed to every participant who engaged in this study. Without their actively participation, this project could not be carried on smoothly, from user requirement study to iterative design and development, and to final evaluation. Their constructive feedback and suggestions contributed to designing this accessible and usable mobile game. Besides, thanks to encouragement and support provided by supervisor, Professor Weiqin Chen, I could keep going when times were tough. This research could not be accomplished successfully without her valuable guidance, asking insightful questions and offering professional advices. Furthermore, immense appreciation to my school, Oslo and Akershus University College of Applied Science for offering me a marvelous opportunity to major in universal design of ICT.

A research paper "*Designing a mobile game for social and cognitive well-being of the elderly*" based on this project has been accepted as a full paper by the AAATE 2017 (The Association for the Advancement of Assistive Technology in Europe) (Appendix H).

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Nan Li

Abstract

This project describes the design and development process for a social and cognitive mobile game and user evaluation in terms of well-being. The objective is to explore underlying connections between game playing and improvement in well-being. A series of literature reviews demonstrates the probability of conducting a study of this nature from several aspects including acceptance of IT products and services among elderly adults, current health-related technology, age-related issues and user interface design principles for the elderly. Following guidelines defined by a user-centred design methodology, the study was conducted in three phases: (1) user requirement study (2) game design and prototype development and (3) final evaluation. In the first phase, Gobang was voted as the target game and participants were invited to examine usability issues. Combined with a heuristic evaluation and semi-structured interviews, preliminary design requirements were gradually specified for the second phase. Next, a prototype was designed and developed in iterations. Each iteration comprised three components: (1) reconsideration of design requirements (2) development of enhanced prototype and (3) user evaluation. Over six iterations, most usability and accessibility issues were resolved and functionality integrated. A final evaluation was conducted in two parts. First, a heuristic evaluation was implemented to examine the game's theoretical performance in terms of usability and accessibility. Second, six evaluators (including new participants) were required to play the game throughout a three-week evaluation period. A combined WHO-5 index test and semi-structured interview were performed to assess participants' farewell condition before and after the evaluation period. Interviews were conducted on a weekly basis to observe differences in daily activities relevant to game playing and social interaction. The results of the final evaluation indicate that participants experienced an enhanced sense of well-being after the three-week play period. A promoted feeling was derived from the following aspects: new entertainment activity, additional pleasure and relaxation, strengthened interpersonal relationships and extended social networks scale. In sum, elderly participants

were considerably satisfied with their game playing experiences and positively affected in terms of well-being and quality of life.

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1 Introduction

Contemporary society has been walking into an aging time. According to data released by the World Health Organization (WHO, 2015b), the number of people aged over 60 years is 0.9 billion, which is about 12.3% percentage of the global population, and this proportion is expected to increase to 20% by the end of 2050, with the number of old adults (60 years and above) exceeding that of teenagers (15 years and below). Population aging appears to be more severe in developing countries. For instance, in China, the pace of aging is accelerating considerably faster than that in many other countries. The average life

expectancy in 2015 was 75.3 years compared to the 44.6 years in 1950 and this value is predicted to reach approximately 80 years by 2050. As people age, they tend to interact less frequently with members of their existing social networks, such as colleagues, friends, neighbours and even families. A possible reason is that some old adults live independently of their children, who move away for better education and employment opportunities. In addition, the number of individuals choosing to remain unmarried and have children is constantly growing. The combined effect of these family unit changes has led to an increase in the percentage of seniors who live alone. As per Europe's demographic statistics, more than 40% of women aged 65 years and above live independently.

Thus, it is imperative to identify new ways to help the elderly maintain social integration and improve their well-being. In this study, we focus on the designing of a mobile game for the elderly as a potential approach to achieve this goal. According to previous studies (Jung, Li, Janissa, Gladys, & Lee, 2009; B. D. Schutter & Abeele, 2010; Tiwari, Astheimer, & File, 2004), playing digital games contributes to the promotion of well-being. In addition, the gaming industry has experienced considerable development in the past decades. In 2016, gamers contributed $99.6 billion to the revenue of the global digital gaming industry, which is 8.5% higher than the value reported in the previous year. It was also the first time that the market share of mobile games exceeded that of PS games by 21.3% ($36.9 billion) (Newzoo, 2017). Mobile games are considerably increasing in number, quality and exposure. Owing to the rapid growth of mobile phone hardware and software over the past decades, consumers can access display effects generally experienced on a personal computer or play station on their smartphones. Today, mobile phone has become ubiquitous A survey conducted by TNS, a market research company, and commissioned by Facebook IQ found that people who play mobile games often are 2.7 times more likely to have a sense of community and belonging and twice as more likely to continue playing the game for social connection.

However, in the case of elderly people, game design must account for physical and cognitive deterioration, more specifically, possible usability barriers in the adoption of various digital products and services (Clarkson, Coleman, Keates, & Lebbon, 2013). For example, interface design in operating systems or applications do not offer adequate accessible features to address physical and cognitive limitations attributed to the natural aging process; this also hampers use experience. Thus, this study accounts for special requirements reported by the elderly. In particular, the elderly participated in the design and development process and recommended requirements for a user-centric design. Focus group interviews were conducted to define the type of game to be designed as per participants' preference. Next, user testing using similar games helped identify underlying problems related to usability and accessibility, which were avoided or resolved in our gaming designing. Next, prototype design and development was cyclically conducted. In each iteration, a prototype was evaluated by the focus group comprising different participants. The objective of doing so was to prevent participants from adapting to the accessibility issues and collect broader feedback from different use situations. Finally, a WHO-5 index test and semi-structured interviewed were performed to help understand if the elderly participants benefited from playing our social and cognitive game in terms of well-being.

The remainder of this paper is organized as follows. Section 2 reviews relevant research. Section 3 discusses the methodology adopted in this study, which includes user-centric design, user requirement study and user testing. Section 4 presents a schedule table indicating the implementation of this project. Section 5 lists the design requirements established during the user requirement study. Section 6 describes the implementation of the iterative design and development. Section 7 provides the results of the final testing consisting of a heuristic evaluation and semi-structured interviews. Section 8 discusses the final evaluation results, including a summary of the design criteria, findings from a comparative study and limitations of this study. Section 9 offers conclusions derived from the current work and recommendations for future work.

2 Literature review

2.1 Elderly population and penetration of IT

Due to manifest development of information technology and growing aging population, the prevalence of social media and mobile applications have potential to be a useful tool for elderly population to improve well-being. Increasing acceptance of smart phones, together with persistent efforts toward user-friendliness of smartphones and apps, have greatly empowered the marginalized group of elderly people to benefit from information technology.

In the report released in 2016 by Chinese Network Information Centre, China had 710 million Internet users up to June 2016, which had an increase of 21.32 million since June 2015. Internet penetration reached 51.7%, up 3.9 percentage point over one year ago. In terms of mobile Internet use, there were 656 million mobile Internet users in China by the end of June 2016. In rural area, netizen accounted for 26.9% of the national total, reaching 191 million. Besides, mobile netizen accounted for 92.5% of the total netizen population, while this percentage was 88.9% in June 2015, as shown in Figure 2.1 (CNNIC, 2016). Manifestly, mobile phone has become an important means to access to Internet while a decline was seen in the utilization ratio of desktop or laptop as means access to Internet. With the enlargement of screen size, improvement of processor performance and better Internet circumstance, the trend of mobile phones becoming the main Internet terminal of netizens is increasingly obvious. In America, the percentage of senior who own portable smart devices is increasing. More than half of elderly online users said that they are active on Facebook. 56% of online adults are over 65 years old, up from 45% a year early (maeve, Ellison, Cliff, Amanda, & Mary, 2015).

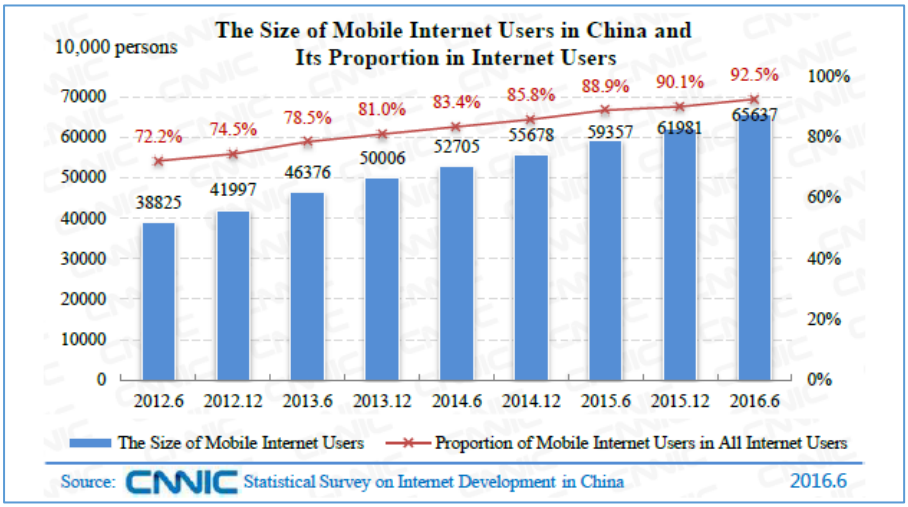

Figure 2.1 China's mobile Internet user scale and its proportion in total Internet user scale

Over last decades, the continuous development of Internet technology and social network has changed the way of communication and interaction; meanwhile, we are benefiting from various internet services, like online shopping, online video, email, remote education, advanced search engine and many other conveniences due to prevalence of information technology. However, not everyone is able to benefit fully from technology development. For instance, the elderly population with varying degrees of physical or cognitive deterioration or disabilities. The proportion of internet users over 50 years old was 4.3% (2015.6), decreased from 5.5% (2014.12) and the proportion of Internet users aged above 60 maintained at 2.4% from 2014 to 2015 (Figure 2.2). Namely, penetration of internet is still low among elderly people. Low acceptance impedes the wide range spreading of new technologies and results in the fact that elderly population cannot benefit from flourish of new technology. In addition, use of mobile phone is increasingly common, and becomes a requisite skill in contemporary life. It is very critical for our society in general to encourage the elderly to overcome any technology anxiety. The good news is that fast growth of mobile phone industry makes a smartphone more affordable with manifestly lower price, and mobile phone penetration is continuously growing among elderly people.

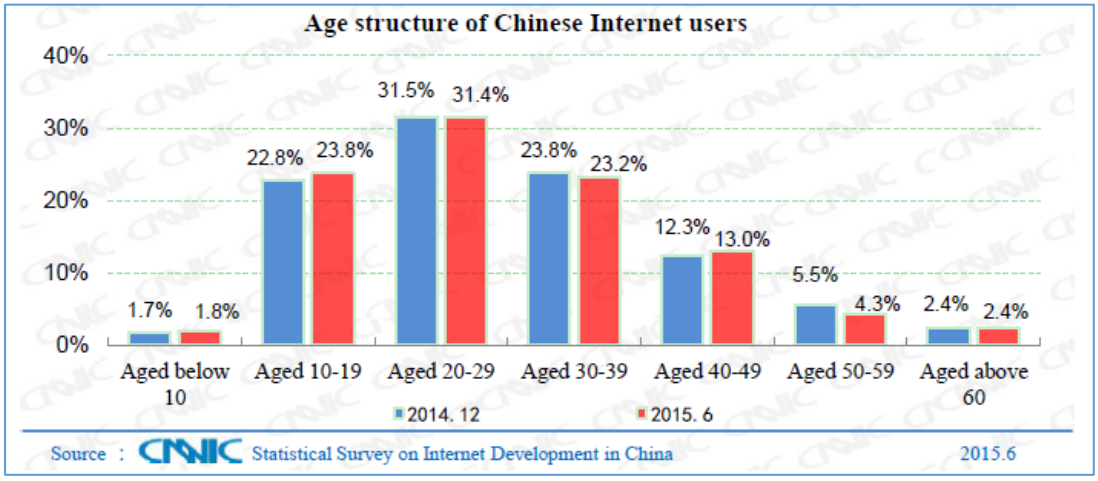

Figure 2.2 Age structure of Chinese Internet users

2.2 What affect the adoption of IT among the elderly?

Previous studies had confirmed that perceived usefulness and ease of use are two factors that have direct influence on acceptance of technology (Renaud & Van Biljon, 2008), while it is undeniable that information technology is playing an increasingly critical role in our daily lives in many aspects. People who access to Internet by smart devices can easily make a clear and fluent video call. Online shopping save time and money for customers, and prevalence of mobile online games enable people to enjoy great fun and pleasure at any time and in everywhere. Health related applications assist care givers to supervise elderly people to take medicine on time (Devos, Min Jou, De Waele, & Petrovic, 2015). Meanwhile, rapid development of information technology and computer science lowers the price of enjoying such services or life style, so increasing amount of population are capable to afford them. From a smartphone to a desktop, and even to an intellectual television, various kind of terminal equipment enable us acquire information, maintain interpersonal relationship, entertainment etc. in a more effective and convenient way. A research that relevant to the usage of blog denoted that perceived enjoyment is also a critical factor that could accumulate acceptance of information technology (Hsu & Lin, 2008).

Nevertheless, how to further popularize the use of information technology products and services among elderly population is still a tough problem. Elderly individuals have higher risk to confront obstacles while they enjoy new technology, because many products are designed without taking their special needs into consideration seriously. The elderly's resistance toward more extensive use of mobile application possibly originates from the lack of accessible and usable features. Excessive complexity in user interface or interaction logic can easily make elderly users overwhelming, and hesitated to try anymore (Kurniawan, 2008). Factors like aesthetical pleasure, semantic clarity, compatibility, comprehensibility, simplicity, terminology, navigability etc. that relevant to the ease of use deserve thorough consideration before carrying on design of interactive system. However, a thankful news is that mature legislation and well-defined criteria for ICT products or services lower the threshold of usage of computer-science techniques, and render guidelines for designers to normatively develop. Existing studies revealed that seniors have strong interests in modern technologies. They are not resistant to trying new techniques and learning new IT skills. Their confidence and self-esteem are very fragile and they dislike being labelled as "technophobic", so they are eager to keep step with modern society development and minimize the gap between the youngers and them. For instance, elderly people pointed out that exchanging information or images between younger generation and them is a vital motivator for them to learn and accept Internet and mobile technology (Romero et al., 2007).

2.3 Age related issues

Ageing process weakens people's capability physically and cognitively, and changes due to age may impact seniors' life quality and limit the extent to which they are capable to participate in routine activities. Similarly, disease another factor that leads to impairment or loss of perception, mobility or cognition ability.

2.3.1 Decline in physical and mental ability

Significant physical decline caused by aging occurs in most case as people gets older. The motor system decline slows down seniors' movements. Loss of vision makes them unable to see the world clearly. Auditory impairment is big obstacle to their formal communication. These inevitable issues destroy seniors' confidence and increase resistance to new technologies. For instance, limited size of keyboard and high accuracy of mouse operation have been the threshold they can hardly cross. A low contrast colour theme may account for that people with vision impairment cannot see clearly. So, that is the reason why W3C requires the contrast rate should be higher than 4.5:1. In the case of achromatopia, greyscale is the element deserves more consideration than others. Further, degeneration of physical functions limits seniors' action capacity and manifestly reduce well-being of later life. Some of them have to reduce outdoor activities and face the fact that high-accuracy operations, such as sewing, repairing or even cooking, have become a huge challenge for them. To reach a high level of accessibility, special demands from users, regarding age, gender, disability or other else, are worthy of serious consideration before development.

2.3.2 Decline in psychological ability

Seniors have higher risk than youngers suffering symptoms due to the decline of mental abilities, like concentrating, work memory, attention, reaction and something else which apparently impede improvement of well-being. For instance, they have difficulty in maintaining concentration over long periods and suffer declines on motor ability (Vasconcelos, Silva, Caseiro, Nunes, & Teixeira, 2012). In other words, seniors cannot benefit from information technology by using computer and smartphone as easily as young people do.

Loneliness, which is a common subjective complaint among seniors, is another aspect bothers their lives significantly (Eloranta, Arve, Isoaho, Lehtonen, & Viitanen, 2015). The prevalence of loneliness among seniors are apparent, about 25%, from 7% to 49% (Dr, Sanders, & Auth, 2004). The popular opinions of elderly people see them as an isolated group with strong need of familial connections. Sustainable bound with their family, friends and peer groups is the contributing factor to wellbeing of seniors (Lindley, Harper, & Sellen, 2008). However, they are restricted to maintain existing contacts or make new friends due to illness and mortality. Their social networks are shrinking because of their increasing frailty.

2.3.3 Seniors' memory features

Memory is cognitive structure that is classified into several abilities play into different tasks: short-term memory, long-term memory and working memory (Hawthorn, 2000). Take an example of working memory, it is believed to be responsible for information storage and process (Shah & Miyake, 1999), and is important for reasoning and the guidance of decision making and behavior. People depend on empirical knowledge and reasonable conjecture to make judgement, while decision making heavily relies on working memory.

Indeed, as people aging, they have increasing difficulties (speed and accuracy) in retrieving memories (Hasher & Zacks, 1988). Deteriorated memory, like working memory, makes it a challenge to remember a new skill or technique such as how to use applications on a mobile phone, because some elderly people are prone to forget what they learnt a few days or hours ago. It is not to say elderly population cannot achieve a goal or accomplish a task. Lots of scholars indicated that there is no concrete association between increasing age and impaired working memory (Salthouse, 1994; Salthouse & Meinz, 1995). The elderly can make decision and accomplish missions as well as the younger people. The remarkable difference is that elderly individuals always spend more time on remembering the process,

and retrieving useful information in their memories to help them finish a mission (Salthouse, 1994).

The changes to their memory also create barriers when they begin learning new technology. For example, interaction with user interface comprises a series of easy or complex actions and movements. It is a challenge for some elderly people to feel confident to act as needed, and they feel frustrated or confused when they make mistake (Zajicek, 2001). Similarly, previous study claimed that icon identification heavily relied on semantic memory, a kind of long-term memory, while reduction of semantic memory normally will only be mild until an extreme old age (Bristow, 2013). Nevertheless, elderly individuals still cannot successfully distinguish and understand the meaning of those icons loosely related to target items (Park, Smith, Morrell, Puglisi, & Dudley, 1990). Beyond that, scholars indicated a tendency of making choice of familiar items repeatedly among elderly people is prevalent. They strongly rely on heuristics and are reluctant to make extensive evaluation and consideration of whatever they are not familiar with (D. Kim & Jang, 2015).

2.3.4 Social support and loneliness

Social support is in reliable association with human health in many aspects (Berkman, Glass, Brissette, & Seeman, 2000), from physicality to mentality, and even to cognition. House et al. indicated that the mortality is higher among the people who perceived less social support (House, Landis, & Umberson, 1988).

Many situations cause decrements of social support, such as divorce, retirement, and bereavement. For example, widowhood is a noteworthy reason that stimulates the form of loneliness. The prevalence of loneliness among people who lost spouse improves the probability of suffering severe psychological issues, like depression. Because of the loss of self-care skills, some elderly people living in nursing home cannot obtain adequate social support, which account for their increasing loneliness. It is revealed that one third elderly home nursing residents seldom had been visited by others (Barry & Miller, 1980). After

some of them moved to nursing houses, they had fewer visitor six months after their relocation (Gueldner, Clayton, Schroeder, Butler, & Ray, 1993). Their children possibly had limited time to visit them due to pressure from employment and education. Besides, geographical location also generates barriers for people who live away from nursing house to visit parents frequently. social units have changed a lot nowadays, that people live more independently after scatter of inhabitancy, from collective urbanization to separated rural homes. At the same time, similar change also happens to family units, that family members also become less dependent than before. (Williams, 2006). On the other hand, Studies revealed that seniors prefer to maintain reliable and familiar relationship with people due to their shrinking social network and lack of social stimulation. In terms of domestic support, elderly individuals actually are reluctant to see their lives be interfered by children in spite of appreciation of their concern (Lindley et al., 2008). One reason why seniors always have resistance to technology is that they are worried about over-protectiveness due to overplaying their fragility. Thus, returning the control back into their hands is a wise choice to protect their self-worth.

Lack of social support leads to various adverse outcomes of psychology, like loneliness (Golden et al., 2009). More seriously, loneliness is a factor that leads to depression, while depression had been verified as a main reason of a series of more severe problems, such as ‘functional disabilities, increased suicide risk, cognitive impairment and morbidity and mortality from other medical conditions’ (Binstock & Agronin, 1999).

Therefore, to what extend supports elderly adults receive from people reliable will exert a huge influence on how much loneliness they may perceive. On the basis of conclusion from the study of Zhu Shuzhen and his group (Zhu, Hu, & Efird, 2012), there is a strong connection between social and family support and cognitive function. Evidence showed that frequent connection with large social network was associated with significant cognitive function decline (Holtzman et al., 2004). Seniors who contact with neighbours or families as a constant mental stimulation are higher possibly to maintain cognitive ability.

2.4 Relative researches about cognitive ability improvement

Game playing is a good way for the elderly to keep their brains running. For instance, elderly users can feel the comfort and delight while playing game (D. Schutter, Bob, & Abeele, 2008). Meanwhile, game playing has probability to help elderly people prevent cognitive disorders such as memory loss (Boot, Kramer, Simons, Fabiani, & Gratton, 2008). Old people have great potential motivations to play games. In the work of Omori and Felinto (Omori & Felinto, 2012), they had done a research about what kind of motivation to play games the elderly could have. Also, they pinpoint oblivious benefits of playing games. For example, while an old man holding his smartphone or tablet, he will concentrate on the game plot and make continuous reaction to changes on the screen. He has to hold device in different postures and tries to move fingers and click on the screen as fast as possible. When playing some digital games, old users are allowed to communicate with people, online or offline status, to get help and feedback immediately, so they can feel intensely connected with others and any problems they met can be handled timely (Shin & Shin, 2011).

Ellis and Bruckman dedicated efforts to building a communication bridge between the elderly and kids in their work (Ellis & Bruckman, 2001). To take advantage of elderly people's wider experience and spare time, they designed a software, Palaver tree online, a community software offers an online platform for elderly people to share historical experience to kids. Their objective was to make history more real and tangible for students or next generation, and enhance their curiosity and motivation for further exploration. At the same time, this platform offered an opportunity for elderly adults to share their stories in person and engage in interaction with teenagers. Elderly people who participated in this activity told stories about historical events in which they were involved or experienced. Kids asked questions about what they have bigger interest in or are overwhelming with. Then all queries and answers were received by both sides through email. They also introduced some interaction elements that bolster elderly users' motivation. The creators of this software

designed an incentive mechanism to award those seniors who are reliable and more regarded. While, their work has interface difficulty, which probably generates interaction barriers when a user needs to view the details about the story while commenting on it. They have to move around the windows.

Videophone and video chatting become a feasible way for people among most areas. There are a variety of available applications and services like Facebook Messenger, Skype, WhatsApp and WeChat available for mobile phone users. People who have their smartphones or tablets connect to Internet can enjoy the clear and fluent video call. It had been proved that computer-mediated communication indeed helps seniors sustain online relationships and stimulates exchange with their social network (Xie, 2008). Hsiu-Hsin Tsai and her colleagues examined the feasibility of videoconference interactive program in the context of nursing home. Their experiment result revealed that the use videoconference interactive system is able to alleviate loneliness and symptom of depression among participants (mean age is 74.42 years old) (Tsai, Tsai, Wang, Chang, & Chu, 2010). On the other hand, there are still big proportion of population lack basic IT experience or hardly afford facilities. Further, the consequence of their experiment found part of participants felt sky about face-to-face video chatting. In some instances, people though videoconference visit is not filial and an indirect way to understand the institution's care quality.

2.5 How modern technologies contribute to elderly's health status?

2.5.1 Digital technology

Digital technology has the potential to both harm and benefit social network. Internet technology is changing the way people interact mutually and even breakdown the form of traditional social activities. But conversely, digital technology provides people magnificent convenience to maintain social ties. People who could not go outside due to physical

restrictions can talk with distance friends, refill prescription, pay bills by e-bank and research useful information online. The prevalence of internet and digital technology breakdowns the limitation in later life existing for long time. Seniors who use internet and digital technology regularly have higher satisfaction of life than less-users or non-users (Choi & DiNitto, 2013).

Multimedia (image, audio and video) plays an irreplaceable and special role in communication. In comparison to textual information, multimedia is in contents and ways to exhibit information. The fact that seniors prefer information in form of images to the textual had been evidenced many years ago (M. E. Morris, 2005). In comparison to text message, images offer more detailed context of conversation like atmosphere, emotion and background. Sharing images also help people who lack interpersonal skills engage well in online chatting because it declines the dependence of language skills. While photo is not the only alternative medium for text, audio and video likewise play a crucial role in communication. Audio help people talk as usual speaking while video allow people to chat face to face. Evidences support that use of video is especially effective for expressing the meaning of laughter, smile and individual gestures. The multimedia use enriches the way of interaction and provides people an effective solution to express feeling and ideas accurately (H. Kim et al., 2013). Speedy development of information technology enables people who are living comfortable lives constantly obtain adequate supports to improve personal life quality, enhance their capability to do what are crucial to them despite manifest barriers. For instance, the internet can help them keep in touch with distant persons within social network and even make new friends online, provide convenient approaches to strengthen feeling of social engagement. Inmaculada Plaza and his colleagues believed that mobile phone and its applications have a significantly promising future (Plaza, MartíN, Martin, & Medrano, 2011). Some authors have concluded that beneficial services can help people with special demands live independently at home and maintain social relationships with other people and surrounding environment (Mikkonen, Va¨yrynen, Ikonen, & Heikkila¨,

2002). The aim of these services is to break down barriers that limit the elderly's ongoing social participation and contribution.

2.5.2 Social community

A Chinese study confirmed that the positive relationship existing between social engagement and quality of life. People who engaged in frequent social activities believed they have better life quality than those who lack social connections with families, friends and neighbours. Elderly people who lack meeting with families or neighbours, do not take part in domestic business and modest jobs have higher risk suffering mobility limitation, anxiety, depression and discomfort (Lei, Xu, Nwaru, Long, & Wu, 2016). Vasconcelos also pointed that lack social interaction has become a harsh problem to elderly people and it may cause negative impact on psychological health (Vasconcelos et al., 2012). Besides, frequent socialization also benefit elderly people's cognitive ability. Comparing with factors like education level or a relatively low baseline of cognitive ability, there is a stronger relationship between the frequency of social activity and cognitive function improvement (Karp et al., 2006).

Besides, participation in social network is also seen as a kind of self-disclosure, whereas self-disclosure can be viewed as a benefit of engaging in social activities. Self-disclosure comprises many social behaviours suck as posting emotion, sharing images or videos, disclosing feeling with intimate friends and even communication with strangers. Studies had verified the validity of improvement psychological and physical health by self-disclosure (Niederhoffer & Pennebaker, 2009). People who honestly share them on social networks are more likely to receive support from others, because other people can better know their conditions and provide appropriate suggestions and help based on their self-disclosure. Meanwhile, people who always disclose themselves online can enhance mental health because they often tell stories about life with other.

It makes much sense to strengthen existing relationship than forging broader social network for seniors, because literature highlights that they are more motivated to sustain the ties with close friends. An elderly people is likely to deal with relationships with others who play different roles in various ways. A Dutch conducted research indicates that colleagues are not as important in social relationship as it was when a person was employed, while family members like parents, siblings and neighbours play an increasingly crucial role in the connection with him or her. In this study, a series of leisure activities is observed and assessed to explore how they affect elderly people's social connectedness. And due to multidimensional characteristics of social connectedness, this notion is divided into different items to evaluate, such as numbers of social relations, amounts of close relations, satisfaction of current social relationship, sense of isolation and feeling of loneliness, etc. For example, elderly people indeed are facing the issue that social relation is shrinking and inevitably suffer increasing loneliness, but they are more gratified with the existing relationship with their social contacts and feel this relation more dependable. Thus, maintaining the social bonds is critical for improving elderly people's life quality. At the same time, among the evaluated leisure activities such as watching TV, doing passive activities on computer, sports, holidays, shopping, cultural activities, hobbies and reading book, some of them have no positive effect on reducing loneliness, like watching TV or listening to radio, while some of them evidently help people aged below 55 solve the issue of loneliness but have less effect to the elderly population. Nevertheless, there are some activities like reading books, conducting cultural activities show a great positive influence in the decrease of isolation. And some hobbies, actualized by playing instruments, singing, hand craft and playing card or chess game, are the best accelerator for facilitating social gatherings. The stronger social gatherings could be, the less physical or mental problems could happen (Toepoel, 2012).

2.5.3 Video game for human health

Since the true video game was created in the early 1950s, digital games have been walking into a rapid development state. In an early age, game was designed for leisure activities and kill time. But nowadays various kinds of digital game are created for diverse purposes rather than helping people enjoy leisure time better. In our society, digital games are created for acquiring knowledge, training new skills or improving physical or mental ability. For example, some of them are playing an important role in assisting medical workers to care patients. In other word, more and more people with different age, background and culture can benefit from the development of digital game (Cota, Ishitani, & Vieira Jr, 2015).

It is a preconception that playing digital games is an exclusive activity for children and teenagers. The truth is that playing games is becoming an important part of many elderly people's daily routine. In America, the average age of game players has already reached 37 years old, and proportion of whom aged over 50 years old arrived at 26%. The most popular three types of video games are social games (31%), action games (30%) and board games (30%) respectively. While social game is the most welcome type of game on smartphone platform, as the third most frequently gamer-used device.

According to the conclusion of a research made by Ijsselsteijn and his colleagues, seniors enhanced their cognitive and physical ability due to the positive impact of playing digital games (Ijsselsteijn, Nap, Kort, & Poels, 2007). Their visual fluency and perception ability were manifestly strengthened during the experiment (Jimison et al., 2010). Gaming shortened the time they made reaction (Clark, Lanphear, & Riddick, 1987). Their motor coordination has significant improvement after a period of gaming time due to the training of hand-eye coordination during playing games. When they accomplish goals, they enhance self-identity and gain strong sense of achievement (Torres, 2011). Game provides real-time feedback that players can see their progress. They may be excited for great achievements or

be frustrated by their unsatisfying performance. Playing games eases their lonely feeling and reinforces their team spirit.

Meanwhile, a study explored the effect of video games to human spatial and verbal memory. Marcella Caglio and her colleagues conducted experiment in which a people experienced a vehicle smash was required to participate in the 3D video game. In the virtual world of this game, the participantneeds to explore each street with backtracking and cut down as many as possible poles and trees along the way he passes. The result indicated the positive effectiveness of such video game on memory enhancement (Caglio et al., 2009). The brain damaged patient had reproduced spatial memory and could learn the sequence of spatial characteristics that were hardly to remember before video game training.

Playing digital games effectively diminish sense of loneliness among elderly people (B. D. Schutter & Abeele, 2010). Two groups of elderly participants were required to accomplish two different tasks respectively within the same period: (1) playing digital game with younger participants; (2) watching television with younger participants. After task finished, researchers found that the group of people who played cooperative digital game (based on Wii) gained greatly positive mood and acquired "*an identification with a younger subjective age*", while the same phenomenon did not emerge among TV-watching group. Positive mood also stimulates the form of social bond between players and decrements of loneliness (Kahlbaugh, Sperandio, Carlson, & Hauselt, 2011).

2.5.4 Virtual socialization within digital games

Social game is one branch of digital game domain, in which players are encouraged to engage in virtual social interaction and communities. More and more people are spending bunch of time on sitting in front monitors, watching TV, surfing online, playing video games etc., while the time spent on doing these is the time spent staying away from personal interaction. Thus, people came up with the idea that converting part of human contact into

the form of virtual social interaction (Williams, 2006). In the aim of this, social digital games are designed for varying type of users, and bring them together because of a game. The concept of social game comprises various categories of games. Multi-player games which allow not less than 2 people participating simultaneously is a representation of social game. Players who either oppose each other or cooperate with others can benefit from social integration or support throughout gaming experience. Social network game is another representation. Players need to play online and interact based on social media networks, like adding friends, sharing scores, online competition (this characteristic is like multi-player game) etc., and this way of entertainment is regarded as a solution to moderating social distance (Ijsselsteijn et al., 2007).

2.6 Elderly people's motivation to play mobile games

Motivation is the reason, extrinsic or intrinsic, that drive you to reach a goal or complete a task. Extrinsic motivation to finish a task can derive from stimulations from outside, like remarkable rewards or a severe punishment. For example, people have strong motivation to play lottery games because enormous amount of reward is quite seductive to them. And negative effects that people want to avoid also contribute to intense motivation. On the other hand, motivation can as well come from aspirations. Intrinsic motivation conforms to people's interests, knowledge or mental demands, and the degree of this kind of motivation is inextricably linked to happiness and satisfaction, the internal factors of an individual. In term of relationship between digital games and motivation, the research conducted by Omori and Felinto concentrate on the exploration of users' motivation to play social games on Facebook (Omori & Felinto, 2012). They finally find a list of key elements in the popular games that encourage participation. For instance, people like casual games because of their light needs for daily commitment to activities. It is easy to learn, to play and to drop out. It is crucial to allow users to establish connection with others through the way of gaming, regardless of helping others unlock an achievement or gain a new adventure. A game designed with great fun absolutely increases players' immersion in it,

and sustainable pleasure and entertainment motivate people continuously focusing on the coming activities and tasks.

For elderly people, they need to know benefits of playing a game. For example, a message that convinces elderly people that playing the game is an effective cognitive treatment for them can be an additional motivation for them to actively enjoy the progress of playing (Brown, 2012). After an elderly people become novice player, special design of a game will be a more significant part in maintaining their motivation. For example, the size of mobile device should not hinder their experience during playing. They do not like playing against time (B. D. Schutter & Abeele, 2010), thus there should be less or no actions need a rush in a game designed for them. Motivational messages are encouraged to appear when an elderly player win an obstacle or make a mistake in order to make them feel proud of their actions or moderate their confusion with “dilemma” (Lucila & Carvalho, 2012).

2.7 Game designed for the elderly

2.7.1 Preliminary UI design principles

Graphical user interface (GUI) provides a direct view of digital products. is a type of interface that allows users to interact with electronic devices through graphical icons and visual indicators. Unlike younger users, seniors always suffer varying degrees of cognitive impairment, which causes decline in visual identification. Reduction of physical and mantel abilities’, such as visual acuity, selective attention, impede their enjoyable experience with interactive interface (Ganor & Te'eni, 2016). User interface should be simple and clear logically and visually. Seniors, as non-experience users, should find out any functions directly without confusion. Visual elements should be typical that have strong connection with elderly individuals’ experience or memories. A combination of visual and contextual contents is considered friendly to seniors. Some principles in graphic user interface are summarized during previous relative researches and render a general direction for designer and developers to follow during their workflow (Marcus, 1995).

Clarity

User interface should be visually clear and linguistically precise, such as visual components, metaphorical elements and textual contents. For example, a metaphorical icon used in user interface, like the example in Figure 2.3, weakens clarity and may not convey exact meaning to less IT experience users. For elderly adults, they probably lack sufficient experience in using internet and IT products, and some of them have not established strong conceptual reflections between a notion and its materialization. Accordingly, it is wise to use textual contents, like titles, tags, or a short description, to interpret what the exact meaning of an interactive element to diminish confusion probably emerge during use period. Fast-changing or fast-moving elements should be avoided in case of elderly people cannot perceive the changes(J. M. Morris, 1994).

Font size is one of the factors that affects clarity of user interface. For elderly people, they have varying subjective preferences for font size. Considering the age-related impairment like visual deterioration, it is necessary to magnify font size when designing user interface for elderly population. However, a previous research found that large-size texts caused a new problem. For example, size of texts has direct impact on how many contents can be displayed on the screen. Researchers noticed that elderly people showed strong preference to view as more contents in one page as possible. It is a noteworthy question deserves consideration that how to balance the size of texts and the contents can be viewed on the screen. Previous works recommended that when designing user interface for elderly users, it is a appreciated to provide a wide range of font size and let users to choose the ideal size for themselves (Darroch, Goodman, Brewster, & Gray, 2005; J. M. Morris, 1994).

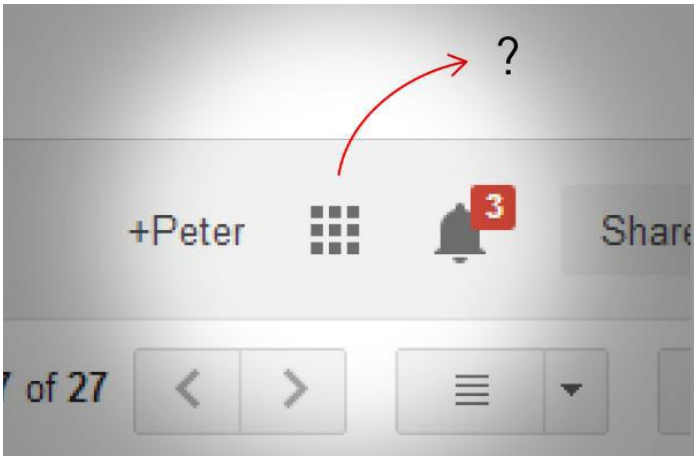

Figure 2.3 A metaphorical icon stands for More.

Operability

Hsiu-Ping Yueh and her partners did a research in exploring seniors' preference to image-view frame layout. They assessed physically functional attributes such as number of functionalities (buttons), size of button (small, medium and large). Their consequence revealed that seniors prefer interface with more buttons displaying on the screen to the design hides more functionalities in submenu. They dislike spending much time on seeking functions they need since prolonged time is one of factors increase the risk of failure in recall, cognition and manipulation (Yueh, Lin, Lu, & Chou, 2011). On the other hand, mobile devices are limited in size. There is always an inclination to cram too many things on the screen. The number of elements is inextricably linked to the size of each element. Hence, designers are required to guarantee the minimum size of touch target. Touch target includes the areas respond to user input. According to accessibility and usability guidelines for android developer, touch target should be at least 48dp*48dp at a minimum. And there ought to be an 8dp wide space between two nearby elements. Size elements at least 48dp high and wide to ensure a physical size of about 9mm regardless of screen size. The recommended target size for touchscreen objects is 7-10mm. Meanwhile, extra space surrounding each touch target is required to guarantee the basic information density and usability. This effectively prevents misoperation due to excessively compact layout.

Compatibility

Contexts of use may vary severely. Different devices are used in various environments. They differ from physical size, operating system, manufacture time and other features, and these characteristics may lead to different user experiences while using. For instance, the same application running on a mobile phone and on a tablet, may have different interface design (Figure 2.4) to fully utilize features and provide accessible functionalities. Mobile phone has the smaller screen size and information should be categorized into different priorities and only those foremost contents should be exhibited in highest priority, while desktop devices have bigger display area and allow more information appearing simultaneously. Even the same operation system could have diverse versions, which offer various functionalities. Take an example of Android, each successive platform version provides new API sockets to support new functionalities based on the update of hardware or software. While new features do not always support previous platform versions. A designer is encouraged to take the variety of devices into thorough consideration before defining design requirements, because not every user has ability to afford new devices that running the latest system. By May 2017, most android devices are still running version 6.0 (31.2%), while the latest version, android 7.0 only accounts for 6.6% of total market share. And lots of android equipment are even running the older versions, like android 4.4 (18.8%) and android 5.1 (23.3%). Therefore, how to improve compatibility is an inevitable question waiting to be solved when a designer targets to serve a broader range of users.

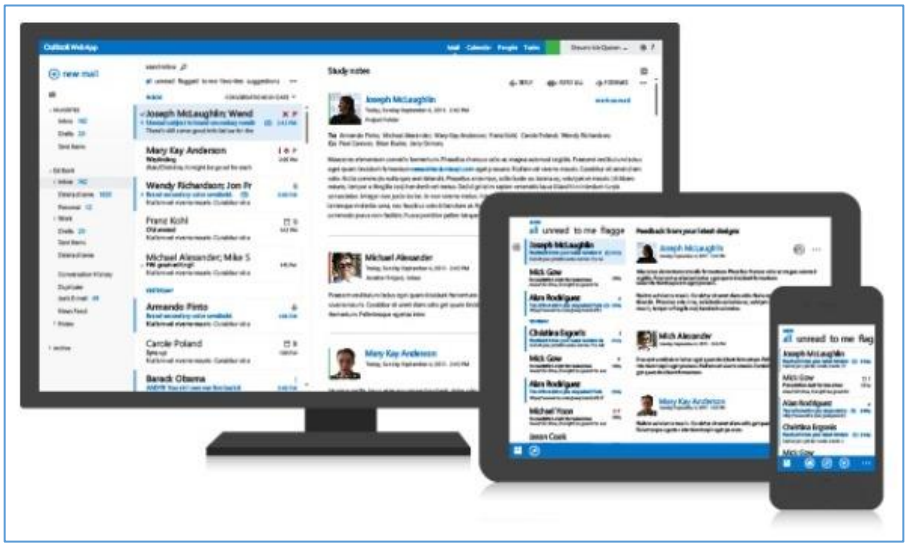

Figure 2.4 A application has different UI on different platforms.

Interaction consistency

Consistency is a fundamental element of designing a usable user interface. Users hope the software or application reacts the way as they expect; otherwise, they would feel confused about disoriented result. An unexpected reaction is much the same as the unwanted. Surprise usually implies something bad rather than something positive, unless users already have such low expectations of their software. Consistency of interaction could be achieved when an interaction matches users' expectation, and in return, users' expectation becomes established through user experiences within their environments. Over time, users learn that certain stimuli have certain meanings or usages, because those stimuli have had those meanings or usages in the past. If designers utilize their stimuli effectively in their products or services, users would be satisfied with expectation fulfilled, otherwise, they need to violate existing stimuli and form new one. For example, based on popular preference for interaction style, the rightmost button in a dialog box is Cancel, while in another it's OK or another button that accepts a user's input. If we swap over these two button, there would be contradiction and cause unnecessary operation mistakes.

Control

Users should have full control of the application. Permit users to customize aspects of the interface while always providing a set of well-designed defaults. For example, allow users to adjust font size and colour theme to guarantee visual clarity in diverse use scenario. Avoid modes since they constrain the actions available to the user. The means to achieve a goal should be flexible and compatible with the user's skills, experiences, habits and preferences. For example, a game should allow players to select from a range of difficulties of task according to their practical skills.

Flexibility

A user interface must be flexible to the different needs of its users, enabling a level and type of performance based upon:

a) Each user's knowledge and skills.
b) Each user's experience.
c) Each user's personal preference.
d) Each user's habits.
e) The conditions at that moment.

Predictability

This principle requires design to provide distinct and recognizable screen elements and cues to the result of an action to be performed. And all expectations should be fulfilled uniformly and completely. The key of predictability is that delivering a predictable, positive experience improves probability of successfully matching the user's expectations – the mental model they already have of how the experience should unfold. To achieve this objective, it is critical to take the context of target users into account, such as their preferences, habits. Designers should understand how people may use the product, what

task the product needs to accomplish, when and where the product is used etc. A well understand of target users and use of context may help designers to predict what demands a product should meet. And a product with high predictability can provide the correct services and displayed what users want to see in right time and place. When what happens on the screen matches what they expect, they're more confident, comfortable and happy. This is the means that keeps users visiting and using what we designed.

Error tolerance (forgiveness)

This part refers to the capability of an application on how much common and unavoidable human errors it can tolerate and forgive. It is essential to presume target users probably make mistakes and activate unpredictable actions by accidence. The consequence of mistakes may push users into dilemma and cause their frustration. A good design with adequate consideration of forgiveness should be able to minimize the possibility of user errors and protect users from initiating catastrophic mistakes. For example, when the system detects a user is terminating current progress, it should inform the user the possible consequence he or she may confront if they insist on the action. Such design gives the user an additional chance to confirm or undo their intention to prevent unwanted events happening. Besides, when an error inevitably has occurred, forgivable human computer interface design should provide constructive clues or messages to help users get out of dilemma. For example, many card games allow players to undo their decision, which was not the best choice.

2.7.2 Accessible design of icon

Icon is the first graphical feature of interface users encounter. Aim of icon is to demonstrate the core functionalities of the product. Some common-used icons even replace text description and become a common sense (Barr, Noble, & Biddle, 2003). A moderate icon design apparently positively affects users' impression when they view the

interface. Also, an icon to be easily touched attributes to low error-press rates for novice users (Yueh et al., 2011).

In the last few years, a tide of ‘simple and flat style’ is becoming hot and popular in graphical user interface design (Zhou, 2014). Apple first imported this design theory into its mobile system iOS7, then other main-stream smartphone manufacturers began to follow this trend. But a recent study on seniors’ preference between skeuomorphism (rich design) and minimalism (simple and flat design) told the truth distinct from general opinion. Seniors prefer realistic icons than those designed abstractly. Consequence of study made by Minji Cho and her partners indicated that seniors got higher scores in understanding icons with high level of realism (Cho, Kwon, Na, Suk, & Lee, 2015).

Icons are required to be understandable and visible via multiple dimensions. For example, icons that can be only distinguished by colour differentiation are inaccessible. Because people with colour blindness have difficulty in distinguishing between blue and yellow, or between red and green. In this case, shape can be an additional distinguish condition in a manner that avoids confusions probably happened to people with special needs (Stilan, Chen, & Bezuayehu, 2011). Netta and her group summarized two elements: level of details and semantic distance, which play an essential role in icon comprehensibility among seniors. Level of details means elements comprised in icon, while semantic distance refers to closeness of the meaning or function an icon presents. Rich detailed icon design in most case help elderly adults understand the meaning of icon, particularly when semantic is quite high. Moreover, the inherent difficulties in exhibiting graphical concept increase seniors’ learning cost. While their experiment result also pointed out the unnecessity of rich details after seniors getting used to icons (Ganor & Te'eni, 2016). More specifically, Chiwu Huang and Po-Ti Chen had verified the previous finding that seniors prefer realistic icon to abstract one. An icon could offer elderly people more concrete cue information because seniors always get to understand a new concept heavily relying on daily life

experience (Huang & Chen, 2015). Therefore, icons designed with real item picture are thought to be well recognized for them.

But ambiguous icon is common in our lives. The screenshot (**Error! Reference source not found.**

P3	male	79	yes	myopia, diabetes	yes	no	no	never	never
P4	female	86	yes	presbyopia	yes	no	no	less than 5 times a week	never
P5	male	64	yes		yes	yes	yes	everyday	more than 5 times a week
P6	male	81	yes		yes	no	yes	everyday	more than 5 times a week
P7	female	71	yes	cataract	yes	yes	no	less than 5 times a week	never

) below is a good example. This is a frame of a popular social network application providing text and voice service in China. We notice that the icon labelled by red box is a non-text content. According to our previous IT experience, we are probably able to speculate about this icon as a “more functions” option. But for people who have scarcity of relative experience may feel confused about it, particularly for seniors. Firstly, they may not notice that or just view it as a decoration instead of a button refers to a specific function can be pressed.

WeChat had 697 million MAUs (Monthly Active Users) at the end of December, said the company today in its Q4 2015 earnings report, almost half of Chinese population.

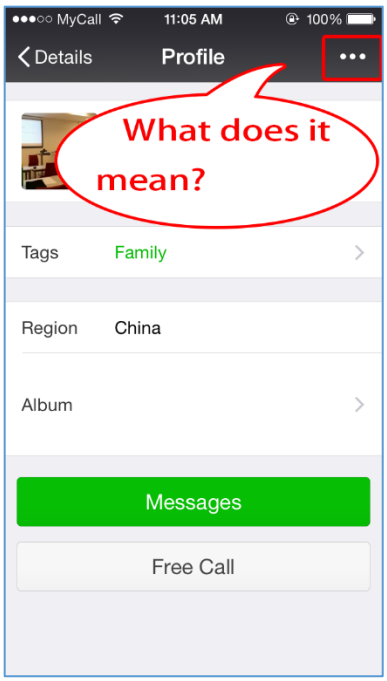

Figure 2.5 Frame of Friend Profile in WeChat

2.7.3 Use of color

Colour emerges in our daily lives and is inextricably linked to exploration of this world. People absorb information by telling the differences between colours and become acquainted with meanings that specific colours stand for. At the meantime, colour also acts as a part in legibility. Along with factors like luminance contrast, polarity of legibility, colour combination and colour difference make a difference in enhancing the way in which people access textual purpose. Traditional principles for printed colour combination is not suitable for those contents displaying on screen anymore because they have different optical characteristics. Unlike subtractive colour printed on surface of real object like newspaper, colours are more integrative when we stare at them on a display screen (Humar, Gradisˇar, & Turk, 2008). And this character of display colour results in higher possibility on visual fatigue and visual strain.

In research on colour combination, people were asked to grade a list of colour pairs based on their performances on legibility. Consequently, yellow on black, cyan on black, white on blue, black on yellow, white on black, and green on black colour combinations gained high scores in the evaluation, while the results for the colour pairs of black and blue, red and magenta, green and cyan, and yellow and white were relatively low.

The same object can be saw slightly differently by different people and basically our perception of environment we are engaging in is literately 'coloured' by the context in which we view it. A good colour perception ability allows us to distinguish various meanings behind different colours, e.g. the role of green and red in traffic signal. But for people with colour perception deficiency, at a minimum, how to tell red and green apart is a severe problem. This should not be under-estimated as roughly 8% of men and 0.5% of women worldwide live some form of color blindness. In one case, colorblind people never know what is real color. They merely have ability to distinguish the lightness of color, dark or light. The image (**Error! Reference source not found.**) below shows 2 mugs, one green, the other red. Left: standard vision. Right: how the image is perceived with a form of color blindness. Obviously, red and green are almost indistinguishable.

Figure 2.6 Left: A normal people's perception. Right: A colorblind people's perception.

Color contrast

Color contrast refers to how different one color is from another color. It ranges from 1:1 to 21:1 based on its luminance, or intensity of light emitted. The higher the difference between the two numbers in the ratio, the greater the difference in relative luminance between the colors. World Wide Web Consortium (W3C) conducts a guideline to help us, which recommends that a color contrast ratio should reach at least 4.5:1 against background for small text, whilst large text should have a color contrast ratio of 3:1 at a minimum. Because use scenarios of mobile is more complex and various than PC. The most typical example is that mobile phone is used in vast range of environments, like outdoors, where glare from the sun and other strong lighting sources will compound challenge in display effect. Such scenario heightens the importance of good color contrast for all users and conducts new requirements to enable people, especially those have visual impairments, to access contents on screen under various conditions.

A decent design of color theme should serve both regular people and people with special requirements. Take what **Error! Reference source not found.** demonstrates above as an example, two colors with strong and significant contrast would not be enough to indicate difference for people who have color blind or use monochrome screen. A report conducted in 2016, Digital Eye Strain Report, found that 61 percent of Americans have experienced eye strain after prolonged use of electronic devices — nearly 2 out of every 3 people. Staring at phone and tablet screens harm our eyes permanently, because they emit HEV light (also called blue light). HEV light is that portion of the visible light spectrum that comprises light with the shortest wavelengths, which carry the greatest potential to damage living tissue. A report made by the Vision Council declaimed that long-term exposure to high level HEV light can damage tissue in the retina of the eye in a way that appears consistent with retinal changes associated with macular degeneration, a leading cause of permanent vision loss in elderly adults. Mary Meeker's Internet Trends 2014 report found that the average American (aged 16-44) spends 444 minutes or 7.4 hours

staring at screens every day. That's 147 minutes of television, 103 minutes on a computer, 151 minutes with smartphones, and 43 minutes on a tablet. Statistical analysis found that in modern society, most people spend as much time staring at screen as we do sleeping.

Dark and light colour

Dark and light colours used in graphical user interface provide different feeling when a user have a glance at it. Light colours create a sense of more open space, while dark colour combination contributes to emphasize visual focus. When it comes to how users "feel" about colour, users typically don't notice a light or white background. However, a dark or black background jumps out. Because in comparison with light colours, dark colours have more visual weight, and we are accustomed to black texts appearing on white background since the invention of printed press.

Here are some suggestions for applying different colour themes. First are scenarios in where light colours do a better job:

1. Reading environments: Study after study has come back with a similar conclusion -- the preferred reading environment is darker text on a lighter background. For example, black on white, but this is not necessary.
2. Responsive websites: When you are designing for large and small devices, it can be more manageable to work with lighter colour schemes so that you don't get caught with some readability issues during responsive scaling.
3. Easy to create contrast: Light colour schemes make it easy to create contrast. Almost any bright or saturated colour will stand out from the background.
4. Elderly audience: Typically, audiences that are older or have accessibility issues prefer this combination.

However, dark color theme also can work well under situations:

1. Apps: One place where dark colour schemes are taking off is in apps. Because they are different from associated websites and specifically designed for small devices, many of the cross-device issues are less of a concern.
2. Design with lots of images: Photos and other image-based elements can look great against dark backgrounds. For highly visual projects that don't require a lot of on-screen reading, this is a great option.
3. Oversized everything: For over-the-top designs, dark colour schemes can work well because size creates enough contrast to increase readability and usability. (The challenge is creating oversized elements on small screens.)
4. Gaming: Player interfaces have been using dark colour schemes for a while and this will likely continue to grow. Part of the phenomenon here is that gamers tend to skew younger and once the audience is used to a certain look, the comfort level associated with it make it the norm.

In a nutshell, according to summarizations listing above, we decide to adopt several suggestions on colour theme. First of all, dark on light is an appropriate choice for interfaces full of reading contents because of high contrast it easy creates. For instance, setting frame is a good place to apply this rule because setting options are typically textual and organized orderly in a restrict area. To ensure that all users access to every words in titles or summaries is primary task, no matter which scenario a user is in. Second, for image-base screen dark theme is more proper.

Declined attention and working memory: the task which needs a player keep certain information in mind for a long period may become a challenge for elderly people. For example, they may have difficulty in remembering information through a series of complex operations.

Back button: it was observed that elderly people prefer to press back button when they are in dilemma. Back button plays a role as a solution to handle disoriented situation (de Barros, Leitão, & Ribeiro, 2014). For example, when an unwilling result appeared, elderly

people might press back button to regress. Thus, it is important to take their preference or custom into account to design applications which conform to their spontaneous interaction style.

2.7.4 Specification & Tutorials

To create a facilitating condition is one of the most useful and important factors that help elderly users to accept new technology. For instance, a manifest guidance, regardless of a piece of video or a brief description, is essential for people who are not familiar with smart technology. Previous researches had proved that proper training programs help old adults foster confidence and positive attitudes and increase their attention to use new technology (Laganà, 2008). Brief instructions prepared for novice users help them acquire basic understanding of products and decrease their confusion and anxiety. A better knowledge of how to manipulate will enhance seniors' confidence and eliminate operation barriers (Yueh et al., 2011). The designers of Help Kiosk (Leung et al., 2012), a supportive design on mobile devices, create an exploratory mode for elderly people to get familiar with the app by trying out its all functions, and moreover allows users to return to the pre-exploratory status. Elderly users have chance to know the possible changes initiated by their actions and be acquainted with the possible consequence caused by their exploration. This mode assures new users of opportunity to practice and familiarize themselves with the functionalities and help them diminish the concern about the unexpected changes to mobile devices due to their actions. At the meantime, their study also certifies the value of a detailed instructions for a product. According to their categorization, three different formats of instruction are tested by participators: (1) text specification, (2) live View and (3) demonstration video. Text specification prescribes the steps of a task needed to be completed, while Live View is a technique to highlight important elements on the screen in order to guide a user to perform a task. Live View is like a real-time dynamic instruction that maps references from text specification to UI on a real device. And demonstration video is a rich-expression instruction that not only indicates how to perform to achieve a

goal, but also show the possible outcome. The result of their user test shows that these three kinds of instruction perform well in helping demonstrate tasks and provide helpful hints in some cases. For instance, text specifications offer “less cluttered information” whilst Live View provides efficient guidance during multiple tasks. Besides, all participants rate highly of video demonstration because “it is visual” and exhibits expected outcomes.

2.7.5 Player motivation

High usability and accessibility are not enough to constitute elderly people’s motivation to play digital games. Aside from what mentioned previously, their motivations also originate from benefits that they can perceive as playing. For example, one of the benefits of playing digital game is to acquire relaxation and pleasure. As people aged, physical or cognitive deteriorations might be the greatest barriers to enjoying the pastimes in the way they did before. But digital games offer a new solution to gain pleasure and enjoyment. Wide range of tastes of people can be fulfilled by diverse types of games, and playing accessible digital games has lower requirements on physical characteristics. Besides, when players think that their skills are higher than required by accomplishing a task, the sense of enjoyment can be achieved. And a friendly social-interactive circumstance also contributes to raising pleasure (Chen, Duh, Phuah, & Lam, 2006). In other word, people can obtain relaxation and pleasure from many aspects of t playing digital games.

Social integration is another remarkable benefit for elderly people. Due to age related reasons as mentioned before, elderly individuals may suffer varying degrees of decrements of social relationship and scale. They are eager to seek new ways as an alternative solution to maintain their social networks and interpersonal relationships. On the one hand, we can see that after retirement elderly population begin participating into various kinds of leisure activities with tremendous passion and motivation (Kopecky, 2011), like tour travel, interest groups, group exercise etc. on the other hand, studies denoted that information and communication technology and computer science provide alternative approaches for

elderly people to remain social connection with others. Playing social digital game is a solution. Elderly people have many choices to participant in games with social elements. For example, they can play multi-player games with others, online or offline. In the comparative study conducted by Kahlbaugh and her partners, the elderly people who engaged in digital game playing obtained social bond with young partners, while the people in control group, who were asked to watch television with young people did not form such relationship. Based on mutual enjoyment in game playing, elderly people felt less loneliness and promoted in sense of well-being due to the great positive mood formed over this period (Ijsselsteijn et al., 2007; Kahlbaugh et al., 2011). And positive mood was considered as a vital factor that moderate the sense of loneliness, life un-satisfaction. By comparison, less interactive activities like watching TV could not achieve the same effect (Kahlbaugh et al., 2011). Or they can construct connection with others by playing social media games and implementing virtual social interactions. This is a convenient approach to construct conversation between people who live geographically isolated. Games that embedded social elements (empowered by social media API) allowed players to add known or unknown contacts, share scores through social media. In some cases, players meet game partners in person thanks to what they are playing together. Their social networks benefit from game playing, strengthened or extended (B. D. Schutter & Abeele, 2010). Playing game also has potential to establish connection between different age groups.

Moreover, players need to continuously find value of game to feed their curiosity or ambition, which motivate them to start the app and begin playing for long time. Kevin Oxland claimed in his book that players' motivation for playing a game comes from two primary aspects. One is desire for victory, and another one is the value of victory they could perceive (Oxland, 2004). No matter which one becomes greater, players' motivation become greater. In the study conducted by De Schutter and Vanden Abeele, one of their participants started learning a game after being encouraged by son(B. D. Schutter & Abeele, 2010). All these forms of behaviors can be regarded as the outcome of playing Gobang, as well as enjoyment and growing closeness in relationship. The higher obviousness of

outcome is, the stronger motivation a player has (Wigfield & Cambria, 2010). Besides, a well-designed goal inspires participants' motivation as well (Oxland, 2004). Players feel more motivated when they perceive that a goal is possible to achieve and this sense of accomplishment helps maintain elderly players engaged (Vasconcelos et al., 2012). A series of well-designed goals is the key factor that keep the player spending time and effort on exploring virtual world and looking for solutions to overcome new challenges. Besides, other researchers have different comprehension of value. Eccles and Wigfield constructed a model to define the concept of value, in which Value derived from four aspects (Eccles & Wigfield, 1995). And because multi-player game is fruitful in three aspects: attainment value, intrinsic value and cost, it becomes so popular and enables players motivated.

3 Methodology

3.1 User-Cantered Design

User-Cantered Design (UCD) refers to the design process in which requirements, restrictions and other elements that have impact on user experience are considered by designers intuitively and thoroughly. It is one of the most effective approaches that enable end users to engage with development process and keep in with designers. User-Cantered Design can be implemented at multi-stage problem solving process. The objective of User-Cantered Design does not only focus on how end users use the product or the service, but also examines the validity of assumptions relative to the design at each phase. By this way, feedback from users timely facilitates refinement of design requirements, and meticulous analysis at user feedback will be transferred into product improvement.

Target users are required to be involved throughout the project, from analysis of demands of users to the evaluation of the accomplished prototype. Their engagement facilitates designers' understanding of the context of use. For example, a project at each phase ought to be assessed based on the defined context of use, to mitigates the risk of not being in line with user requirements. A serious consideration of context of use is critical to determine design requirements (corresponding to user's demands). Designers should take the tasks and conditions of users into thorough account. For instance, user interface should provide a good combination of different size-colour fonts, backgrounds and layout style to fulfil users' unique demands in different use scenarios.

The target users of this project is elderly people (aged over 60). People who engaged with this project helped us define design requirements and participated in design evaluation phases. They were encouraged to tell us their feelings, attitudes and ideas relevant to user experience from the perspectives of usability or accessibility. A specification made to demonstrate a series of questions that participants may arise about this project. For instance, how to conduct a user test, how their feedback contributes to

design requirements specification, what aspects relative to accessibility or usability they are required to pay adequate attention. During the phase of requirements gathering, a thorough consideration of the context of use contributed to elimination of design components that are irrelative to users' root needs. Their primary personal information was collected with their permissions, such as age, gender, education and employment background, retirement situation, disease history and living status. Additional essential information need to be acquainted with was recorded during the following user test. Part of people aged over 60-year-old are still working for extended career due to a variety of reasons. So, target group ought to include people both retired and employed.

3.2 User requirements study

The objective of this study is to explore the connection between playing social and cognitive games and overall well-being of elderly people, and to be aware of how to design usable and accessible mobile games for them. A thorough understanding about how elderly people use mobile phone and what general experience they have in game playing is useful and helpful for designers to know them better. First, focus group interview help us to gain valuable information about target users. Their demands were collected, such as expectations for what an accessible social game should be like and their needs for specific features that help application become more usable and enjoyable. Additionally, critical understanding about their context of use, what are users' tasks and goals, what is a user experience level etc. were gradually clear as the interview conducted. Second, user testwas adopted to keep our mind on users' real needs. As an approach to gain constructive suggestions from participants, feedback acquired from elderly participants helped us avoid continuously paying attention on non-core issues and being frustrated with massive irrelative requirements.

There were four aspects on which we kept an eye throughout the process of user requirement study: accessibility, perception, understandability and robust. According to

W3C mobile accessibility instruction, mobile applications should be evaluated in terms of four aspects: perceivable, operable, understandable and robust. Due to the less requirements from the view of Robust, it was emerged with other three domains. Therefore, robust was not listed in checklist temporarily. Perceptibility refers to the ability to see, to notice or to realize a specific object, particularly the unobtrusive targets. In this subject, mobile accessibility requirements keep an eye on negative factor links to the limited screen size. Key points like text features (size, weight and style), zoom or magnification and contrast of contents were taken into consideration. Operability stands for the ease of manipulation. When a user conducts operations like input, browse, click, tap, switch or others, how to design user interface accessible can improves the accuracy and productiveness is the subject deserves our persistent exploration. Mobile accessibility regulations managed to design a series of criteria and focus on improvement of usability and accessibility of user interface on mobile platform.

Before conducting user requirement study, our participants were asked to sign a participation consent form, which specifies their legal rights and briefly introduces the purposes of this project. They could terminate participating in the test any time when they have willing to cease and their privacy were guaranteed to be secured all the time. For example, their real names appeared in this thesis in the form of index number, like P1, and their tunes were processed to be indistinguishable in the files that recorded interview conversation.

3.3 User testing

User testing is an indispensable part of user cantered design pattern. Designers can obtain insightful understanding about how a target user uses a given product or a system and keep tracing changes in target user demands. Besides, user testing is also helpful to examine whether the product meets the intended purposes and ensure a project keeping on track.

Throughout the process of design and development, user testing was conducted when new functions were added. A mock-up prototype with new features was delivered to participants and they completed installing with the help provided by families who also knew about the project or from video guidance. Before conducting user testing, new features and new testing requirements were introduced to participants or their families, as assistants, after acquired their consent. For example, participants were requested to use the application outdoor to test legibility of user interface in high lumination environment, and sometimes they were asked to evaluate readability of user interface in dark environment. User testing helped us target the shortcomings of this game on usability, ease of use and understandability, and fixed one by one according to their priorities. Problems inextricably linked to bad user experience were fixed immediately while those not so serious were arranged to be repaired later. This phase was aimed to code with the underlying problems that could appear when an elderly participant experienced, and eliminate barriers before conducting final user testing.

When design and development of this game was completed, the final user testing was conducted to evaluate performance of this social and cognitive game and assess its potential influence on promoting overall sense of well-being of elderly people. In accordance with plan, elderly participants were requested to play the game for a defined period. Over this period, they were asked to share experience with their friends or neighbours about the game playing.

4 User requirements study

4.1 Semi-structured focus group interview

In Feb. 2016, a preliminary semi-structured interview was conducted with 6 elderly participants. Table 4.1 shows demographical information about them, while Table 4.2 precisely indicates the statistical information about their preference to game-relative behaviours. We asked whether they are willing to learn and play games on mobile. It was pleased to see that most of elderly respondents expressed great curiosity and motivation for learning a digital game after I showed how to play an interesting and light-level html based game on mobile phone to them. However, severe health problem indeed became an obstacle to enjoying the pleasure from playing games. People who were physically in better shape generally had more positive attitudes to trying and learning new skills. For example, a respondent with serious cataract told us she nearly loses eyesight and listening to radio is the only pastimes in her spare time. Besides, operations in the game that have additional requirements on accuracy became great barriers to people had mobility impairments, like mild Parkinson patients.

Interview questions are listed in Appendices B. We collected their basic information like age, gender, education and employment background, as well as health condition. Additionally, we asked questions about their social activities and preferences in later lives, like how often do they meet friends or families? How often do they visit neighbours? They were required to conduct a subjective assessment of their senior lives. We, at the same time, conducted a survey about their acceptance of information technology. For instance, we collected information about what kind of mobile phone they are using, how many of them are familiar with computer manipulation, how many of them are using smartphone, what kinds of application do they use in a daily basis, do they play games on mobile, do they have social media account and use social media application, etc.

According to the results of the interview, visual impairment was found to be a common symptom that most elderly people had. Elderly participants suffering varying degree of visual impairment needed to wear glasses or squint at screen to watch screen contents clearly. Most games lack sufficient consideration of accessibility. For example, games did not allow users to adjust font features like size, so participants felt hard to watch small contextual connects. Small interactive components also created barriers when elderly users experienced. Some of them had to use nail to tap the correct place, while touch screen of smartphone could not recognize nail-touch action every time. However, it is noteworthy that most elderly participants still had strong interest in learning how to play games if sufficient guidance were provided. For example, they are taught by family members, friends face to face, or there are detailed specifications offered.

During the interview, several games with different level of difficulty and complexity in operation and logic are displayed to them. After we ask their feeling and intention about learning some of these games, their answers reveal that casual games, which have less difficulties and complexity, are more welcome than harder ones. First, they do not intend to spend too much times on learning and playing. Casual games are easier for them to pick up and drop off. More importantly, they could achieve a goal or win and then gain sense of achievement and success easier when they play a causal game. Complex games in which require considerable eye-hand coordination would become a huge challenge to them and are prone to cause their frustration.

Table 4.1 Profile of participants

	P1	**P2**	**P3**	**P4**	**P5**	**P6**
Age	60	62	81	74	86	87
Gender	F	M	M	M	F	M
Retired	No	Yes	Yes	Yes	Yes	Yes
Health condition	Myopia			Presbyopia mild Parkinson	Presbyopia	Presbyopia

Mobile phone use?	Yes	Yes	Yes	Yes	Yes	Yes
Smartphone use?	Yes	Yes	Yes	Yes	No	No
Social media use?	Yes	Yes	Yes	No	No	No
Mobile game experience?	Yes	Yes	Yes	No	No	No
Frequency of game playing	Everyday	1-3 times a week	4-5 times a week			
Time for each game experience	0.5-1 hour	10-20mins each time	10-20mins each time			
What kind of game do you play?	Chess and card games, HTML5 games provided by WeChat	HTML5-base games provided by WeChat	HTML5-base games provided by WeChat, some casual-intelligent games downloaded from app market			
Do you know how to download game?	Yes	Yes	No	No		
Would you like learning to play games?		Yes		No	Yes	Yes
Need assistance for learning?		Yes		No	Yes	Yes

Table 4.2 More statistic about participants

Age Span	Number	Retired	Mobile game player	Would like to learn playing casual (new) games	Would like to learn complex games?
60-70	2	1	2	2	1
70-80	1	1	0	1	0
80-90	3	3	1	2	0

Total number	6	5	3	5	1

4.2 User testing on similar Gobang games

Firstly, a preliminary interview was conducted to map the participants' experiences with games and social media. They were asked to play a selected list of casual mobile games (Flappy Bird, Connect Two, Gobang, and Chinese chess) and vote one for the most-wanted mobile game. Compared with large and complex games, casual games are easier for elderly people to learn and play. Tasks in casual games are comparatively simpler and easier to accomplish, and they could gain a sense of achievement and success more easily when they play. The results indicated that participants preferred Chinese chess and Gobang One reason is that Chinese chess and Gobang are rather popular casual games in China, with which every participant is familiar. They did not want to spend much time on learning how to play. The second reason is chess games have less time pressure. Motor and cognitive deteriorations due to aging slower reaction time and make it difficult to figure out correct solutions while playing (Vasconcelos et al., 2012). While, Flappy bird and Connect Two need players to act as soon as possible because quick reaction and movement are the fundamental of victory.

Then, we chose Gobang for further research in this project because it is more globally popular than Chinese chess. More importantly, in comparison with Chinese chess, Gobang game typically requires less time than Chinese chess and that means players have more flexible control of time on game playing. To assess accessibility and usability features of existing Gobang games, we evaluated those rated highly in app store by following mobile accessibility principles and user testing. Six high-rated (higher than 3.5) Gobang games were downloaded from Google Play market and installed on an Android phone.

Table 4.3 Accessibility requirements Checklist

Title	Category	Description

Perceivable	Text size	Default text is clear and legible.
	Resize	Allow user accommodate text size by changing size.
		Responsive size accommodation
	Contrast	Fulfill suggested color contrast (4.5:1 or higher)
		Text contents
		Graphic contents
Operable	Touch target size	Touch target is at least 9mm*9mm, and surrounded by enough inactive space.
	Touchscreen gestures	Gestures should be as easy as possible. Report any difficulties in gesture operation.
	Accessible button	Interactive elements like buttons should be easily reached when device is held in different positions.
Understandable	Semantic explicitness	Labels and texts contents should be explicit and concise.
	Consistent layout	The view of multiple pages in placement of repeated components should be consistent

An understandable design helps users to get familiar with the product or service through clear and logically consistent design, regardless of user interface or functionalities. At its simplest, a well understandable design reduces the cognitive load on users and reinforces mental module surrounding the product functions. We evaluated two aspects: semantic explicitness and consistent layout. Textual contents, such as tags on buttons, title and its corresponding summary, need to convey exact meaning to users. And consistent layout requires reserving locations of some screen elements (navigation, search box, main content, buttons) and arranges them consistently, because users have strong memory of location (Scarr, Cockburn, & Gutwin, 2013). A consistent design allow users to anticipate next action based on their previous experience.

Except one Gobang game failed to be installed, other five applications successfully run on the test device. After heuristic evaluation following mobile accessibility principles, their common and respective problems which violate regulations are listed in Table 4.3.

First of all, taking a glance at whether these applications satisfied perception requirements or not. Size of texts in different components, regardless of base view, menu or alert window, mostly ranges from 12dp to 18dp. One of them had textual contents smaller than 12dp in size, which may create legibility barriers to elderly players. In fact, participants indeed complained about excessively small font size and inconsistent language used in an app. None of them provide a setting option to allow the user modifying text size in the game. Except small font size, these five applications as well were not responsive to system-level accessibility characteristics. Many devices provide diverse functionalities to improve usability and reduce inaccessible issues, such as zoom, large fonts and captions. For instance, some operating systems provide large font mode for users with visual or motor impairments, but not all applications utilize this function for themselves. Obviously, five investigated applications were not able to make response to text magnification in android system. This means their small font size is a permanent accessibility issue for some people.

To assess colour contrast of text against background, screenshots of main interactive frame were took for six games to examined the font colour contrasts. Consequence indicated that three of them do not offer a satisfying colour contrast. Combining low contrast with small font size, there would be a huge doubt that whether elderly users can play these Gobang games satisfyingly.

Additionally, ambiguous icons accounted for the confusion arose among elderly players while playing. For example, what kind of information does an icon comprises two overlapped hands stand for? Is there any perceived connection between a key and ‘Help information’? Would people consider an icon that comprises two people standing in line refers to ‘About’? And is a cycle figure successfully able to convey meaning of ‘Withdraw’ (Figure 4.1)? These questions were arising in either examination and user test following the guidelines of mobile accessibility. Participants reported that these icons are somehow

abstract and unfamiliar to them and as a result they could not speculate the correct meaning of part of them.

Figure 4.1 Ambiguous icon examples

Ways of interaction is diverse, from single tap to double tap, rapid press to long press, switch or rotate, shake or slide. No matter how complex a gesture is, the root point requires fingers to move exactly and halt on the correct place. It is quite important to guarantee the minimum size of touch area, because small touch area can lead to operating errors. For instance, when small targets are grouped closed to each other, users may accidentally hit the neighbouring target and initiate unintended actions. To avoid accidental operation, users have to reorient their fingers, from finger pad to fingertip or conversely. As a result, reorientation of gesture or fingers slow down movements and force users to hit the target harder. In comparison with hitting with fingertips, tapping with finger pad is a more nature and comfortable choice. But finger pad covers entire touch target and block visual feedback. Users cannot see the target spot they are trying to hit. In a relevant research, the result indicated that errors made by user declines as the touch target increases (Parhi, Karlson, & Bederson, 2006). Namely, the larger the touch key size, the higher the success rate and pressing convenience. Consequently, there should be a reasonable minimum touch area to ensure basic hit accuracy.

Requirements from the perspective of graphic user interface of Windows Mobile, Nokia or other companies or organizations vary vastly and are not consistent with each other at all. iOS suggests UI designers to ensure touch target not smaller than 44*44 pixels, while Google user interface design guideline recommends that touch target should be at least 48*48 pixels, which results in real size of 7*7mm approximately. Meanwhile, there should

be at a minimum 1mm space between two nearby interactive components to assure information density and usability. Due to the test platform, Android, I measured the size of touch area for each element in these six applications. Half of them may lead to operating error due to small touch area on chessboard (around 5*5mm) and one of them organize buttons without interval space, like Figure 4.2. However, some designers found out new solution to gaining adequate touch space on small screen. For example, one Gobang game allow players to use direction controller to move cursor to select position on where to put chess pieces. Direction controller (Figure 4.3) is comprised of four accessible buttons: Right, Left, Up and Down. Another application enables users to magnify a certain area on chessboard through single tap first and then put a finger on the corresponding place where he intends to put a piece on (Figure 4.4). The reason why designers have to explore new interactive approaches for play Gobang is when a player is going to try press a certain spot, finger covers the entire intended place and block visual feedback. When touch area is smaller than finger pad, any tilt of finger may initiate unintended action. Beyond direct and underlying barriers listed above, we also found defects of operating logic. For example, some applications would be quitted when users press system return button, even if only did they want to return to first page in application from playing frame. Our users repeatedly revealed that some applications cannot store playing progress as they had to pause playing to pick up a phone call or do something else more urgent. Therefore, every time after switching back to the game, they had to replay from the beginning. That is not intelligent or user-friendly. Also, participants advised that there should be a caution when user initiate dangerous actions like quit or delete. They think assistant information helps keep consistent with context and reminds them what they are doing now and what they are going to do next.

One of participants hoped to configure application before he started experience. Many applications ask users to complete preference setting at the first time when they use. This setting procedure is always done combined with a tutorial that helps users to understand

what each setting item means and to choose the preferable option based on their own requirements and preferences.

Figure 4.2 No interval space may cause operating errors.

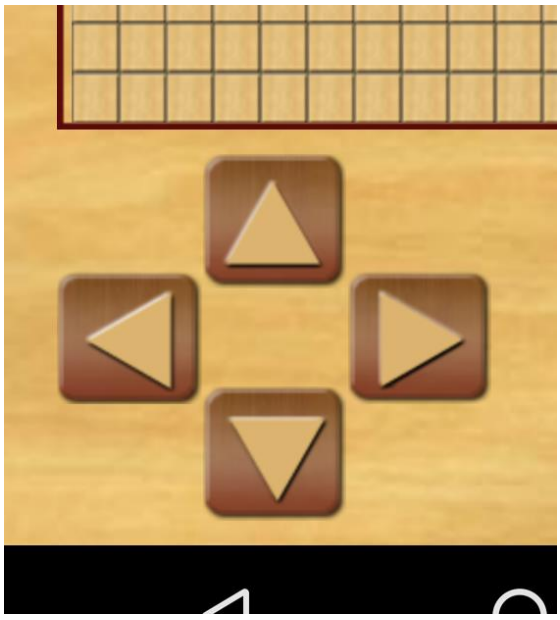

Figure 4.3 Direction controller

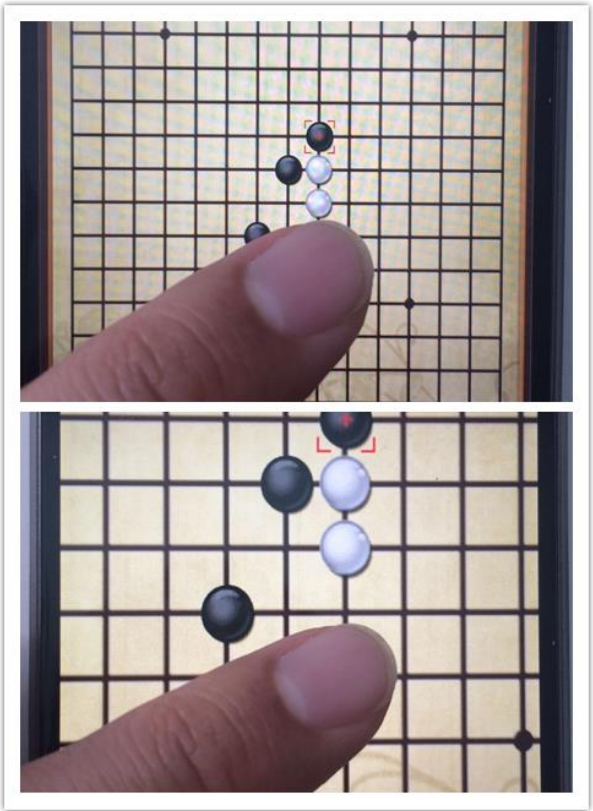

Figure 4.4 Up: before single tap; down: interface magnified after tapping

We found that several tested applications require additional system-level permissions before players started playing. Participants were confused about why these game-irrelative permissions are required, such as permission for location, making call, sending message. Some Gobang applications even asked users for approval of using camera and microphone, even though no function, which complete its job by camera or microphone directly or indirectly, could be found. Participants who are experienced in mobile use noticed this phenomenon immediately when they began to play, and had misgivings about the risk of privacy leakage and property loss. While people who are novices at smartphone use may neglect to deny the request for these risky permissions. More severely, these people are more prone to disclose their private information and be attacked. Thus, from this view of point, to design a secure product is one of the key points to diminish users' misgivings and defend their security.

4.3 Identify user requirements

As trying to explore the connection between social games playing and its positive effects on seniors' cognition ability is our research target, we will design an accessible and understandable social game. Reflection on the problems that elderly users may encounter when they play the game will guide to define initial design requirements.

According to primary user test, a light casual game, Gobang, was chosen as the target game of this study. A primary prototype will be provided to show participants more details about this game, such as interior functionalities, fundamental user interface and logic of operation. In turn, feedback collected from elderly participants will contribute to the optimization of design requirements and the development in the following interations.

4.3.1 Functionalities

First, Gobang provides a single-player mode, in which a player can play Gobang with the computer rival. Second, this game can automatically record information of playing, like how long a player consumed and how many pieces a player put on chessboard totally when he or she won. Information of playing constitutes to game record collection. Score list exhibits the information that was recorded only when a player defeated the computer. Score list is updated when the player achieves higher scores.

To fulfill social attribute, Gobang provides share options that allow the player to share something interesting about the game he/she was playing. When a game is over, the application captures a screenshot for the last view of chessboard when the player decides to share. This screenshot was stored locally and shared to the contacts of the player by means of social media sharing. Here WeChat is adopted as it is the most popular individual instant message tool and social media (an embedded function named Moment) in China.

In terms of usability and accessibility, Gobang grants the player the approval for individualizing the configuration of the game. For example, the player can modify the font size of textual contents in preference setting frame. Background of chessboard can also be changed to acquire the proper legibility and distinguishability in diverse environments. A night mode theme is provided to moderate stimulus to vision in dark environments. Additionally, the scale of chessboard is modifiable. Because screen size and resolution are varying severely on mobile phones, players need to adjust the configuration of chessboard to ensure the minimum size of touch area on their own devices.

4.3.2 First-stage interview

When the primary prototype was basically finished, we invited five participants to help us evaluate its performance in terms of usability and accessibility.

Table 4.4 demographic information of participants

	Gender	**Age**	**Employment**	**Education**
P1	male	72	retire	secondary education
P2	male	64	working	college degree
P3	female	71	retire	primary school
P4	female	64	retire	college degree
P5	male	68	retire	bachelor
P6	female	74	retire	secondary education
	Health Condition	**Mobile experience**	**use of social media**	**use of mobile game**
P1	presbyopia	over 2 years	WeChat	often
P2	myopia (750°)	over 10 years	WeChat, Weibo	often
P3	presbyopia	half a year	None	never
P4	myopia	5-6 years	WeChat, Weibo	not often
P5	mild presbyopia	9-10 years	WeChat, Weibo	often
P6	good	Over 2 years	WeChat	Not often

Five participants, who aged from 64 to 72 years old engaged in primary prototype evaluation. All of them suffered varying degree of visual impairments, presbyopia or myopia. And one of them was still working. Regarding IT skills, they had primary experience

on the use of mobile phone and were capable to accomplish simple tasks individually, such as making phone call or check messages. And four of them were users of WeChat.

Table 4.5 Characteristics of the mobile phone used by interviewees

	Device screen size	**Preferable font size**	**Touch area (10*10)**	**Is touch area big enough?**
P1	4.7 inch	>22sp	8*8mm	yes
P2	4.5 inch	>24sp	7*7mm	yes
P3	5.0 inch & 9.7 inch	>24sp	9*9mm	satisfied after practicing
P4	4.3 inch	>22sp	4*4mm	less satisfied
P5	5.0 inch	>22sp	9*9mm	yes
P6	4.7 inch	>20sp	8*8mm	yes

Information about the hardware platforms was collected by user interview, such as what kind of device they are using, what screen size of their equipment is and do their devices support system-level font size modification (Table 4.5). This preliminary investigation enabled us to construct an overview of the possible running environment, and helped us design the game more compatible to varying hardware characteristics. In sum, the popular size of mobile screen was 4.5-5.0 inch approximately. Therefore, based on 10*10 chessboard (10 rows and 10 columns) we designed, touch area for each single finger tap theoretically was from 7*7mm to 9*9mm and this size satisfied Android usability and accessibility requirement (not less than 7*7mm). But we noticed a fact that thus far there were people still using mobile device with screen smaller than 4.5 inch. A 10*10 chessboard probably negatively influences the accuracy of operation and leads to more mistakes. For example, P4 was using a 4.3-inch mobile phone and she complained about the narrow size of each square that equalled to 4*4mm big approximately. She had to slow down her actions and put down index finger on the correct place very carefully. Even so, she made mistakes more than other people during playing this game. It is out of question that maintaining a single interactive element not less than 7*7mm on all kind of devices is critical for elderly users.

Then we asked participants about their preferable font size of textual contents. A frame in Gobang game was designed to show texts in different size from 12sp to 30sp, and participants were required to vote the minimum size of text that could be read clearly, as shown in Figure 4.5. To furthest eliminate deviation caused by wrong gestures in which people do not hold a phone as they playing mobile game, we asked participants to simulate playing games on mobile. Each participant held the phone in a comfortable and genuine posture. Distance between eyes and screen was remained reasonably while sitting in a place with adequate lumination. Feedback gathered from participants revealed that size of text was supposed to be larger than 22sp, and 24sp was the size satisfied people with additional visual requirements due to special reasons like myopia.

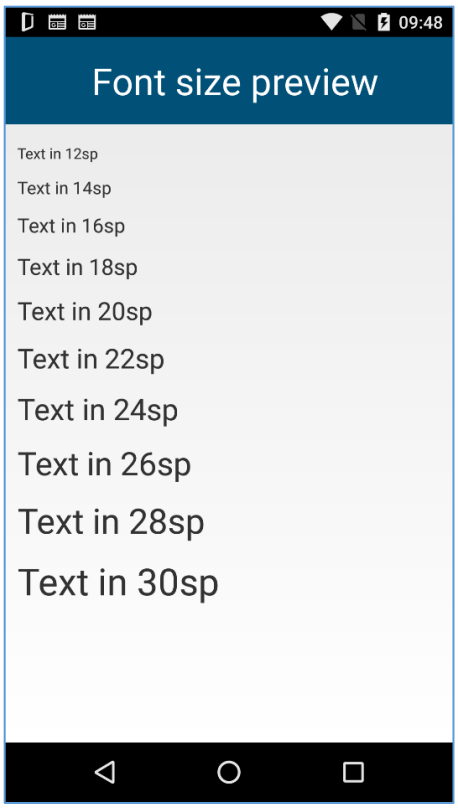

Figure 4.5 Text in different size from 12sp to 30sp.

5 Design and development

5.1 First iteration

5.1.1 Implementation

A new digital prototype was designed, which comprised three primary functions: (1) single-player mode, (2) score list, (3) preference setting. In single-player mode, the user could play Gobang against computer rival. When a game was over, the game automatically recorded gaming information like the time and steps a player consumed in a game. Players could review previous scores, consisted of data relative to time and steps, in score list. This prototype also provided a simple preference setting frame. For example, users could adjust font size of textual contents display in setting screen. And scale of chessboard could also be adjusted by the player.

5.1.2 Feedback

After use evaluation assisted by two elderly participants, some problems in terms of accessibility were found. For instance, the icon exhibited in Figure 5.1 was unnoticeable and ambiguous to elderly participants. Except P2, others either did not notice such a button located on right top of screen or queried the meaning of it (Figure 5.2). However, this is the only visible button on that frame, providing two additional options: ‘replay’ and ‘settings’. Official definition of this pattern is ‘More options’, while senior participants in our user test project were not able to understand the meaning of it successfully or in a short time. From their view of this issue, they suggested such functions should be visible directly to users instead of being hidden in submenu. Designers should place critical operable components in obvious place with concise interpretation, like a label rather than decorating them with aesthetic or ambiguous icons.

While participants playing this game, all of them complained that the computer player acted so fast that elderly players had difficulty in tracking computer rival's latest reaction. Especially when there had been lots of pieces on chessboard, players felt confused when they had no idea how the rival acted. If they are not aware of the latest action of computer player, they cannot figure out the best strategy and make the right decision. They gave a piece of advice that the latest action of computer should be highlighted with remarkable symbol and players should have more time to get ready to trace action of computer.

Figure 5.1 An icon causes confusion among elderly participants.

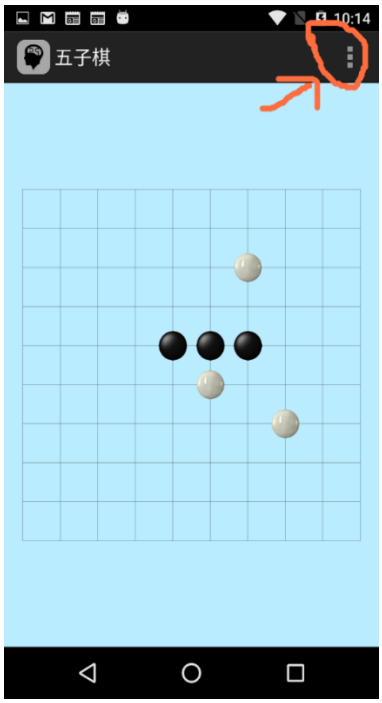

Figure 5.2 A button located at the corner is unnoticeable.

Participants hoped to see visible difference between various font size options directly, because they had no idea about what does the actual size of texts look like. As shown in Figure 5.3, users need to switch between three options until one of font sizes satisfies their requirements. If direct difference between font sizes was displayed and users could know which one is their best choice, operation could be simplified.

Figure 5.3 Interface of font size adjustment

Board game requires player to put piece on intersections made by rows and columns, and clarity of these vertical and horizontal lines directly makes influence on accuracy and correctness of tap. We adopted value of 1pt as line weight for rows and columns in primary prototype, and senior participants all suggested to strengthen weight of lines. Since 1pt lines were fuzzy against background colors like in Figure 5.4. Excessively thin lines led to decrements of distinguishability in bright circumstance. For example, P1 could not see lines on chessboard clearly under sunlight, and light blue background color exacerbated the problem as well.

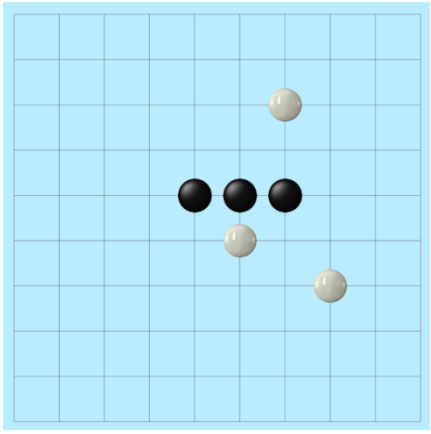

Figure 5.4 Lines are fuzzy against light blue background.

Application icon, as a critical element that provides users an overview of what an app is generally designed for, should covey core meaning and purpose of an app by effective combination of figures or, namely, concrete graphic design. As our primary prototype adopted an icon irrelative to Gobang (Figure 5.5), senior participants P1 and P4 had trouble finding our game from application list or application drawer. When they have not cultivated a logic connection between an unconversant pattern and an unmatched meaning behind it, they hardly find target out rapidly if they did not read the app name under the icon. Thus, a precise graphic expression is much effective and crucial than merely relying on literal contents. Thus, speculating whether an app is what they are looking for by having a glance at icon might be their preferable choice.

Figure 5.5 An icon caused confusion among elderly users.

Additionally, our senior participants experienced some troubles on operation. It is a popular trend that mobile manufactures locate buttons on the bottom of screen. In general, android phone put ‘Return’ button on right bottom corner, where is closed to the manipulating hand, particularly nearby thenar. P4 reported that unwilling actions like return or quit were always initiated because her thenar touched ‘Return’ button by accident. Another participant suggested there should be a precaution in case of a user initiates an action that is going to change status of current progress. For example, there should be an alert that asks the player for confirmation of the action to prevent quitting the game when he or she presses the button ‘Quit’ unwillingly. Such anti-humanized designs out of question cause annoyance and less considerate ‘glitches’ lower user experience.

An interesting phenomenon was noticed while implementing the test. The users, who were more experienced in mobile using arose stricter aesthetic requirements on user interface design. Points like color, shape, layout management had a crucial impact on their first impression of a game. For example, several participants like P2 denoted that the user interface of the game thus far was not aesthetically satisfying. Monotonous colors and a pile of simple shapes made this game application more like an unaccomplished prototype and could not inspire them to play for more time autonomously. Elderly participants, who lack experience on playing mobile games, also agree this opinion. They believed a pleasant interface with vivid, well-matched color scheme, lovely shape of interactive elements, user-friendly layout management, etc., could provide aesthetical pleasure. So, designing a good-looking interface was going to be a part of future work, and maintaining UI well accessible should be kept in mind all the time.

5.2 Second iteration

5.2.1 Implementation

In this version, it supported Chinese and English languages and this application could switch corresponding language automatically when system language changes. Problems

emerged in last iteration were solved in this phase. For example, ‘quit’ and ‘restart’ were two fundamental and frequently used functions while people playing this game, but they were hidden in submenu that was not findable as shown in Figure 5.2. In this version, core functions in this application were accessible and were placed on screen obviously. And interactive elements were interpreted with textual clues. We hoped these improvements could help elderly users to access their wanted functions with more ease.

In setting frame, title and summary had larger line space and more difference in text style. Different items were arranged with significant margins and the size of texts were larger than 20sp. When a user reset font size, this application could provide a list of options interpreted with examples, as shown in Figure 5.6. Thus, users could be aware of what size they prefer to use as they making choice.

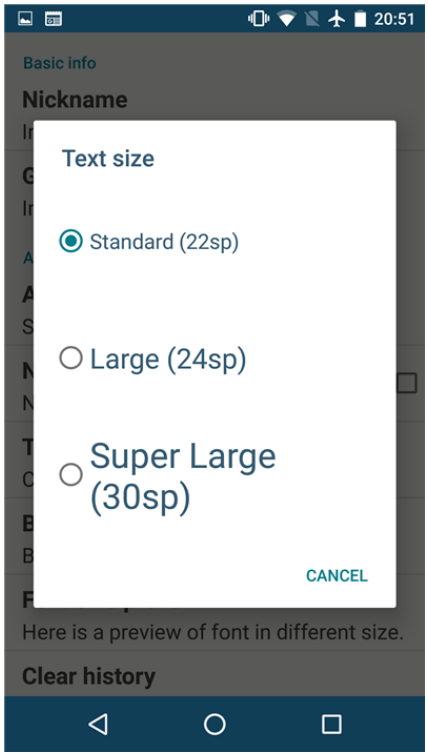

Figure 5.6 Options stand for different font sizes

We also integrated the part of “social sharing” in this version with open source API supported by Tencent. In China, WeChat had nearly 0.89 billion users who are active online

monthly by the end of 2016. The number of elderly WeChat users reach more than 7.5 million (Tencent., 2016). Compared with younger users, the elderly construct conversation with others by audio or video more frequently, and they like repost what appeal to them. They could accomplish simple tasks like sending text messages, voice messages, video chatting and sharing contents they are interested in to their friends. Theoretically, “social sharing” is not a big manipulative problem for elderly WeChat users.

5.2.2 Feedback

A few feedbacks were gathered after evaluation. P5 was satisfied to see improvements happened to accessibility features in this version. For instance, providing Quit buttons with an alert was thought an effective way to preclude quitting by accident. All texts were displayed in big size and conveyed meaning clearly and precisely.

However, he still found some issues existing in this prototype. He pointed out in Night Mode, lines on chessboard were not distinguishable because color of chessboard became too dark. P3 had met the same problem as P5, that dark color of chessboard in Night Mode made finding black pieces not an easy job. Red mark that was designed to highlight the latest piece was hard to observed against dark background, said by P5 (Figure 5.7). He noticed that the picture he shared on WeChat was displayed as a file, instead of a picture, with a name comprised a string of numbers. He reported that people may be unwilling to open a strange file in consideration of security. So, the shared file should tell receivers what it is to diminish their concerns about security. He believed well-designed shared contents could attract receivers to check what he received and make response.

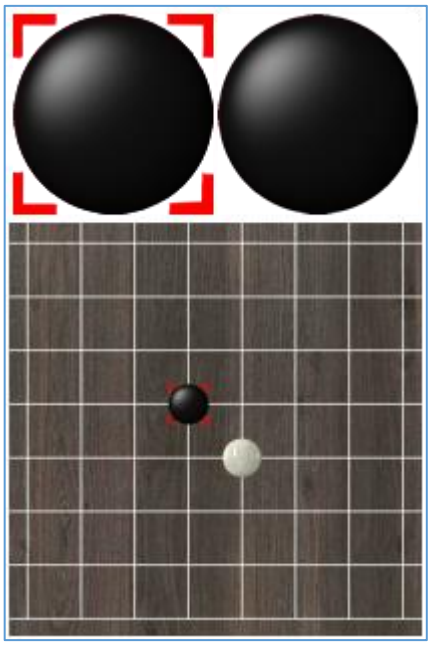

Figure 5.7 Red mark is not obvious when background is dark.

P3, as a person never used any social media before, told us that learning how to use share scores by ‘social sharing’ is not difficult, but she had few contact on WeChat. Her social relationship became simple and fixable after retirement, and lost contact with people due to less meeting gradually. She suggested Gobang should provide multiple-player mode which was believed more helpful and appealing to the elderly. As a member of an interest group, she goes to the garden with people live nearby to play card or board games regularly. She hoped to play games with friends on her pad, because bringing a pad is more convenient than carrying a set of chess along with a less portable chessboard.

Additionally, she was not familiar with icons of different share options and titles of these options are too small to see, marked with red lines in Figure 5.8, but after practices she remembered how to share scores by hitting the correct button. If the target users are elderly people, who lack knowledge about the existing association between a typical pattern and its corresponding meaning, designers ought to give priority to textual contents to convey meaning of any functions.

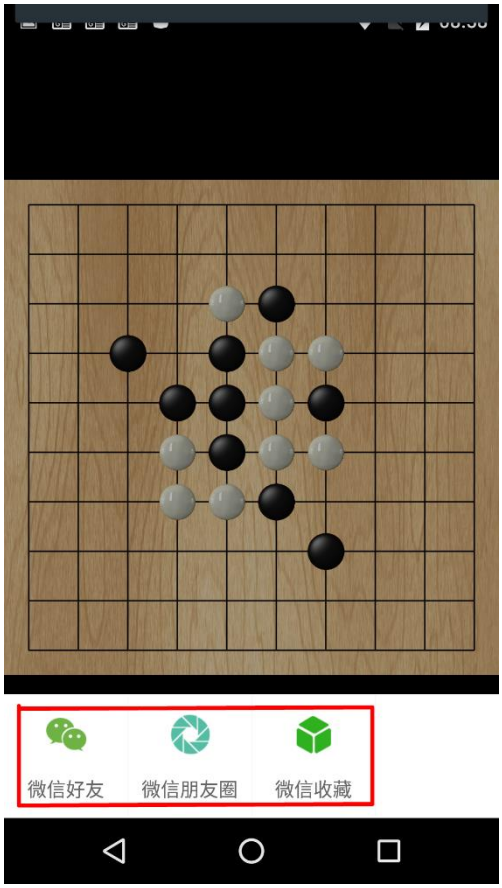

Figure 5.8 Small tags are not readable for P3.

5.3 Third iteration

5.3.1 Implementation

This time we added and integrated the functionality of history in the new version of prototype. The functionality of history provided a place where the screenshots are exhibited as thumbnails in a 3*X grid layout (3 columns and X rows). To watch more details, users could view the original screenshot by hitting the thumbnail, and use fingers to zoom and pinch it (Figure 5.9).

5.3.2 Feedback

After evaluation, P6 suggested to add a return button in the history frame as in other frames (Figure 5.10). This was a part of remaining operation consistence. Because after a period of use, she got used to tapping return button provided by this app rather than that offered by system to return to last frame. We also found that the set of buttons on the bottom of screen provided by android system, which consists of return button, home button and menu button, automatically disappeared while the application was running. In the case, a participant felt confused because she could not find an effective way to quit current screen fast. Because the user may want to accomplish other tasks due to individual reasons while playing the game, it is important to provide a solution to quit the game. She also suggested that us to allow users to share the screenshots while they are browsing in history frame. If so, she can send the screenshots to friends if she thinks they are interesting.

Because we forgot to tell P6 about gesture operation we added in this version, she did not notice and use this function until we told her. In next update, we intent to use images or videos to show new features provided by this application before users begin to use. Because return button on the bottom of screen was too close to the visual buttons provided by system, P6 denoted that the lack of adequate white space around Return

button leads to the increasing possibility to hit visual buttons by accident, as shown in Figure 5.11. From this view of point, to ensure enough white space between different operable elements is an important step to prevent unnecessary misoperation. Barros and his colleagues held the same opinion in their study that designers should be cautious when they position interactive elements towards to the edge of screen in case of triggering unexpecting actions (de Barros et al., 2014).

Because a screenshot only captured what was on chessboard when a player finishes a game, interviewee thought there should be more detailed information, such as gaming time displays on screenshot. If so, she would have more valuable things to comment with others. She told us that the screenshots exhibited as thumbnail ought to be categorized and displayed in time, because it was hard to find out the one she wanted to show her friends from a full screen of images listed without order.

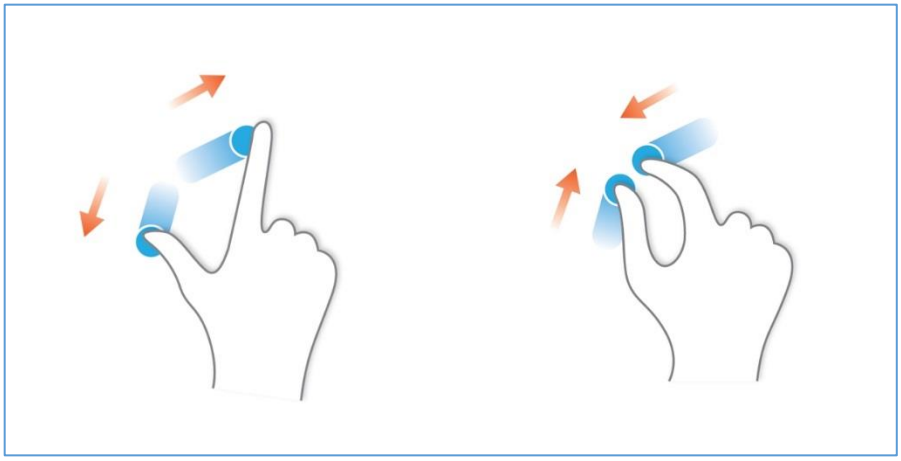

Figure 5.9 Gesture operations of Zoom and Pinch.

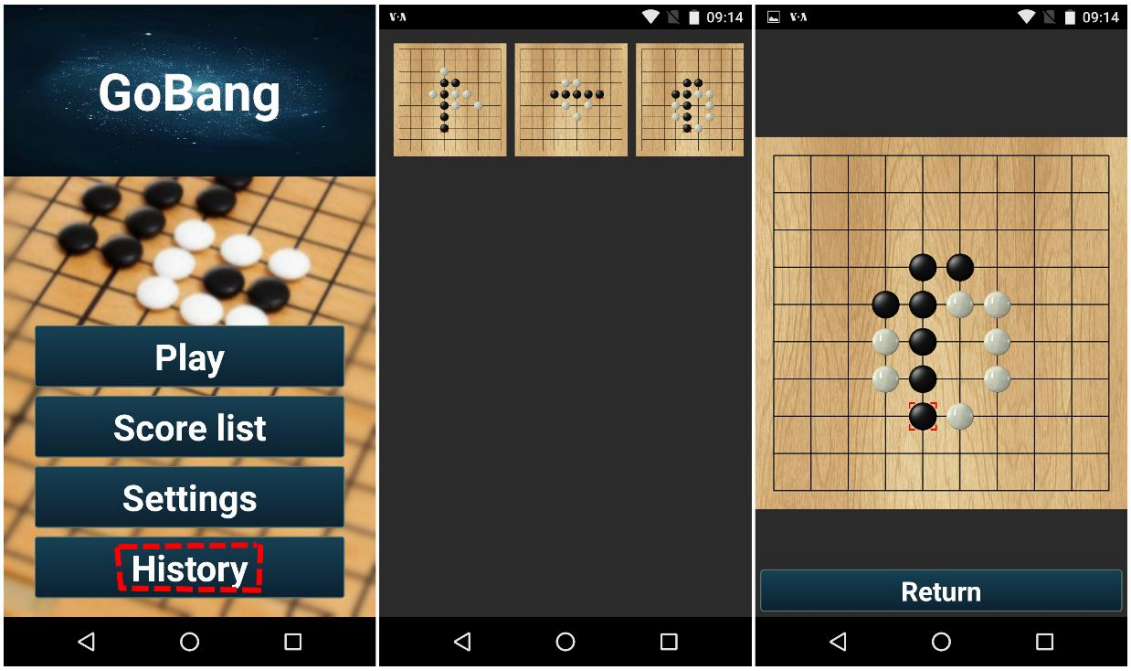

Figure 5.10 History allows players to view screenshots took before.

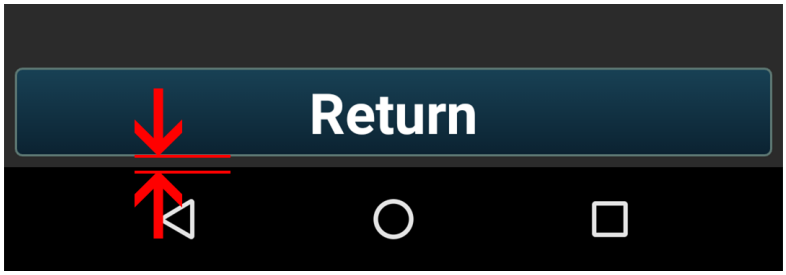

Figure 5.11 Lack of white space between operable elements leads to misoperation.

5.4 Forth iteration

5.4.1 Implementation

In this iteration, issues that bothered our participants during their use during last phase were handled. For example, we adjusted space between different interactive elements to help players to avoid touching unwanted place in-deliberately.

To solve the problem mentioned by P6 in iteration 3 that she could not realize to use the gestures to control browsing screenshots in History frame, we added an instruction page for our elderly participants. The instruction page appears when this game is running for the first time after installation and provides guided information by graphical and textual specification (Figure 5.12). Colour difference between texts on crystal hint page and galley page was not significant, so we amended the colour for hint page as the screenshot on the right side.

5.4.2 Feedback

After evaluation, elderly participants denoted that white texts on guide page were not clear against the background, particularly when there were pictures cramming whole screen (Figure 5.13). To solve this problem, guide page was redesigned to make texts and patterns prominent by improving opacity and diminishing interference from contents on the frame underneath guide page (Figure 5.14). Furthermore, users had only one chance to watch the instruction page after installation. If they did not read it carefully and skipped it by tapping the screen deliberately, they could not watch the specification anymore. Therefore, there should be an option in setting frame that allows a user to watch it when they need to know who to use gesture control.

Also, because this guide page was defined to be skipped by a hit of screen, wherever. During the use P4, he reflected that the action of skip was so easily triggered by mistake. As

a result, he might miss the opportunity to watch guide information. Thus, it is suggested that when irreversible consequence is going to change, the application should warn users about the possible consequence they will face and allow them to undo their unpredictable or unwilling action.

To help the user recollect more specific details about the game screenshot they are sharing with others, we planned to draw the information includes gaming time and step of a game on the screenshot. But this solution was invalidated when we reviewed the prototype that realized this function. Because texts drew on the screenshot could not provide a satisfying legibility. There was no sufficient space for placing textual information on a picture. Another solution was figured out to indicate clearer and more legible game information (Figure 5.15). After consulting participants, texts showing in the place marked by red colour (place 1) were more legible than the one marked by green colour (place 2), because the simple background (place 1) effectively reduced interference and enhances colour contrast of texts.

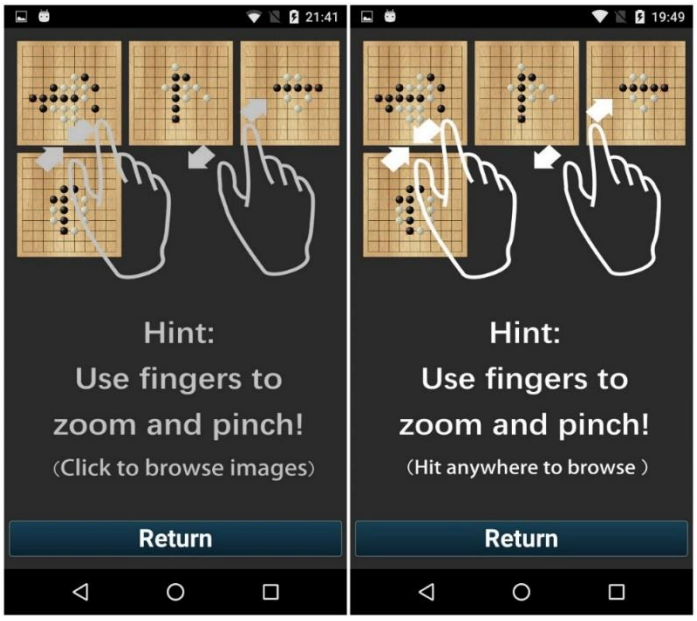

Figure 5.12 Instruction page

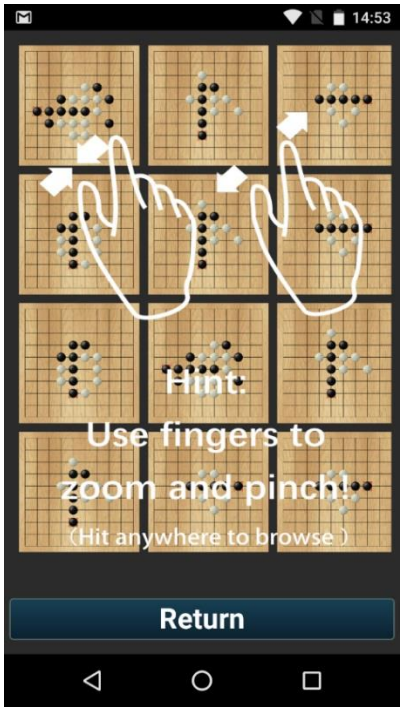

Figure 5.13 Contents in white color are not readable

Figure 5.14 Black background highlights the contents on guide page.

Figure 5.15 Texts marked by red color are more readable then that marked by green color

5.5 Fifth iteration

5.5.1 Implementation

In this iteration, problems reported in previous phase were solved. And a set of well-defined themes was provided in this game. Colours adopted by each theme fulfilled the minimum requirement on colour contrast, which requests contrast ratio of foreground against background is up above 4.5:1.

5.5.2 Feedback

As per the feedback of participants, this game was hoped to provide multi-player mode that allow players compete against each other. Some participants regularly gather with people who have the same interests, and organize races and other entertainment activities. They believed a phone or a pad, on which chess or card games can be played, was more portable than a cumbersome chessboard and a box of chess pieces. Participants reported that score list was a low-frequency used function., because they hardly reviewed scores or show high score records to others. Thus, in next iteration this part, score list, should be displaced by another function that is more valuable to elderly players, such as a multiplayer mode.

5.6 Sixth iteration

5.6.1 Implementation

This time Gobang had a new visual effect design. Four color themes had a unified visual style which mainly consist of striking colors like white and light grey. Four accent colors were used to provide difference in visual effect and to prevent a sense of inconsistence probably caused by massive amount of vivid colors.

To stimulate competition and help players form stronger motivation to play this game, badge system (Figure 5.16-a) was added in this version, in which achievements of the player were represented by different type of badges. For example, a beginner who has not won many times only has a badge made in common material and marked with “Lev.1”, while an experienced player has a badge with superior material, vivid color and higher level number. In multi-player mode, two players could compete against each other on the same device (large devices like a pad are recommended because of size advantage). Information about how many times two players won respectively was indicated on the right top corner of screen (Figure 5.16-b).

Figure 5.16 (a) badge appears on the top of home frame; (b) gaming information is indicating the top of screen in multi-player mode

6 Final evaluation result

This section discusses the participant recruitment process and findings of the face-to-face interviews. The objective of the final evaluation is to explore whether playing Gobang helps the elderly perceive an improved sense of well-being and strengthens their social connections.

6.1 Participants

Six elderly people aged 60 years and above participated in the final evaluation: three people aged between 60 and 69 years old, two people were between 70 and 79 years old and one was older than 80. Participants did not exhibit symptoms of dementia, psychosis or severe physical disabilities and they were accustomed to using smartphones (Android) and mobile applications. P1, P2 and P6 participated in previous evaluations and P3, P5 and P7 were new participants recruited through the social networks of P6. Prior to conducting the user evaluation, participants were briefed on the project and subsequent evaluation. All participants signed the consent form and were aware of their responsibilities. Demographic information such as gender, age, education, employment, IT experience and living status were also collected.

Throughout the three-week period of experience, participants were required to use every function independently and as frequently as possible. To better understand their feelings of playing during this period, a semi-structured interview was administered every week. Questions focused on the possible changes in playing behaviours such as frequency of use or acceptance of a certain function. More details are listed in Appendices D.

6.2 Procedure

The final evaluation was conducted with four parts: heuristic evaluation, pre-interview, weekly interview, and post-interview. The heuristic evaluation was conducted to technically

assess Gobang's accessibility as per the guideline published by W3C. The pre- and post-interviews were performed to collect data for the following comparative study.

The World Health Organization Five-item Well-being Index (WHO-5) test was performed during the pre- and post-interview since fluctuation in scores could be indicative of participants' overall sense of well-being. Participants were asked to rate themselves on a scale of 0–5 for each question. The raw score was calculated by adding up the values for the five answers and the final and percentage scores were obtained by multiplying the raw scores by four. As per the WHO-5 index interpretation, participants with a raw score of less than 13 have poor well-being and are recommended to participate in further tests to determine depression levels.

In addition to the WHO-5 test, participants were asked to answer questions that covered participants' living status, social connections and technology skills as well as psychological, physical and cognitive well-being. Differences in the results between both interviews demonstrated whether playing Gobang affects elderly participants' quality of life and the benefits derived from the game. Specific questions are listed in the Appendices E and F.

6.2.1 Heuristic evaluation

The heuristic evaluation was conducted to identify possible usability and compliance issues. In particular, it assesses user interface performance from aspects such as system visibility, match between system and the real world, freedom of control, consistency and error prevention on (Nielsen, 1993).

First, in terms of visibility, all textual content was set to larger than 20 px. Participants appreciated the tag size for buttons or titles, summaries for each setting, and content on alert dialogs. Owing to visual deterioration, P1, P3 and P4 had stricter requirements for font size; for example, they preferred medium- and large-sized font to small-size ones. P7

mentioned that the icon tags that appeared when sharing scores on social media (WeChat) were too small to read (Figure 6.1). Nevertheless, she was able to understand the meaning of the icons on the basis of daily use experiences. On the other hand, P3 and P5 stated that they fail to correctly comprehend the icons if they are unable to view the tags. APIs of social sharing forbid developers from making appearance changes to icons and tags for technical issue purposes. Thus, future work should consider attaching explainable texts to the three buttons.

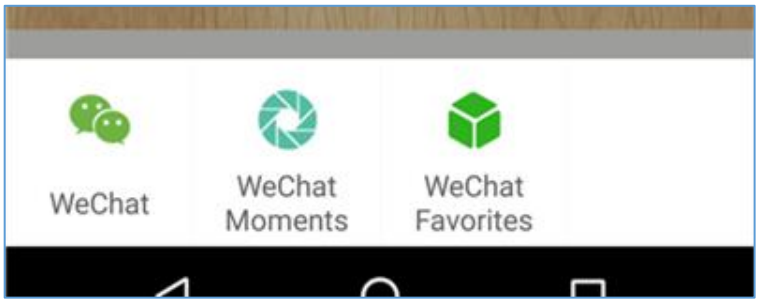

Figure 6.1 Tags for each share option are too small to most elderly participants.

The lasted version of Gobang provided multiple themes to satisfy participants' aesthetic sense, which were designed with four different primary colours.

Interactive elements were distinguishable due to the satisfying ratio of contrast (higher than 4.5:1), which met the requirements for user interface design on mobile platform defined by WCAG. The colours of the interactive element outline significantly differed from those of the areas around it, and thus, users could easily perceive the shapes and colours of operable elements.

To examine legibility of four themes in different lumination environments, evaluations were conducted during the day and night time. P1, P2 and P5 were required to use the Gobang application in a park between 13:00 and 15:00 PM on a sunny day. To simulate conditions of real use, participants were required to use the app outdoor (a no shelter place) and indoor (a low lumination place). The results indicated that participants were

satisfied with the UI distinguishability under different themes. In the daytime, the interactive elements were noticeable and textual information could be read easily and in poorly illuminated environments, the reduced brightness and dark colours decreased the stimulus to participants' eyes while maintaining legibility.

Screen brightness is a key factor affecting legibility. When the phone screen was not sufficiently bright, participants had difficulty in watching screen contents clearly. On the other hand, the same problem was not reported when the brightness of screen was strong enough. However, there was a noteworthy phenomenon that part of elderly participants was unaware of that phone screen brightness can be adjusted by themselves. Automatic brightness adjustment was banned unknowingly on the mobile phones used by some participants, and some people bear the low brightness set for indoor usage and forgot to modify when using outside. Participants were then asked whether they would like to grant Gobang permission to automatically modify screen brightness: while some preferred to manually modify their settings, others allowed the application to automatically adjust them.

In addition, participants reacted positively to the other heuristics aspects; for example, Gobang's high levels of simplicity and linguistic clarity allowed access to basic functions in few steps and clear and effective communication with the participants.

6.2.2 Pre-interview

WHO-5 test

To monitor possible changes in well-being, we multiplied the raw score by four to obtain the percentage score, where a percentage score of 100 denotes the best quality of life and zero the worst. A 10% or higher difference indicates a significant change in well-being (John Ware, 1995). While P1, P3, P6 and P7's score was higher than 13, P2 and P5's was lower. In particular, P2's total was three and he scored zero in Q3 and Q5. According to the

interpretation for WHO-5, P2 has severe welfare issue and is at the risk of experiencing depression.

A common problem in the lives of the elderly is the lack of pleasure and enjoyment. More specifically, the participants were unsatisfied with their current living status and desired elements that allow them feelings of happiness and connectivity with the outside world. P3, a 79-year-old male, considered his life to be rather boring. His children lived or worked in other cities and generally had few visitors. For P3, lack of family and friend support was the key reason underpinning his severe loneliness. P6 and P7 were also bothered by their restricted social interactions. Once they had retired and began living independently, their structured social relationships, in which they felt comfortable and familiar, diminished and gradually weakened. This caused a sense of loss as they realized they were no longer surrounded by people. Nevertheless, they were significantly enthusiastic about establishing new social connections and making new friends. They understood the importance and necessity of maintaining interactions and communication with others and believed social connectedness is a crucial factor that helps maintain cognitive ability.

The result also highlighted issues relevant to the quality of rest. Participants who reported a low score for Q4 were often unable to rest or sleep satisfactorily. The top key reasons were physical issues and pressure. Some participants also had low scores for Q3, 'I have felt active and vigorous'. Most of them invariably continued with their daily routine but lacked entertainment and sufficient social interactions. Except watching TV, gardening and feeding birds, they hoped for new sources of enjoyment in their daily lives. The participants unanimously mentioned the need for novelty in their lives, for example, new lifestyle and new skills, which they showed willingness to learn. It appears that the elderly needs a good enough 'excuse' that drives them towards opening up to the world and breaking restrictions that limit their social interactions.

P2 reported the lowest overall score for the survey and often experienced depression. He spent most of his day caring for his parents and thus, did not have much time for himself. Thus, he was unable to participate in activities organized by former colleagues or classmates: 'It is enviable to see them have fun together in many activities. I could not attend them. I felt very alone and a little sad as I saw the photos they posted on WeChat'.

Additional questions

Participants were asked additional questions to better understand their welfare conditions. According to responses to Q1, 'Do you feel healthy?', four participants reported they were not in good condition, physically or psychologically. These participants suffered various illnesses and deterioration such as visual impairment, diminished motor ability, arthritis, diabetes, hypertension and cardiac arrests. Declined motor ability restricts scope for action and certain chronic diseases increase stress and decrease duration of daily activities, which in turn lead to limited enjoyment levels.

As for Q2, 'Are you experiencing significant cognitive deterioration?', two participants reported varying degrees of obliviousness. They would easily forget certain items during their daily routine and felt frustrated when they were unable to execute their original plan. Another issue was decreasing ability to learn new skills and accept new concepts. For example, P5 lacked confidence to independently use Alipay, an online payment tool, even though he had done so many times. More specifically, he faced difficulties in accurately recollecting the payment procedure. P7 reported a similar experience with the video chat option on WeChat.

Half of the participants responded negatively to Q3, 'Do you consider yourself happy?'. In general, they were dissatisfied with their lives. They no longer were attracted to or thoroughly immersed in their regular activities and routines. In addition, lack of meaningful and enjoyable activities was mentioned as a key hindering factor leading to dissatisfaction.

As for Q4, ‘Do you occasionally feel alone?’, four participants declared they often felt lonely and considered lack of social integration as the main reason. For instance, their interactions with their co-workers diminished to a certain extent post-retirement and some of them lived independently and thus, did not communicate with their families as often.

In response to Q5, ‘Would you like to contact others actively?’, half of the participants stated they would not do so unless they had a sufficiently good reason. Shortage of appealing communication was thought as another reason that worsens the situation. For example, they would share news or photos on WeChat only if they were of interest to both the recipient and sender. P3 and P6, who were not members of any social media platform, contacted others through phone calls or by visiting them personally, although the frequency of contact was as low as once a month or less.

All six participants agreed that frequent interactions and effective communication reduce feelings of loneliness. P1 believed her mental health and motor ability could benefit from communication and interactions with others.

Table 6.1 WHO-5 index for pre-interview

Index	Q1	Q2	Q3	Q4	Q5	Raw score
P1	4	5	3	0	2	14
P2	1	1	0	1	0	3
P3	4	4	3	3	2	16
P5	3	2	2	3	2	12
P6	3	4	4	3	3	17
P7	3	4	3	2	2	14

6.2.3 Weekly interview

Interviews were conducted per week throughout the user evaluation. Specific questions with focus on Gobang’s use situation were defined and participants were required to answer them on the basis of their experiences in the past week. The objective of the

weekly interviews was to acquire pivotal information on behavioural differences and guarantee participants' constant engagement in the evaluation.

Over time, all the participants accepted the game. While in the first two weeks, most of the participants played Gobang 3–6 days per week, in the third week, more than half the participants (4 persons) played it every day (Figure 6.2). Interestingly, half of the participants played the game every day in the first week. They were encouraged to play it as more as possible but were free to discontinue playing. Their voluntary willingness to play as often verified their attitude of acceptance. The frequency of game playing increased from 2–4 times per day to 4–6 times per day in the third week (Figure 6.3). Most participants spent at least half an hour playing the game once they became aware of its features(Figure 6.4).

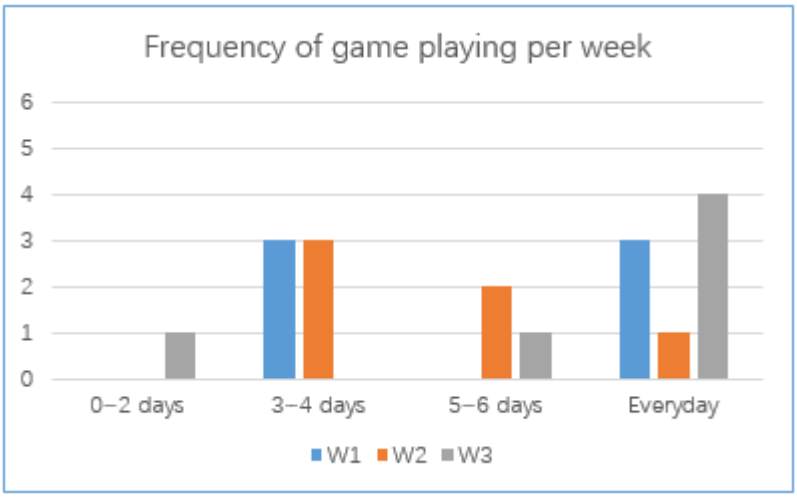

Figure 6.2 Frequency of participants' game playing per week.

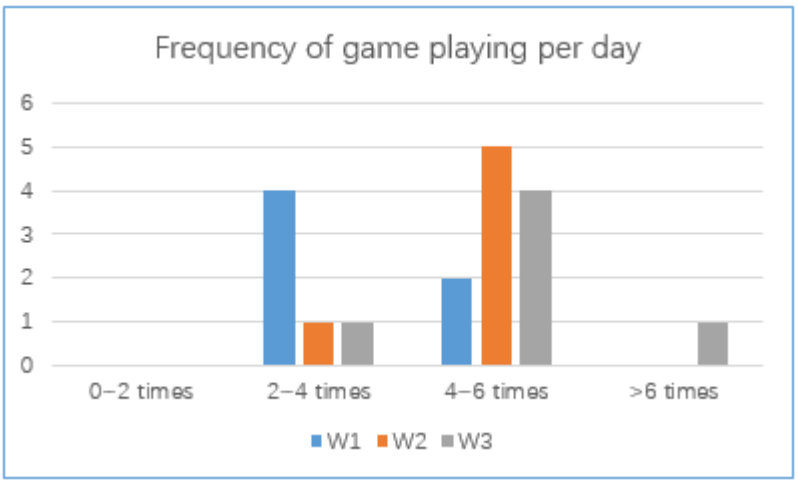

Figure 6.3 Frequency of participants' game playing per day.

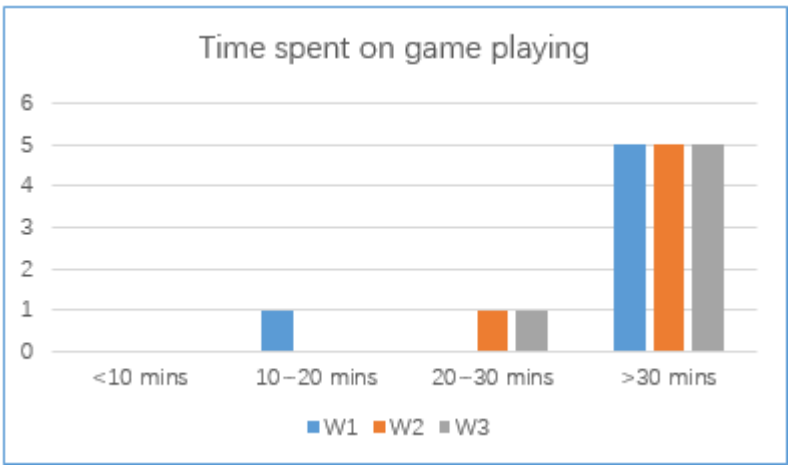

Figure 6.4 Time spent by participants on playing the game.

Unlike their overall attitude of acceptance, data collected during their use experience indicated that social sharing was not as useful as expected. Excluding the two participants who did not have social media accounts, the number of participants who shared their scores with others constantly descended during the test period (Figure 6.5). In addition, further interaction after sharing game messages (scores) was not satisfactory but positive. Figure 6.6 demonstrates that while participants received a response from their social media contacts in the first week, this did not continue into the subsequent weeks.

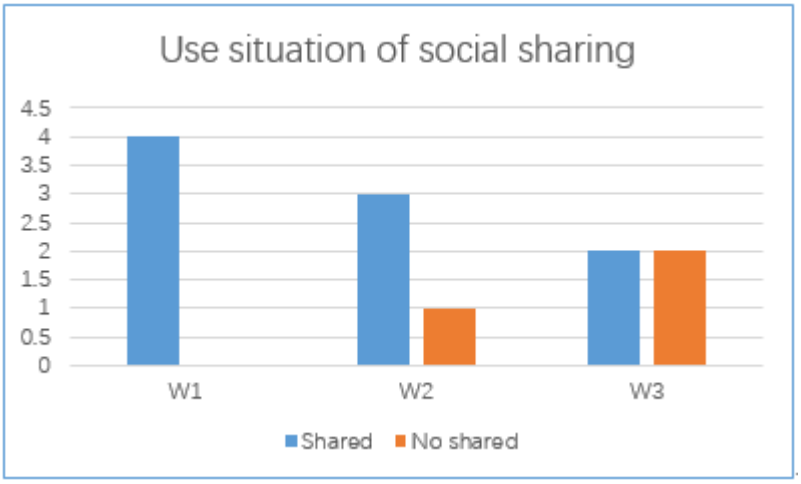

Figure 6.5 Use situation of social sharing (excluding two participants).

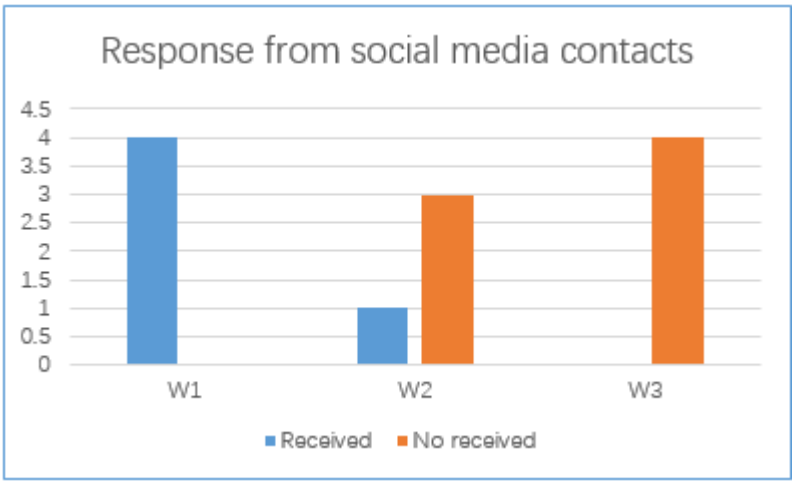

Figure 6.6 Response from other upon sharing scores (excluding two participants).

Another noteworthy phenomenon is that the history function was ignored in the latter two weeks (Figure 6.7). Despite five participants experiencing the function in the first week, none of them continued to use it in the subsequent period.

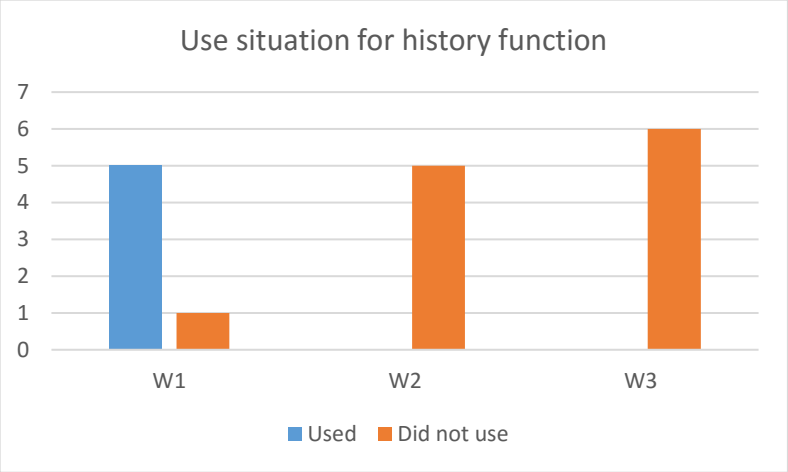

Figure 6.7 Use situation for history function

In terms of intensifying social interactions, Figure 6.8 shows that the number of participants who considered playing face to face enhanced social connection was higher than that of participants who favoured social media sharing. To eliminate the effect of different variables, Figure 6.8(b) excludes data for P3 and P7 because their results were not reflected in Figure 6.8(a). Nevertheless, P3 and P7 agreed that playing face to face would strengthen their social interactions.

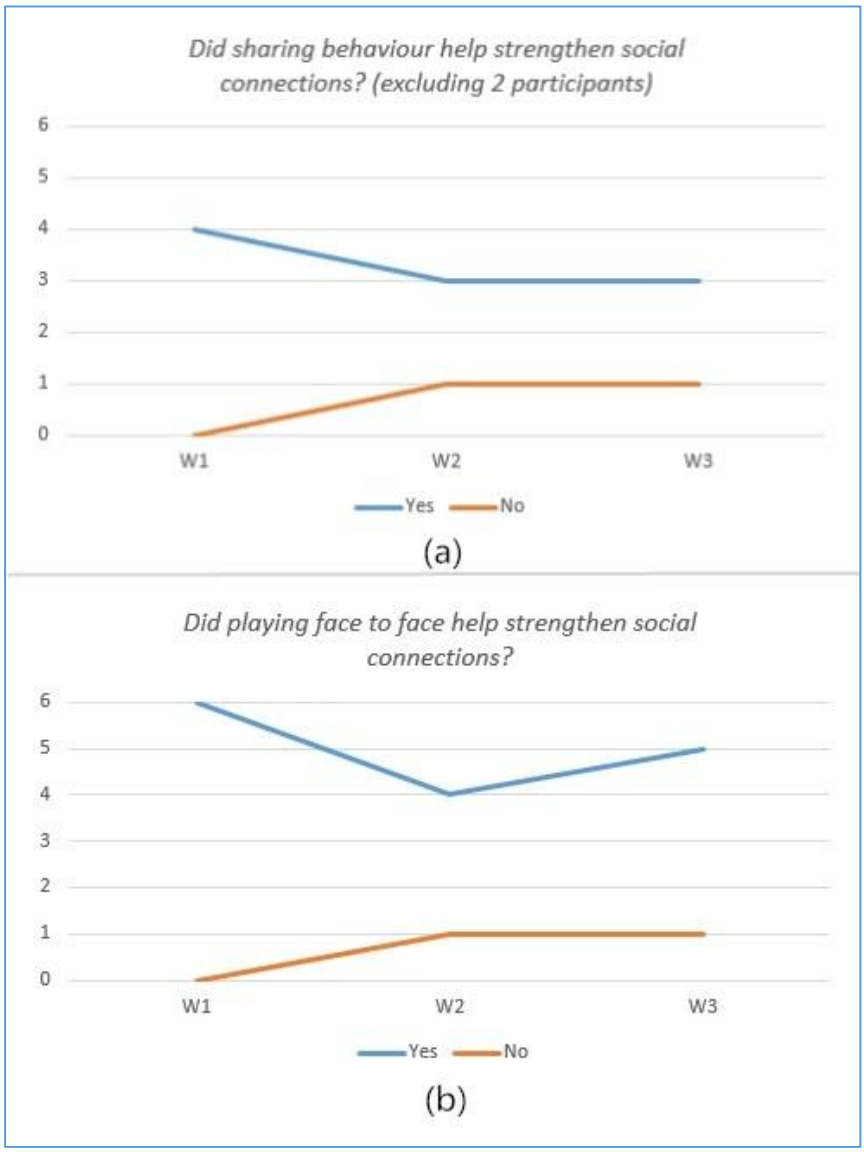

Figure 6.8 Comparison of two ways to intensify social connections (a: online sharing; b: playing face to face).

6.2.4 Post-interview

Participants' final scores in the post-WHO-5 test increased in varying degrees. We categorize them into two groups. The first group comprised P1, P3, P6 and P7, who scored 13 and above in the test, and the second group consisted of P2 and P5, who scored less than 13. Table 6.1 shows that the increase in scores for the first group was lower than that for the second; for example, P3 and P6 scored marginally higher in Q5 and P7 had higher

scores for Q1 and Q5. An obvious improvement can be noted for P1 compared with others in the first group. Nonetheless, the second group reported an improvement in their score for no less than three questions. In particular, P5 scored higher in three questions (Q2, Q3, and Q5) but lower in Q4 and P2 showed significant improvement. P2's scores increased for four questions (Q1, Q2, Q3 and Q5) and his degree of increase for Q3 and Q5 (3) was the highest. Considering P2's condition and scores for the pre-WHO-5 test, his total score in the post WHO-5 test increased from 3 to 12, which was the most significant improvement among all the participants. P5's score decline for Q4 can be attributed to family affairs, which is irrelative to game playing.

The differences in results between the two WHO-5 indices were sorted in descending order (Table 6.2). Interestingly, the higher scores in the pre-WHO-5 test, the lower the degree of score increase in the post-WHO-5. In other words, there should be a negative relationship between the pre-WHO-5 score and the scope for improvement in the post WHO-5 test. To elaborate, P3, P6 and P7 got higher scores in the pre-WHO-5 index test, but their post-test scores did not increase significantly. By contrast, P1, P2 and P5 reported a considerable improvement in well-being because the degree of score increase was greater than 25%. P2, in particular, demonstrated substantial progress with a 300% increase in the WHO-5 well-being index throughout this three-week use period.

Participants who were relatively satisfied with their currently life derived no benefit from the game in terms of well-being. This could be because they (P3, P6, and P7) have broader range of social activities and their social interactions are stronger (e.g. P5). In addition, they have already cultivated few mutual hobbies which enable them to meet other people with common interests.

In Table 6.3, all scores less than three are marked with a green background so that differences occurring following the three-month play period can be clearly observed. For example, it is apparent that five participants scored four, while only one scored three for Q5: 'My daily life has been filled with things that interest me'. This indicates that all the

participants had interesting things to do throughout the month. The progress is notable because only one participant scored as high as three in the pre-interview.

Furthermore, all the participants reported similar scores for Q4, 'I woke up feeling fresh and rested', in the pre- and post-WHO-5 test. This means that participants who lacked rest continued to face problems after the three-month period and thus, playing Gobang seemed less helpful. Three participants showed improved scores for Q3, 'I have felt active and vigorous', and consequently, all six of them felt active and vigorous within more than half a month. This suggests that playing Gobang positively affected their emotional status. Regarding Q1 and Q2, except P2, most participants had already scored higher than three in the pre-WHO-5 and thus, no significant increase in score was found for each answer.

P2 appears to benefit from playing the game considerably more than the others. In particular, his scores for Q3 and Q5 improved from 0 (never) to 3 (more than half a month) and the total score for the post-WHO-5 test was 12 (a 300%) increase. This suggests that Gobang gained his interest and influenced his sense of well-being.

Table 6.2 Differences between both WHO-5 test results

	Q1	Q2	Q3	Q4	Q5	Raw score
P1	0	0	1	1	2	4
P3	0	0	0	0	2	2
P6	0	0	0	0	1	1
P7	1	0	0	0	2	3
P2	2	1	3	0	3	9
P5	0	1	1	-1	2	3

Table 6.3 Pre- and post-percentage scores for WHO-5 index and difference between them

	Pre-percentage score	Post-percentage score	Difference (%)

P6	68	72	5.88
P3	64	72	12.50
P7	56	68	21.43
P5	48	60	25.00
P1	56	72	28.57
P2	12	48	300.00

Table 6.4 Comparison of pre- and post-WHO-5 test results

Pre-WHO-5						
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Raw score**
P1	4	5	3	0	2	14
P2	1	1	0	1	0	3
P3	4	4	3	3	2	16
P5	3	2	2	3	2	12
P6	3	4	4	3	3	17
P7	3	4	3	2	2	14
Post-WHO-5						
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Raw score**
P1	4	5	4	1	4	18
P2	3	2	3	1	3	12
P3	4	4	3	3	4	18
P5	3	3	3	2	4	15
P6	3	4	4	3	4	18
P7	4	4	3	2	4	17

According to the post-interview results, all the participants were satisfied with Gobang's performance, regardless of the level of enjoyment and accessibility. Compared to the other Gobang games, the participants experienced fewer accessibility issues throughout the play period. In addition, they reported feelings of enjoyment and relaxed entertainment in their daily lives. For example, P2 was completely focused when playing Gobang because it relaxed his mind and distracted him from thoughts that depressed him. In addition, participants considered the badge system to be an effective approach to maintaining their level of enthusiasm. Badge system reflects a player's achievements and each badge denotes

the player's current gaming level. Players began showing off their badges to others as they believed it enhanced competition among players: 'I do not want to be the last one. If I see somebody has got a higher level badge or score, I try to exceed them and tell them "I am better than you."' (P3). All respondents believed that strong competition was an attractive feature of the game. According to P1, 'Victory brings a tremendous sense of achievement and I enjoy competing with my friends. Since I got a great score, I would like to share the pleasure with others. I desire their praise as it pleases me very much'.

Some of the participants were not open to the concept of social media sharing. For example, since P3 and P6 did not have social media accounts, they were unable to provide feedback regarding their social sharing experience. P7, the only respondent aged over 70 years old and with a social media account, believed that social sharing could not effectively strengthen her connection with people in her friend list for the following reasons. First, she did not have many close contacts, such as peer friends, on social media. Second, because of her unfamiliarity, she was not confident enough to encourage her peers to use social media. She mainly used social media to communicate (audio or video chats) with her children. Finally, she considered IT technology to be an issue. Social media is expected to serve as a tool that promotes interaction and connectedness among people and failing to find sufficient respondents would demotivate the use of the tool. The younger participants shared scores with friends on social media more frequently than the elderly individuals. In addition, their friend list comprised a higher number of contacts, including classmates, colleagues, organization partners and relatives. Unlike P7, other participants' peer contacts had sufficient experience in common IT technology use. Accordingly, social media and instant messaging (IM) are already a part of their daily lives. The younger participants also positively appraised the effect of social sharing on establishing and strengthening social connections. For instance, P1 developed significant interest in the game and preferred to tell her friends when she won and her scores. Occasionally, she even discussed strategies with others. Throughout the study period, she had a new topic to talk about and this triggered more interesting topics and further communication: 'If I received a response to a

shared game result, we'd begin to talk more about our lives, families, works or children. And I would feel our relationship becoming closer'. P2 agreed with P1 that sharing game scores with others could help enhance their connection: 'Since I began playing this game, I something new choice to share with my friends on the chat group. I was also pleased to see that some of had begun playing the game and sharing their scores with each other'.

However, it is noteworthy that the frequency of social sharing declined during the play period. In their interviews, some explained social sharing occurred between an existing social relationship and further interactions, for example, responses and discussions, were more likely among intimate relationships. Thus, social sharing had a more positive impact on strengthening rather than expanding social connections. Second, the participants revealed that game-related communication was limited. Scores sharing was mainly to share pleasure with friends, while message sharing was to return the praise. As exception, however, was P1 whose friend was equally interested in playing Gobang. They often shared related news on social media and talked about the game using IM tools. Nevertheless, they also agreed that online communication, especially on the mobile phone, was not as efficient as face-to-face interactions.

All six participants experienced the multi-player mode during the study period. Compared with sharing scores on social media, playing chess face to face with others was considered a more effective approach to strengthening social connections. This is primarily because face-to-face communication involves instant response. For example, when a game ends, players can immediately discuss the details of the game, such as scope for improvement and feasibility of the strategies applied. Such interactions are difficult to realize on social media. Moreover, some participants stated that typing on a phone to explain complicated ideas can be time consuming. Further, many participants preferred chatting about, for example, their lives, interesting news and personal stories, while playing the game. This way, they were able to gain moral support and companionship. P3 said 'Since this game is installed on my pad, I like to go out and play it with other elderly people

in the park. Bringing a pad is much easy and more convenient than bringing a heavy chessboard with its big box of chess pieces. And I like to show others something interesting like photos of my granddaughter, funny videos or news. I would prefer bringing the pad to park because we can do a lot on it'. P7 added that 'Some elderly people who watched at first would join us and challenge the winner. This gives me the opportunity to chat with people I don't know and make friends. I feel good about it'. Thus, it appears that this corporative game contributed towards establishing new connections and strengthening new ones. More specifically, because of this game, P3, P6 and P7 were more motivated to meet their game partners and maintain frequent communication. They all stated that playing Gobang reduced their sense of isolation: P5 claimed 'Winning is not everything, but I can share the pleasure this game provides with my friends. We gather regularly and play the game together. I feel less lonely while I stay with my friends'.

P1 and P2, who had shared their scores on social media or using IM tools, also help the same opinions as those of P6 and P7, that is, playing face to face improves social connections: 'Since we started playing this game, we have a new common topic. I play Gobang with my colleagues during lunch time and we all enjoy the fun. I also like sharing scores with my friends and telling them how much of an expert I have become'.

7 Discussion

7.1 Design criteria summary

7.1.1 Mobile application design

First, it is imperative to guarantee that every component is visible to and operable by the elderly. To fulfil this legibility requirement, the contrast and size of screen elements must be elaborately designed and arranged. For example, as per feedback acquired through the user requirement study, text size should be no smaller than 22 sp. To lower the risk of misoperation, interactive components should preserve no less than 7 mm X 7 mm space for finger touching. In this study, Gobang reported higher performance in the multi-player mode on a device with a larger screen such as a touch pad. Players' actions are generally restricted to the space available on a chessboard. In the case of mobile phones, whose screen sizes range from 4.0 to 6.0 inches, the touch area for each action does not satisfy the minimum requirement in play mode. Participants playing Gobang in the multi-player mode are more likely to make mistakes when doing so on their mobile phones than a tab. They cited the manner in which they held their device as the key reason. In the multi-player mode, players preferred to place the device such that both sides can clearly view the screen (see Figure 7.1 (b)). Compared with how a mobile phone is held in the single-player mode (Figure 7.1 (a)), the gesture in Figure 7.1 (b) is less intuitive and restricts users' movement and speed. Thus, magnifying the touch area reduces the possibility of a misoperation because it widens the space around the target and thus, the action is more successfully detected.

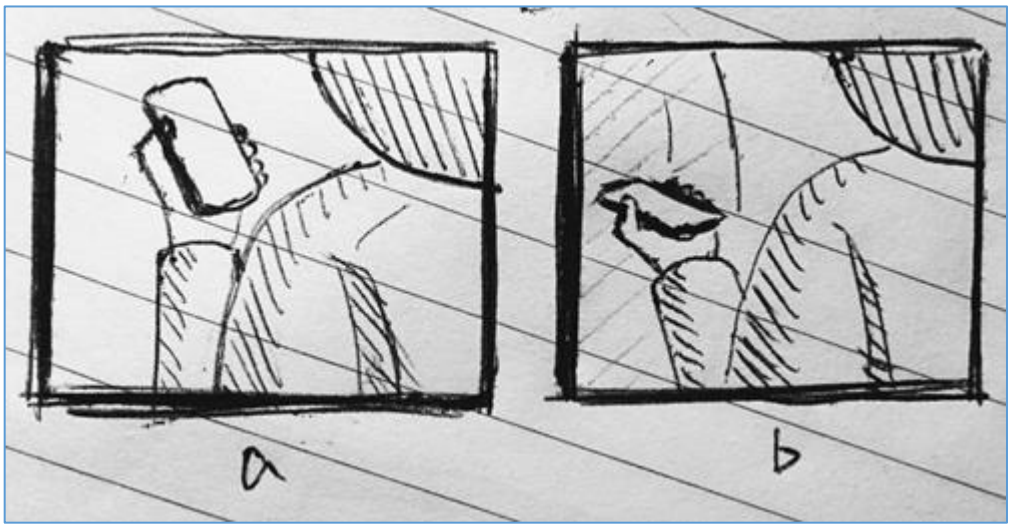

Figure 7.1 Two preferable ways of holding a device in different play modes: (a) single-player mode (b) multi-player mode.

Our observations revealed that elderly participants make fewer errors than expected when using the single-player mode because it allows players greater freedom in positing the device and more intuitive operations. Following few practice attempts, all participants were able to play Gobang, albeit with few barriers. Thus, it is necessary to expand the operative area and offer sufficient space to detect a player's action, which can help elderly users avoid making mistakes.

Icon, as an ideogrammatic aspect of a UI design, should convey meanings directly and precisely. It must be a symbol that is easily comprehensible and navigates the user to explore the inner functions of the operating system. However, some elderly individuals lack IT experience and thus, an icon alone is insufficient to express its meaning. For example, not all elderly persons know the meaning of a gaming controller symbol. Similarly, some may be unable to link a key symbol with its meaning, 'Help' (Figure 7.2). Thus, a designer first must create a clear and precise icon that is sharply displayed on devices with diverse resolutions. Second, designers must account for whether elderly users are familiar with the symbol. Sufficient time must be invested in determining icons and matching them with an

appropriate meaning. Third tip, each icon must be attached with a concise title or tag so that elderly users can decipher their meaning using a linguistic approach.

Figure 7.2 Two icons causing confusion among elderly people.

Next, we offer few recommendations to improve a game's operability. First, the size of a touch area, such as a button or switch, must be enlarged. It is also crucial to ensure that the blank space around or between components is broad enough. As previously mentioned, sufficient operative area helps reduce the possibility of a misoperation, that is, unintended users action. Second, operative elements that have same or similar functions must be positioned in the space on different frames. For instance, basic manipulation within Gobang can be performed using operating buttons at the bottom of different frames (Figure 7.3). In the single- and multi-player modes, the Home and Replay buttons are located in the same place and order. High layout consistency helps elderly users easily locate and understand functions.

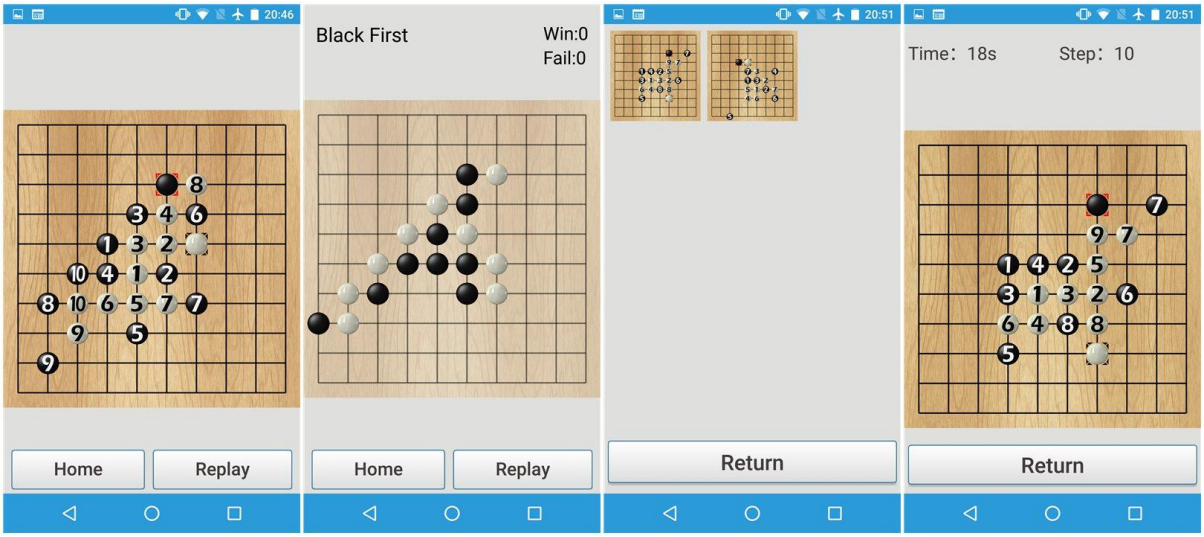

Figure 7.3 Basic manipulation using buttons at the bottom of various frames.

Designers should also account for error tolerance. First, elderly players should be granted a chance to regret their actions which may be risky in certain cases. Risky actions can lead to irrevocable consequences or frustration. For example, the system should alert players when it detects a possible erroneous act such as terminating a game in progress or quitting an application. In addition, elderly players should be made aware of the consequence of their actions. More specifically, in case of an intentional or accidental erroneous action, uses must be prompted with an alert that explains the consequences. This will help players establish better control and gradual familiarity with the game. However, designers must ensure that the text for the alert is concise as in the case of titles, tags and explanative summaries and visually and semantically clear. Finally, a well-designed instruction guide is necessary to ensure that an elderly user can easily learn the game. For example, texts, graphs and short videos can help elderly players learn new playing techniques and interesting functions.

7.1.2 Game design

Game design is part of application design; however, designing an application is not equivalent to designing a game. In addition to following certain principles defined to

guarantee basic usability experiences, a game designer must consider factors such as ways to stimulate players' motivation.

Over the study period, the participants grew increasingly concerned about their success. It appeared that they were particularly motivated during multi-player games because they felt a strong sense of engagement and enjoyed the rivalry. They commented on game strategies and exchanged experiences while playing with the hope that they would perform better in subsequent games. Vasconcelos et al. noted similar behaviours among their study participants and believed players relationships can benefit from such social interactions (Vasconcelos et al., 2012). Encouragement from others also stimulated motivation to participate. Playing Gobang facilitates such positive interactions in various forms, effectively diminishes feelings of loneliness and enhances a sense of involvement. This denotes high intrinsic value which is positively correlated with interest or pleasure derived from accomplishing an actual task.

The badge system was designed to sustain the player's next goal. A badge and rank number denotes a players' achievement and a superior badge is the best representation of the value attained while playing the game. The more games a player wins, the higher the rank and value of the badge (i.e. from copper to gold). Differences in badges sustains players' gaming motivation and this phenomenon is more prominent among users who play Gobang often. Gobang is a light, casual game and players are not required to spend much time and can easily exit the game. Thus, the cost of playing Gobang is not as high as playing other games.

This result conforms to Eccles and Wigfield's theory, that is, high attainment value, intrinsic value and low cost of gaming contribute to perceived value (Eccles & Wigfield, 1995). In other words, the higher the value provided by a game, the stronger the motivation (Oxland, 2004).

Table 7.1 Game design criteria specified for elder players

Index	Aspect	Explanation
1	**Perceivable**	
1.1	Font	Size and style of the chosen font.
1.2	Contrast	Contrast of texts and patterns.
1.3	Icon	Icon and symbols used in an app.
2	**Operable**	
2.1	Size	Size of interactive components and blank area around them.
2.2	Layout	Consistency and accessibility of layout.
2.3	Error tolerance	Allows a player to make mistakes to certain extent.
3	**Understandable**	
3.1	Interpretive contents	All textual contents. Focus on precision and concision.
3.2	Instruction	Teach a player how to use the game.
4	**Motivation**	
4.1	Desire for victory	Help to improve self-esteem from competence.
4.2	Value of victory	
4.3	Perceived benefits	Relaxation, enjoyment, strengthened interpersonal relationship

7.2 Impact on the wellbeing of the elderly

Changes in the WHO-5 test score indicate that the participants experienced an increase in their level of well-being. On the basis of their interview responses, there are three basic changes.

First, elderly people experienced enjoyment and relaxation as playing Gobang and though playing game is pleasing way to pass time. A new badge and higher level developed a strong sense of achievement, motivation and sustainable competition among multiple players. Further, the game expects a high concentration level from players because they must anticipate their rival's next step and accordingly determine solutions. Thus, playing Gobang successfully distracted people (e.g. P2) from reality and thinking about affairs considered depressing. This finding is consistent with that of Ijsselsteijn et al. (Ijsselsteijn et al., 2007). In addition, elderly player who gathered in public placed to play the game face to face felt morally supported.

Second, their relationship with others was strengthened and social network extended. When participants played the game face to face with others, they also shared stories and feelings and in return, they received support and consolation. In addition, gaming face to face facilitates friendship and eliminates a sense of isolation. Some participants established new friendship while playing Gobang in a public area.

However, a recent research suggested that multi-player games are likely to cause negative perceptions among the elderly (B. D. Schutter & Abeele, 2010). A possible reason is that the elderly prefers to play games on the basis of their own schedule rather than oblige strangers and their plans. In addition, fear of failure impedes the acceptance of multi-player games. In fact, some elderly individuals even excused themselves and felt irritated when they made a mistake or lost the game. However, this study's participants welcomed multi-player Gobang and did not report feelings of frustration during both the weekly and post-interview. This is possibly because the elderly participants did not play with a random used but visited the same place and played with their friends and acquaintances. Nevertheless, future research must consider exploring the type of elderly players who dislike multiplayer game and which games cause negative perception.

In comparison, social media sharing did not effectively enhance interpersonal relationships. The low penetration of social media was found to hinder the use of the social sharing function on Gobang. Players whose friends do not access social media often are less likely to rely on social sharing to maintain contact. However, a majority of the middle-aged population has adapted to the use of popular IT products or techniques and thus, the low penetration of social media will be less of a concern once they age.

Third, participants believed that playing Gobang helps maintain mental flexibility and physical mobility. Their opinion conforms to findings of previous studies (Ijsselsteijn et al., 2007; Pyae, Luimula, & Smed, 2016). In addition, they considered constant gaming to develop their ability to react, eye-hand coordination and logical analysis. They also felt morally supported and less lonely when gaming with others. The real clinical effects of

playing this game is not the objective of this research; nevertheless, participants' opinions appear to be consistent with findings in the extant literature (Kahlbaugh, Sperandio, Carlson, & Hauselt, 2011).

In sum, elderly people indeed benefit from playing digital games in many aspects, physically, psychologically, or emotionally. And playing games has potential to be an effective and low-price approach to improve overall well-being of elderly population. There should be a promising future and valuable market for game industry to cater varying kinds of demands of the increasing elderly population. Gaming companies should take responsibility to design aging-friendly games with remarkable benefits for the elderly.

7.3 Limitation of this study

This research is not free from limitations. First, the number of participants who engaged in the evaluation of the iterative design and development process is limited. To obtain diverse feedback, no less than two participants should engage in the evaluation process. To avoid adaptation to underlying usability problems or becoming less sensitive to unreasonable design, researches must refrain from including the same participants in subsequent evaluations. Nevertheless, six participants were insufficient to construct an overview of existing usability and accessibility issues. Elderly people have different daily routines, social interaction preferences, and abilities to adapt new technology skills and hence, this study's participants might not represent the entire elderly population and the designed test scenarios might not cover all daily live situations. Thus, we recommend future research with a larger sample that covers broader age groups, a balanced gender proportion and diverse education and employment backgrounds.

Second, the Gobang application in this study may have overlooked certain usability issues and its findings may not meet all demands of the elderly population. As per the interpretation of Jacob Nielson's model, 15 test users were theoretically sufficient to cover almost 100% of the usability issues which exist in a prototype. Nevertheless, five users are

sufficient to reflect nearly 80% of the underlying usability problems in a test (Nielsen & Landauer, 1993; Virzi, 1992). A disadvantage of using a larger sample group is the possibility of redundant information. Thus, it is reasonable to state that usability or accessibility issues identified in this research through user evaluations are typical and cover most cases and the conclusions are reliable and constructive for future studies in relevant domains.

Third, another aspect that deserves deeper consideration is ways to simulate appropriate context of use while conducting user tests. For some, behaviours are not spontaneous and their reactions may differ from those observed in reality. In other words, contexts simulated in user testing are not 100% accurate as people's reactions may not be spontaneous or natural.

Fourth, this study focused on the WHO-5 test to acquire empirical data relative to the overall well-being of participants. The results of this test may not reflect every factor that directly and indirectly influences welfare. Unpredictable factors, like health situations, inhabitancy conditions affect participants' subjective assessment of well-being and the consequence of WHO-5 cannot reveal more details in what happened to a given aspect of one participant's life. For example, P2, who reported the most impressive progress score on the WHO-5 test, believed his changed living environment had a greater impact on his sense of well-being than playing the Gobang game. Thus, a better understanding of participants' lives from broader and detailed aspects, such as physical activities, sense of loneliness, self-esteem, that are inextricably linked to overall well-being can facilitate a more in-depth analysis of the effects of playing social and cognitive games.

Finally, test duration affects the level of improvement within a given space. To observe the potential effects of playing a social game on well-being, final evaluations were conducted within three months and interview were administered on a weekly basis. Some of the participants recommended the game to their friends in the final phase of the user test. However, owing to the time limitation, differences in their social relationship following the establishment of a common interest could not be considered in the study.

8 Conclusion and future work

8.1 Conclusion of current work

The objective of this study is to elucidate if playing a social and cognitive game can improve the elderly's well-being and identify a user-friendly design for games that can be played on their mobile phones. The design and development was user centric and accounted for user demands and handling issues faced during the play period. Elderly participants (aged 60–87 years) were invited to participate in a series of interviews and evaluations. Accessibility problems were thoroughly examined through iterative cycles of the design application; each cycle included requirement definitions, design and development and evaluation.

Gobang is game in which users can play against a computer in a single-player mode or against another player in the multi-player mode. People with a social media account (in this study, WeChat) can share their game scores with their contacts through social sharing and non-social media users discuss scores recorded by Gobang.

The WHO-5 index test was conducted as a final evaluation to assess participants' subjective psychological well-being. Compared with the scores of WHO-5 test considered before experiencing Gobang, each participant reported more than a 10% increase in the post-test, indicating improvements in their well-being. Furthermore, feedback obtained from semi-structured interview performed following use experiences revealed that participants perceived feeling of relaxation and enjoyment while playing. Users who played Gobang often and in the multi-player mode strengthened their social relationships (e.g. friends, neighbours and families). In addition, some of the elderly participants established new friendships while playing Gobang in public areas such as parks. By contrast, social media sharing was not accepted by all participants. Here, individual IT techniques and social skills as well as content for sharing are relevant to their acceptance of the feature.

Future research is warranted to overcome problems unresolved in this study and explore other factors influencing well-being. In addition, it is useful to design more effective approaches that the elderly can adopt to socially interact with others and to increase active gaming participation in this age group. Further, online gaming could create interaction opportunities for people who live in regions that are geographically isolated. Finally, multi-media elements such as sound, graphics and videos can enrich the quality of interactions and increase enjoyment levels. We leave this aspect for future work.

The findings of this study validate the positive impact of playing social games on well-being. Nevertheless, a few questions and hypotheses are left to be verified in future study.

8.2 Future work

First, further research must prioritize the limitations highlighted in the current work. For example, a more specific and professional welfare assessment must be implemented. The overall sense of well-being is affected by many aspects, including physical activities, social interactions, interpersonal relationships, feelings of loneliness, self-esteem and confidence. This study conducted semi-structured interviews to identify factors potentially impacting well-being. However, to fully understand the effects of playing social and cognitive games on the well-being of the elderly, individual evaluations of diverse aspects should be conducted.

Second, it is important to conducting longer term evaluations to observe participants' behaviours and reactions and establish the probability of the elderly extending their interpersonal relationships using social media networks and sharing services. In addition, although divergent from the current topic, researchers must also attempt to explore how social sharing can better serve elderly users. This behaviour was not prevalent among this study's participants because they seldom received response upon sharing their scores on social media and those who did receive a message were probably no interested in the game or typing a response. This issue can be resolved by using a simplified response system. As

shown in Figure 8.1, users can simply tap on the thumbs-up (like) or thumbs-down (dislike) and the system automatically sends a corresponding message to the opponent. In this way, players can easily send and receive messages without spending time on understanding the message and typing out a response. Another potential solution is making the content to be shared highly interactive or interesting, thus piquing the elderly users' curiosity to explore the notifications and messaged they receive.

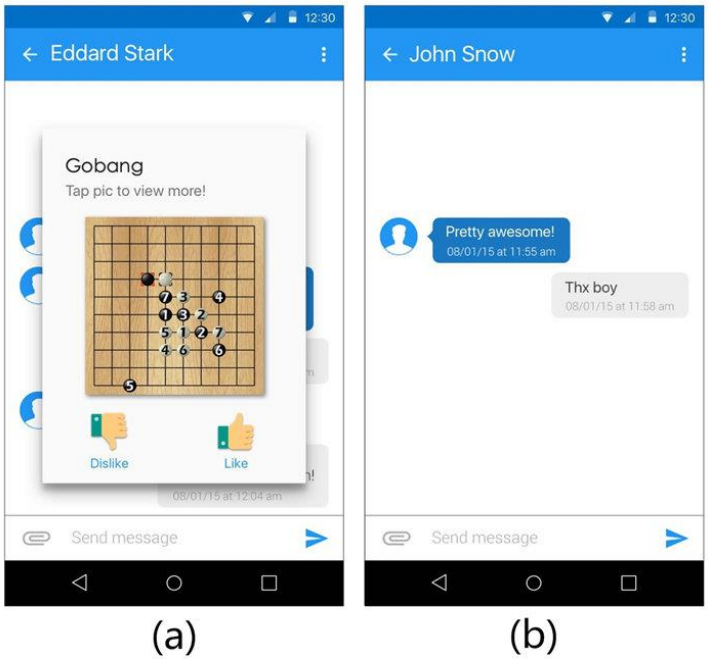

Figure 8.1 (a) Like and Dislike button (b) message received as per users' choice (like/dislike).

Finally, social games design social games should stimulate the elderly population's active socialization by encouraging them to explore both the known and unknown. The participants in this study followed the instructions provided and played Gobang with the others, although it remains unclear whether they would do so spontaneously. A noteworthy example is Pokémon Go, in which teenagers are encouraged to go outdoors to collaboratively accomplish a mission. In doing so, they acquaint themselves with other players and even cultivate new friendships. It is a promising study topic to explore whether the same approach can be adopted for the elderly population. For example, if a game was

designed on the basis of the memories of elderly players, and provided attractive reward, could they pay as much passion as much as that teenagers paid in Pokémon Go? Trefry indicated that one of the core elements of casual game is to “borrow familiar contents and themes from life” (Trefry, 2010). In this study, time and technical factors impede further exploration of these areas, which undoubtedly deserve further efforts.

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10 Appendix

A Participation consent form

INTRODUCTION

This research project aims to explore connection between playing social and cognitive games and quality of elderly people's lives. At the meantime, accessible features and requirements will be discussed and applied while implementing design and development of this application.

Due to target user group of this research is elderly people (above 60-year-old), we are going to invite you to participate in this project and looking forward to any valuable feedback you provide. Your experience and opinions are the key fact that influent our conclusion.

WHAT IS INVOLVED IN THIS STUDY?

If you determine to participate part of your private information will be collected and recorded, such as your age, gender, education and employment background, disease history and experience on mobile/application use. This series of questions will help us analyze and anticipate your preference and behaviors, and contributes to prototype design. You will also be asked to participate in interviews and give feedback according to your experience on application user tests. Features of your living environments are another key fact that we will observe and record because they affect your behaviors, physically and psychologically.

RISK

During this study, you will be asked to install our application on your mobile phone and experience all functions it provides. We will never collect any information about your privacy through the whole project and will be trying to offer the most reliable technical support. But you should be aware of possible risks. For example, installation of out app may

lead to launch failure when you open this application due to compatibility issues. And we may ask you to share required information to your friend s through your own social media. The shared information will not be offensive but we hope you know about this as earlier as possible.

CONFIDENTIALITY

We will take the following steps to keep information about you confidential, and to protect it from unauthorized disclosure, tampering, or damage. If this study was published, your name will be represented by pseudonym and any clues by which any people could identify your identity will be processed to protect your privacy from disclosure.

YOUR RIGHTS AS A RESEARCH PARTICIPANT

Participation in this study is voluntary. You have the right not to participate at all or to leave the study at any time. Deciding not to participate or choosing to leave the study will not result in any penalty or loss of benefits to which you are entitled, and it will not harm your relationship with us.

PARTICIPANT CERTIFICATION

I have read the above information and I consent to participate this study.

Consent of Subject

Signature Date

_____

B Interview questions defined for user requirement study

1. How old are you?
2. What is your job? Are you retired?
3. Do you have any symptoms listed below?
   a) Presbyopia
   b) Myopia
   c) Color blindness
   d) Parkinson
   e) Others
4. Do you live alone? How often do your children or relatives visit you?
5. Do you feel lonely sometime?
6. How often do you visit your neighbors?
7. What is your education background?
8. Do you use mobile phone? What kind of mobile phone do you use? Do you use any smart devices (smartphone, tablet, laptop or desktop)?
9. If you have smartphone, how often do you use it?
10. What kind of purpose do you use smartphone for?
11. Do you have any entertainment activity with your friends?
12. Do you play video games on mobile?
13. If you play or played mobile games, do you have met some problems impeded your pleasure?
14. Do you think the font is clear enough for you to see in different circumstance? Do you think a good color theme is helpful to improve legibility?
15. Do you think the icons are all understandable in the applications you used before?
16. Did you successfully find out all the functionalities you need in the applications you used before? Do you think the interface of these application is accessible to you?

C Summarization of achievements in each iteration

Figure 10.1 Form of achievements in each iteration

Index	Implementation	Participants	Test method	Feedback
1	1. Allow user to play chess with AI; 2. Record gaming information (time and step); 3. Score list is provided for players to check later; 4. Allow user adjust font size of texts in Preference screen;	4	User interview	1. Elusive icons confuse elderly users; 2. Undetectable setting entrance that elderly users are not easy to find out.; 3. Insufficient time prepared for elderly user to make reaction; 4. Specific examples should be provided to indicate differences between various font sizes; 5. Grid lines on chessboard is too thin for elderly users to see; 6. Buttons underneath the operating hand can be activated by accident; 7. Vivid colors are hoped to adapted in UI design; 8. Texts of setting items should be bigger and more distinguishable;
2	1. Multi-language support (English and Chinese); 2. Main function entrances are showed on welcome page (home page); 3. Icon has been redesigned	2	User interview	1. Dark color is not a good choice for chessboard; 2. UI layout is not adaptive to large screen device; 3. In an addition to social sharing, offline sharing is more important for elderly players who do not have social media account;

	properly; 4. Most texts appearing in this app are no smaller than 20px; 5. Social share API is embedded; 6. Chessboard has several colors for choice and grid lines are stronger and clearer;			4. Icons and descriptions are not clear for some elderly people;
3	1. Remove dark chessboard option; 2. Add an embedded gallery and allow users to view gaming history (stored as pictures);	2	User interview	1. There should be a specification for the use of gesture control; 2. Operation lacks consistency; 3. Layout of some interactive elements is narrow;
4	1. Specification of gesture control is loaded when the app launches first time; 2. Optimized operation consistency; 3. Defined a dark theme to improve readability; 4. Optimized arrangement of UI elements; 5. Allow the user view gaming information while browsing history screenshots;	2	User interview	1. Dark theme was monotonous. As a game, lively and vivid colors were encouraged;

D Questions defined for weekly interview

Weekly survey

1. Did you play Gobang last week?
2. How many days did you play Gobang last week?
   0-2|3-4|5-6|7
3. How many times did you play Gobang in one day on average?
   0|1-2|2-4|4-6|>6
4. How much time did you spend on playing Gobang each time on average?
   <10 min | 10-20 min | 20-30 min | >30 min
5. Did you have communication with friends on Gobang game you played last week?

Online part

1. Did you share game result with friends on WeChat?
2. Did your friends who receive shared message talk about this game with you?
3. Did any of your friends who receive your share show enthusiasm for Gobang?
4. Did you recommend any of your friends to play Gobang with you?
5. Did any of your friends share game result with you in return?
6. Do you think sharing behavior helps you get much connected with others?

Offline part

1. Did you play Gobang with others face to face last week?
2. Did others give you any suggestion while you were playing?
3. Did you display the screenshots of Gobang game you played to others last week?
4. Did others give you any recommendation based on screenshots you showed?
5. Did playing Gobang create more topics for you to talk with others?
6. Did playing Gobang stimulate meeting with others?

E Questions for pre-interview

In the last three weeks,

1. I have felt cheerful and in good spirits
   ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
   ☐less than half of the time (2) ☐occasionally (1) ☐never (0)
2. I have felt calm and relaxed
   ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
   ☐less than half of the time (2) ☐occasionally (1) ☐never (0)
3. I have felt active and vigorous
   ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
   ☐less than half of the time (2) ☐occasionally (1) ☐never (0)
4. I woke up feeling fresh and rested
   ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
   ☐less than half of the time (2) ☐occasionally (1) ☐never (0)
5. My daily life has been filled with things that interest me
   ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
   ☐less than half of the time (2) ☐occasionally (1) ☐never (0)

Consider your current symptoms and overall sense of well-being and answer:

1. Do you feel basically healthy?
2. Do you feel alone now and then?
3. Would you like contact others (friends/neighbors/families) actively?
4. Do you agree frequent contact with others (friends/neighbors/families) helps ease loneliness?

Scoring: The raw score is calculated by totaling the figures of the five answers. The raw score ranges from 0 to 25, 0 representing worst possible and 25 representing best possible quality of life. To obtain a percentage score ranging from 0 to 100, the raw score is multiplied by 4. A percentage score of 0 represents worst possible, whereas a score of 100 represents best possible quality of life.

F Questions defined for post-interview

In the last three weeks,

6. I have felt cheerful and in good spirits
   ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
   ☐less than half of the time (2) ☐occasionally (1) ☐never (0)
7. I have felt calm and relaxed
   ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
   ☐less than half of the time (2) ☐occasionally (1) ☐never (0)
8. I have felt active and vigorous
   ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
   ☐less than half of the time (2) ☐occasionally (1) ☐never (0)
9. I woke up feeling fresh and rested
   ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
   ☐less than half of the time (2) ☐occasionally (1) ☐never (0)
10. My daily life has been filled with things that interest me
    ☐all the time (5) ☐most time (4) ☐more than half of the time (3)
    ☐less than half of the time (2) ☐occasionally (1) ☐never (0)

Consider your current symptoms and overall sense of well-being and answer:

1. Do you feel basically healthy?
2. Do you feel alone now and then?
3. Would you like contact others (friends/neighbors/families) actively?
4. Do you agree frequent contact with others (friends/neighbors/families) helps ease loneliness?

Special part for post-interview:

1. Do you enjoy playing this game?
2. Do you still have troubles in playing?
3. Can playing this game make you feel happier or relaxed?
4. Would you like sharing information with others in single-play mode?
5. Would you like playing Gobang with others f2f in multi-play mode?
6. Can socially sharing help you keep in more touch with others?
7. Can playing Gobang f2f help you keep in more touch with others?
8. If you experienced both ways, which one do you think has more significant effect on strengthening contact with others?
9. Does playing Gobang have any positive impact on your life? Are you going to recommend this game to others?

G Demographics of participants in final user evaluation

Figure 10.2 Demographics of participants in final user evaluation

	Gender	Age	Retired?	Health condition	Smart mobile use?	Social network use?	Mobile game use?	Frequency of using mobile phone app	Frequency of playing game
P1	female	60	no	myopia	yes	yes	yes	everyday	everyday
P2	male	62	yes		yes	yes	yes	everyday	less than 5 times a week
P3	male	79	yes	myopia, diabetes	yes	no	no	never	never
P4	female	86	yes	presbyopia	yes	no	no	less than 5 times a week	never
P5	male	64	yes		yes	yes	yes	everyday	more than 5 times a week
P6	male	81	yes		yes	no	yes	everyday	more than 5 times a week
P7	female	71	yes	cataract	yes	yes	no	less than 5 times a week	never

H The paper accepted by AAATE2017

A Mobile Game for the Social and Cognitive Well-being of Elderly People in China

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Abstract. China, like many other countries, is facing the challenges of an ageing population. Literature has shown that the lack of social interaction has a negative impact on the physical health of the elderly, and playing games can be beneficial in maintaining or even improving their cognitive abilities. This study describes the design and development process for a social and cognitive mobile game and the related user evaluation in terms of well-being. The objective is to explore the underlying connections between game playing and the improvement of well-being among elderly people in China.

Keywords: Mobile game, elderly, social, cognitive, well-being

Introduction

The global population is ageing rapidly. A report by the World Health Organization estimates that the population of people aged above 65 years will grow from around 524 million in 2010 to 1.5 billion by 2050. Most of the increase is contributed by developing countries. In other words, the vast majority of elderly people will live in developing countries and pose pressing challenges for national infrastructures.

As the country with the largest population, China is one of the developing countries facing the challenges of an ageing population. The number of people aged 65 and over is projected to swell to 330 million in 2050 from 110 million in 2010. Today, the average life expectancy in China is 75.3 years, which is remarkably higher than in 1950 (44.6 years). This average value is expected to reach 80 by approximately 2050. Meanwhile, the number of elderly people who have only one child is growing. These people are confronted with the

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reality that their time with their children is limited and that they may spend the majority of their ageing days alone. In addition, due to the increasing cost of living in urban areas, the percentage of elderly people who intend to move to rural areas is increasing continuously. This means that elderly people in China are living more independently than ever before. Compared with younger people, they are generally less adaptive to modern information technologies. This is not to say that they resist accepting new technology; in most cases, their rejection of technology is more due to inaccessible interface designs and unfriendly interaction styles. At the same time, elderly people are more likely to experience the loss of social connections. Changes in their lifestyle and circumstances, such as retirement and bereavement, exacerbate this loss of social contact. Declining physical capability also reduces opportunities to connect, so it is not easy for them to engage in a wider range of social activities. Therefore, elderly people are likely to feel lonely. A recent study indicates that elderly people prefer to maintain the existing social relationships with people they know rather than make new friends to extend their own social network.

Loneliness is a factor that leads to various mental issues, such as depression and cognitive impairment. Through their study, Zhu and his colleagues found that there is a strong connection between social and family support and cognitive function. Evidence showed that frequent connections with a large social network was associated with significant cognitive function improvement. Seniors who stay in contact with neighbours or their families experience more constant mental stimulation and have a higher chance of maintaining cognitive ability.

Studies have also shown that participating in entertainment activities is beneficial to maintaining or improving the cognitive ability of elderly people. For example, Khoo and his research partners observed the positive impact of entertainment activities on social behaviour. Individuals who participated in a collaborative game demonstrated improved social skills. They trained abilities like defining goals, decision-making and problem-solving. During the process, abilities like effective communication and efficient co-operation were

practiced because they are the cornerstones of collaboration. An early study compared the performance of two groups of elderly people (aged 69 to 90) in a reaction-time test. The experimental group was asked to play a certain digital game for five hours per week for five weeks, and the control group did not play the game. The results of this study showed that the game-playing participants performed better on the final testing. They reacted more rapidly and had a better sense of well-being.

Literature has shown that engaging in social activities has a positive effect on improving the well-being of elderly people, and playing digital games is also useful in engaging in pleasurable activities and broader social networks. In China, video game consoles have only been available since 2015; thus the majority of elderly people in China have not experienced video games. In the meantime, the fast growth of the mobile phone industry in China is making smartphones more affordable, and smartphones are becoming increasingly popular among the elderly. Although larger tablets may have advantages in terms of screen size, they are not very portable and most of them do not provide a voice-calling function. For these reasons, tablets are not very practical compared with smartphones, especially when elderly people are outdoors or on the move.

The aim of this research is to explore the underlying connections between game playing and improvements in well-being among elderly people in China. To achieve this goal, we adopted a user-centred design methodology. We have studied and tested a carefully selected list of mobile games with users and collected a list of special requirements from elderly users for an accessible and usable mobile game. Based on these requirements, we iteratively carried out various design, development and evaluation phases. The feedback from each evaluation was used to improve the prototype. Through this research, we hope to provide suggestions for the design of mobile games for elderly people.

Methods

The user-centred design (UCD) method is adopted in this project. Six elderly users (aged 66 to 87 years; four male and two female) engaged in the user requirement study. Firstly, a preliminary interview was conducted to map the participants' experiences with games and social media. They were asked to play a selected list of casual mobile games (Flappy Bird, Connect Two, Gobang, and Chinese Chess) and vote for one as the best mobile game. Compared with larger and more complex games such as Massive Multiplayer Online Role-Playing Games (MMORPG), casual games are easier for elderly people to learn and play. The required tasks in casual games are comparatively simpler and easier to accomplish, and elderly players can gain a sense of achievement and success more easily when they play. The results indicated that the participants preferred Chinese Chess and Gobang to the other games in the test set. One reason is that Chinese Chess and Gobang are rather popular casual games in China with which every participant was already familiar. They did not want to spend much time on learning how to play. The second reason is that chess games involve less time pressure. Motor and cognitive deteriorations due to ageing cause slower reaction times and make it difficult to figure out the correct solutions during game play. In Flappy Bird and Connect Two, players need to act as soon as possible because quick reactions and movements are the fundamental elements required to win the game. We chose Gobang for further research in this project because it is more globally popular than Chinese Chess. More importantly, in comparison with Chinese Chess, the Gobang game typically requires less time, which means that players have more flexible control of the time during game play.

To assess the accessibility and usability features of existing Gobang games, we evaluated those that are rated highly in Google Play by following mobile accessibility principles and user testing. Six highly rated (higher than 3.5) Gobang games were downloaded from the Google Play market and installed on a mobile phone. A number of issues were found during the evaluations. These included the small font size and lack of possibility to adjust it, inconsistent language use, poor colour contrast, ambiguous icons,

complicated gesture use, unintuitive workflow and required system-level permissions that are irrelevant to the game.

Based on the analysis of the collected data, an initial list of requirements was gathered. Next, a prototype was designed and developed in iterations. Each iteration was comprised of three components: (1) a reconsideration of the design requirements, (2) the development of an enhanced prototype and (3) a user evaluation. User feedback from each evaluation was used to improve the prototype. In addition, we took into consideration the design principles of mobile application and game design during the iterations. Over six iterations, most of the usability and accessibility issues were resolved and the functionality was integrated.

Description of Gobang

The Gobang game starts with a home screen that provides four buttons leading to the other basic functions (Figure 3). The play button shows the core frame for the Gobang game. During game play, Gobang automatically records the time and number of pieces that the player uses. The pieces of both sides (black and white) on the board are marked with numbers to show how the game is progressing. At the end of the game, a screenshot capturing the finishing board is taken and stored locally. Gobang allows players to send this screenshot to their contacts directly or post it on social networking media. Users can receive comments from other people or engage in further communication about their score. Some users go to public meeting places, like a park or a garden. The multi-player mode is designed for occasions when people gather together; they can play together and discuss with each other. Such a play mode used in public places has also been shown to provide elderly people with opportunities to get to know new people.

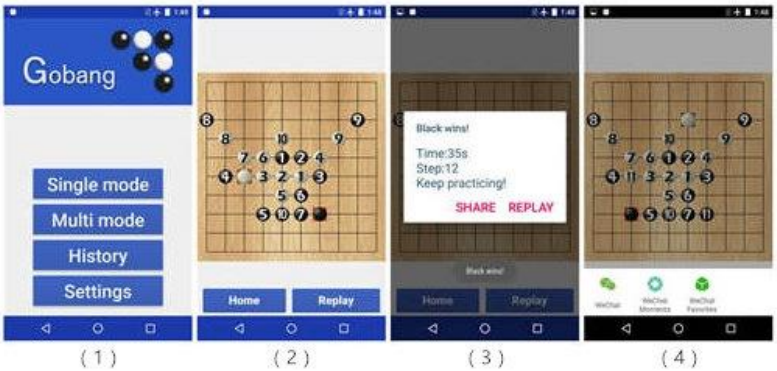

Figure 3. The Gobang player interface: (1) the play button on the home screen, (2) a scene of Gobang play, (3) an alert dialog at the end of a game and (4) options for sharing the screen.

Gobang has an embedded gallery for browsing screenshots (Figure 4). The history button brings the user to a list of thumbnails. Full-scale screenshots can be shown when the user taps on the thumbnail images. When the history feature launches for the first time, instructions appear to show users how to use the gesture controls before they begin browsing the screenshots. More details associated with any full-scale screenshot are shown at the top of the screen.

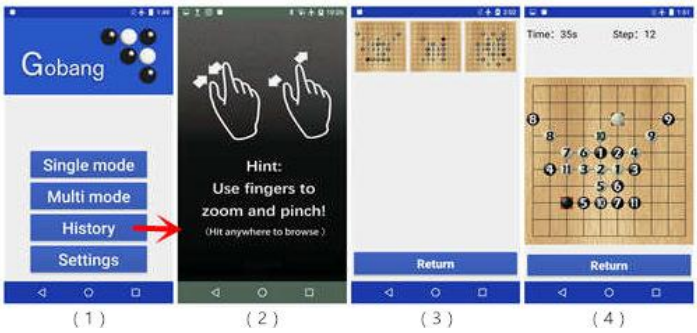

Figure 4. The Gobang history interface: (1) the history button on the home frame, (2) gesture instructions, (3) thumbnails (4) and a full-scale screenshot with detailed information.

Elderly people are more likely than younger generations to suffer from physical limitations, such as reduced motor skills or declined vision. We have taken these into consideration when designing our Gobang. For example, the settings menu (Figure 5) allows

elderly users to modify the font size and choose their preferred colour theme. They can also reset the size of the game board and choose the difficulty level.

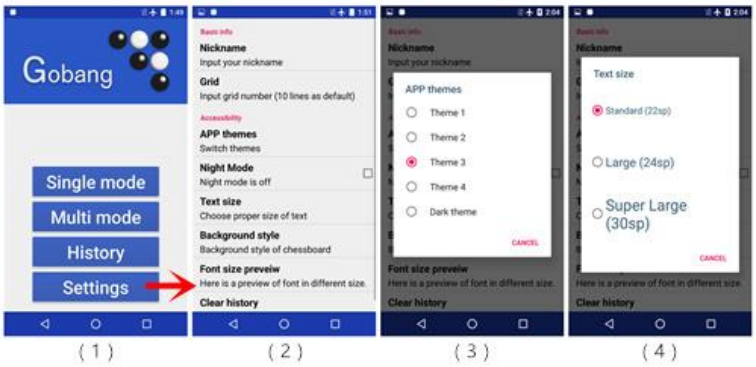

Figure 5. The Gobang settings interface: (1) the settings button on the home frame, (2) the items that can be changed or reset, (3) the diverse colour schemes (4) and options for font sizes.

Evaluation and preliminary results

We have developed a mobile Gobang game with a user-centred design approach. Users were involved in the initial requirement gathering and all the iterations of the design and development; their feedback has helped improve the usability and accessibility of the game.

To understand the potential effect of playing the Gobang game on the well-being of the elderly, we have recently conducted a study during which six participants used Gobang for one month. All functions of this game were briefly introduced to the participants before the user test. They were encouraged to try every function provided by the game, such as the single-player mode (playing against the system), multi-player mode (two players competing against each other) and sharing game scores, either online or offline. A series of questions combined with the World Health Organization Five-item Well-being Index (WHO-5) was used to assess the participants' living status, social connections and technology skills as well as their psychological, physical and cognitive well-being before and after the evaluation

period. Interviews were conducted on a weekly basis to observe the differences in daily activities relevant to game playing and social interaction. The preliminary results of the evaluation indicate that the participants experienced an enhanced sense of well-being after the three-week play period. Compared with the scores on the WHO-5 test conducted before the participants experienced Gobang, five out of six participants demonstrated an increase of more than 10% on the post-test (Table 2). This indicates an overall improvement in their well-being.

Table 2. Differences between pre- and post-test percentage scores for the WHO-5 index

Participant	Pre-test percentage score	Post-test percentage score	Difference (%)
P6	68	72	5.88
P3	64	72	12.50
P7	56	68	21.43
P5	48	60	25.00
P1	56	72	28.57
P2	12	48	300.00

On the basis of their interview responses, there are three basic changes. First, the participants experienced enjoyment and relaxation playing Gobang and generally thought of playing the game as a pleasing way to pass time. Reaching a higher level in the game resulted in a strong sense of achievement, motivation and sustainable competition among multiple players. Further, the game requires a high concentration level from players because they must anticipate their rival's next step and determine solutions accordingly. Thus, playing Gobang successfully distracted people (e.g. P2) from focusing on affairs that are considered depressing. This finding is consistent with that of Ijsselsteijn et al. In addition, elderly players who gathered in public places to play the game face-to-face felt morally supported.

Second, their relationships with others were strengthened and their social network was extended. When the participants played the game face-to-face with others, they also shared stories and feelings; in return, they received support and consolation. In addition,

gaming face-to-face facilitates friendships and eliminates the sense of isolation. Some participants established new friendships while playing Gobang in a public area.

However, a recent research study has suggested that multi-player games are likely to cause negative perceptions among the elderly. A possible reason is that the elderly prefers to play games on the basis of their own schedule rather than oblige strangers and interfere with their plans. In addition, the fear of failure impedes the acceptance of multi-player games. Some elderly individuals even excused themselves and felt irritated when they made a mistake or lost the game. The participants in this study welcomed multi-player Gobang and did not report feelings of frustration during the weekly discussions or the post-game interview. This is possibly because the elderly participants did not play with a random user but visited the same place and played with their friends and acquaintances. Future research must also include more participants and consider the type of elderly players who dislike multi-player games and which games cause negative perceptions.

Social media sharing did not effectively enhance interpersonal relationships. The low penetration of social media was found to hinder the use of the social sharing function on Gobang. Players whose friends do not access social media often are less likely to rely on social sharing to maintain contact. Playing face-to-face with others was considered a more effective approach to strengthening social connections.

Third, the participants felt that playing Gobang helps them maintain mental flexibility and physical mobility. Their opinion is in agreement with the findings of previous studies In addition, they considered consistent gaming a good way to develop their reaction ability, hand-eye coordination and logical analysis. They also felt morally supported and less lonely when gaming with others. The real clinical effects of playing the game is not the objective of this research; nevertheless, the participants' opinions appear to be consistent with the findings in the existing literature.

In sum, the participants were considerably satisfied with their game playing experiences and positively affected in terms of their well-being and quality of life. A supportive feeling was derived from the following aspects: new entertainment activity, additional pleasure and relaxation, strengthened interpersonal relationships and extended social networks.

Conclusion

Owing to the rapid development of mobile phone hardware and software over the past decades, mobile phones and smartphones have become ubiquitous. A survey conducted by TNS, a market research company, and commissioned by Facebook IQ found that people who play mobile games often are 2.7 times more likely to have a sense of community and belonging than those who do not play and twice as likely to continue playing the game for social connections. However, in the case of elderly people, game design must account for physical and cognitive deterioration; more specifically, it must account for possible usability barriers in the adoption of various digital products and services. For example, the interface design of operating systems and applications often does not offer adequately accessible features to address the physical and cognitive limitations attributed to the natural ageing process; this also hampers the user experience. This study accounts for the special requirements reported by the elderly. The elderly participated in the design and development process and recommended requirements for a user-centred design. Focus group interviews were conducted to define the type of game to be designed according to participant preferences. Our users tested similar games and helped identify the underlying problems related to usability and accessibility, which were avoided or resolved in our gaming designing. Our prototype design and development was cyclically conducted. In each iteration, a prototype was evaluated by a focus group comprised of different participants. The objective was to prevent the participants from adapting to the accessibility issues and collect broader feedback based on different user situations. Finally, a WHO-5 index test and semi-structured interviews were performed to help us understand whether the elderly

participants benefited from playing our social and cognitive game in terms of their well-being.

We are currently analysing the data from the evaluation. Through the research, we have identified several important issues that need further attention. For example, the overall sense of well-being is affected by many aspects, including physical activities, social interactions, interpersonal relationships, feelings of loneliness, self-esteem and confidence. This study included semi-structured interviews to identify the factors potentially impacting well-being. However, to fully understand the effects of playing social and cognitive games on the well-being of the elderly, individual evaluations of diverse aspects should be conducted.