Using Technology to Address the Problems of Malnutrition and Dehydration in Older Adults

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To Dad, losing you hurts me the most. I miss you, deeply.

Until we meet again.

Abstract

Malnutrition and dehydration of important problems for older adults even in developed countries such as the UK and both have many serious health consequences. This programme of research developed an app, MyHealthyLiving, to support older adults in monitoring their intake of liquids and fruit and vegetables. I followed a user-centred design lifecycle and conducted six studies, starting with focus groups to understand the older users' needs and wishes, through expert and user evaluations, to a two week field study of the use of the app by 15 older people. Using the data from the user evaluations, a new set of evidence-based heuristics for the development and evaluation of tablet apps for older people was also produced.

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Acknowledgment

To God, this whole journey would not be possible without your blessings.

To my Mum, brothers and sisters, thank you for the constant prayers, countless patience and moral support. I love you all.

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Linda

Author's Declaration

I, Zaidatol Haslinda binti Abdullah Sani, declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as references.

Some of the material contained in this thesis has appeared in the following published papers and poster:

- **Abdullah Sani, Z. H.,** & Petrie, H. (2017). Evaluation of an App to Support Healthy Living by Older Adults. Paper presented at the Proceedings of British HCI 2017 – Digital Make-Believe, Sunderland, UK.

- **Abdullah Sani, Z. H.,** & Petrie, H. (2017). User Evaluation of an App for Liquid Monitoring by Older Adults. In M. Antona & C. Stephanidis (Eds.), Universal Access in Human–Computer Interaction. Human and Technological Environments: 11th International Conference, UAHCI 2017, Held as Part of HCI International 2017, Vancouver, BC, Canada, July 9–14, 2017, Proceedings, Part III (pp. 86-97). Cham: Springer International Publishing

- **Abdullah Sani, Z. H.,** Petrie, H., Swallow, D., & Lewis, A. (2016). Three Case Studies on Methods of Working with Older People on the Design of New Technologies. Universal Design 2016: Learning from the Past, Designing for the Future, 229(Studies in Health Technology and Informatics), 153 - 164. doi:10.3233/978-1-61499-684-2-153

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Chapter 1

Introduction

Mobile applications ("apps") are now increasingly becoming a source for delivering health interventions to promote healthy attitudes and behaviours among community living older adults. By "community living", for the purpose of this programme of research, I mean older adults living independently in their own homes rather than those living in care homes, sheltered accommodation or hospitals. One main objective for these interventions is helping community living older adults to adopt healthy lifestyles. An impressive body of research has also show that mobile apps can help community living older adults in many ways. For instance, mobile apps can be used for community living older adults with type 2 diabetes (Fukuo et al., 2009) or age-related macular degeneration (Hakobyan et al., 2016) to self-monitor their diet, to engage in physical activity (Fan et al., 2012; King et al., 2016), or to remember to take medications (Dalgaard et al., 2013). This programme of research aims to design and develop a mobile app, called MyHealthyLivingApp, to allow the community living older adults to monitor whether they are eating sufficient fruit and vegetables (FV) and drinking sufficient liquid, to delay or prevent them from becoming (more severely) malnourished or dehydrated.

Older adults[1] are a large and fast growing proportion of the United Kingdom (UK) population. The Office of National Statistics (ONS) predicted that the older adult population in the UK will increase from 11.6 million in 2015 to 18 million in 2039 (ONS, 2015, 2016b). Increasing life expectancy is one of the reasons for the greater number of older adults in the coming years. The ONS (2013a) estimated that in the UK people born in 1947, who turned 65 in 2012, have a life expectancy of 86.2 years for men and 88.9 years for women. These figures are predicted to increase over the next 25 years, with men who turn 65 in 2037 having a life expectancy of 89.1 years and women a life expectancy of 91.7 years ONS (2013a). The ONS estimated that at age 65, men can expect to live 58 percent of their remaining life in good health, and women can expect 56 percent (ONS, 2011). The ONS also estimated a relatively small increase in the young adult population aged 18 to 64

[1] People aged 65 years or more (see Section 2.3 for further readings of the definition of older adults)

years in the next two decades (ONS, 2015). These two factors of an increasing number of older people and a static number of younger people means that the old-age support ratio (OASR), the ratio of the number of working people to support each older adult (UN, 2015) will sharply decline in the coming decades (ONS, 2013b).

One common health problem for older people is dehydration. In the UK, according to the National Health Services (NHS), dehydration is often associated with other health problems such as malnutrition (NHS, 2015). These health problems are often associated with psychological factors such as bereavement because widowhood cause widowers to lose interest in food related activities (Callen & Wells, 2003; Shahar et al., 2001) and physiological changes such as dental and oral status that influences liquid and nutrition intake (Suominen et al., 2005; Wright et al., 2005). In addition, factors such as lack of knowledge in consuming the right amount and type of liquid and nutrition intake also contributes to these health problems.

In relation to liquid intake, a four-year survey by Public Health England and the Food Standards Agency found that the average daily non-alcoholic liquid intake of older adults aged 65 and above in the UK was only 1.2 litres for men and 1.3 litres for women (Bates et al., 2014). This is well below the recommendations provided by the British Nutrition Foundation (BNF) that men drink 2 litres of non-alcoholic liquids per day, and that women drink 1.6 litres (BNF, 2017). Dehydration among older adult requires constant treatment (Campbell, 2016; Dunn, 2015; Marshall et al., 2016). Dehydration can lead to tiredness, poor mental performance, physical weakness, dizziness and increased risk of falls (Frangeskou et al., 2015; Masento et al., 2014). Furthermore, prolonged dehydration can lead to longer hospital admission, increased morbidity and mortality rate (El-Sharkawy et al., 2016).

The ONS (2013c) reported that in 2011 4.6 million (52%) of older adults (aged 65 and over) in the UK have long-term health problems which limits their daily activities, with malnutrition being one of the common health problems (AgeUK, 2017). Elia and Smith (2009) estimated that 1.3 million adults aged 65 years and above are malnourished or at-risk of malnutrition, including those living in the community. Four nutrition screening surveys in the UK (conducted in 2007, 2008, 2010 and 2011) with a total of 31,637 malnourished individuals (mean age of 64.5 years) found that the prevalence of malnutrition increases with age (Russell & Elia, 2014). Of these malnourished individuals, 55% (17 504) were older adults, and 74% (23 411) were living in the community.

In relation to nutritional intake, one common problem for older adults is consuming the recommended daily servings of FV. The World Health Organization (WHO, 2016a) and the NHS[2] recommend eating at least five servings of 80 grams of FV a day, a total of 400 grams. However, the four-year survey by Public Health England and the Food Standards Agency found that for older adults (aged 65 and above) in the UK, the average FV intake was only 320 grams per day (Bates et al., 2014). Studies with older adults in other developed countries have also shown that older adults do not consume the recommended servings of FV intake and have mixed knowledge about the recommended number of servings of FV (Power et al., 2014; Saba & Vassallo, 2012). Inadequate consumption of FV increases the risk of coronary heart disease (He et al., 2007), increases mortality rate (Bamia et al., 2007), and lowers quality of life (Anderson et al., 2011; Gopinath et al., 2014). Section 2.4.5 provides further discussion of older adults' attitudes, knowledge, and perception on FV intake.

Malnutrition remains a low priority in clinical care and professional training. Even though treatment guidelines to overcome malnutrition do exist, however there has been no overall approach or analysis of the guidelines (Brotherton et al., 2010). Poor knowledge about malnutrition among professionals is also a concern (Guest et al., 2011). Studies by McWhirter and Pennington (1994) and Guest et al. (2011), 17 years apart, both showed that clinicians in the UK focused on severely malnourished patients rather than the mildly malnourished ones. Guest et al. (2011) analysed 1000 malnourished patient records and 996 non-malnourished patient records gathered from the Health Improvement Network database. The analysis showed that clinicians prioritise their treatment to severely malnourished patients (mean age 72 years) rather than the mildly malnourished patients (mean aged 60 years). This shows there is an age gap of approximately 12 years between treated and untreated malnourished patients (i.e. mean age 72 years of treated patients minus mean age 60 years of untreated patients). Therefore in my opinion, individuals who are malnourished may be experiencing 12 years of unnecessary hardship in relation to malnutrition, which is often associated with other health problems including dehydration

[2] http://www.nhs.uk/Livewell/5ADAY/Pages/5ADAYhome.aspx

(NHS, 2015). As research to date appears to focus on older adults and severely malnourished individuals, I believe that there is a need for my programme of research to focus on community living older adults who are at-risk of malnourishment to delay or prevent them from becoming (more severely) malnourished or dehydrated.

To overcome these health problems, from a Human Computer Interaction (HCI) point of view, I am most interested in factors such as lack of knowledge or awareness about nutrition and hydration. By focusing my attention to these factors, I felt I could make a contribution to enhance the health and well being of community living older adults as maintaining good heath is important for physical and mental performance for community living older adults.

Many researchers have suggested that using mobile technology may be a promising tool to promote healthy attitudes and behaviours among older adults. However, the review of the literature concerning mobile apps predominantly focus on community living older adults with type 2 diabetes (Fukuo et al., 2009) or age-related macular degeneration (Hakobyan et al., 2016) to self-monitor their diet, to engage in physical activity (Fan et al., 2012; King et al., 2016), or to remember to take medications (Dalgaard et al., 2013). There have also been studies that aimed to raise awareness about older adults' wellbeing by self-monitoring wellness (Doyle et al., 2014). However, little work has been done in designing and evaluating mobile apps for at-risk community living older adults to support them in maintaining good nutrition and intake of liquids, and thus can help minimise the risks of becoming malnourished.

This programme of research also investigates methodologies that are appropriate for working with older adults to develop technologies. I investigated the methodological use of focus groups and expert evaluations.

Krueger and Casey (2014) described the focus group as a *"planned series of discussions designed to obtain perceptions on a defined area of interest"* (p.2). The common practice is for focus groups to be conducted with a number of people led by a skilled moderator (Stewart & Shamdasani, 2014) who is familiar with the topic of discussion (Krueger and Casey (2014). There are mixed views in the literature about the optimal number of participants to have in a focus group. Literature has shown that focus groups have been conducted with as little as two (Goodman et al., 2004; Lyons et al., 2013) or three participants (Inglis et al., 2003) and as many as 23 (Braithwaite et al., 2004) or 31 participants (Gloet, 2002) per discussion. Studies within HCI have also conducted focus groups with various numbers of participants. For example, there were four participants per discussion in (Massimi et al., 2007b), seven participants in (Kurniawan, 2008), 11 participants in (Hitchens & Lister, 2009; Martín-Duque et al., 2016), and 13 participants in (Scanniello et al., 2016).

Furthermore, reviewing the literature shows there is no definite number of participants for focus groups in terms of the age of participants, especially with older adults. Many researchers found it difficult to conduct a focus group either with a small (as few as two) or large (as more than 12) number of older adult participants per focus group. For example Inglis et al. (2003) found that working with more than three participants aged between 54 to 86 years per session was hard to manage. They reported that some of the characteristics of the older adults, for example having poor hearing, or a poor ability to follow the discussion, could influence the session negatively. Another example, Lines and Hone (2004) aimed to elicit user requirements for an alarm system. They found that working with 12 participants aged more than 65 years per focus group tended to discuss unrelated topics and to have side discussions among themselves. This led to difficulties for the moderator in managing the sessions.

Hawthorne et al. (2006) found that discussing quality of life issues with four to six participants aged more than 80 years was difficult to control. In another study, Brondani et al. (2008) found that having five to nine participants, aged between 64 and 93 years, per focus group had participants who made a few attempts at dominating the discussion. Lyons et al. (2013) had focus groups of two to ten participants aged more than 65 years, with a mean age of 75.2 years, and found that often the participants discussed irrelevant topics amongst themselves. Buykx's (2013) study aimed to investigate meal planning, shopping and cooking habits of 15 older adults aged 60 and above in 4 focus groups. The author found 33% of the duration of the focus groups was not related to the goal of the discussions. Little information was given on the number of participants the author had per discussion. Section 3.1.1 provides further discussion of focus groups as a data collection method.

These mixed views on the optimal number of participants per focus group and the age factor interested me to explore on the issue of the size of focus group with older adults and how this affected the information elicited.

The common practice of expert evaluation is where a group of usability experts worked individually and evaluate the user interface of a system against a set of heuristics. After the experts have worked through the system, they come together and discuss all potential problems they have found and come up with an agreed list of problems, and rate them for severity. In this programme of research, an existing set of 33 heuristics for evaluating apps developed for older adults proposed by Silva et al. (2015) was investigated in the context of collaborative heuristic evaluation (CHE) (Petrie & Buykx, 2010). CHE is an expert evaluation method in which the experts worked as a group to identify potential usability problems, but rate the problems privately. This allows the experts to disagree about the severity of particular problems. In addition, CHE has been shown to be an effective method for conducting an expert evaluation as it allows experts with different areas of expertise to work together.

The evaluation of the first prototype of the app brought to investigate the use of the picker as an interaction technique. A picker is a “view that uses a spinning-wheel metaphor to show one or more set of values” (Apple Inc, 2017). A common picker for mobile technologies is the DatePicker (see Figure 1.1). It allows users to input the date and time values. To select a value, a user would place a finger on the value and scroll up or down. The selected value appears in a darker text in the centre of the view (see Figure 1.1). A review of the literature revealed no studies which had investigated the suitability of the picker for number entry for older users on tablet computers, although this is a popular design option and more detailed research is needed into the suitability of different interaction techniques on the tablet for older users. Thus, a study was conducted to investigate the older adults’ performance on number entry tasks on a tablet computer and a desktop computer (PC).

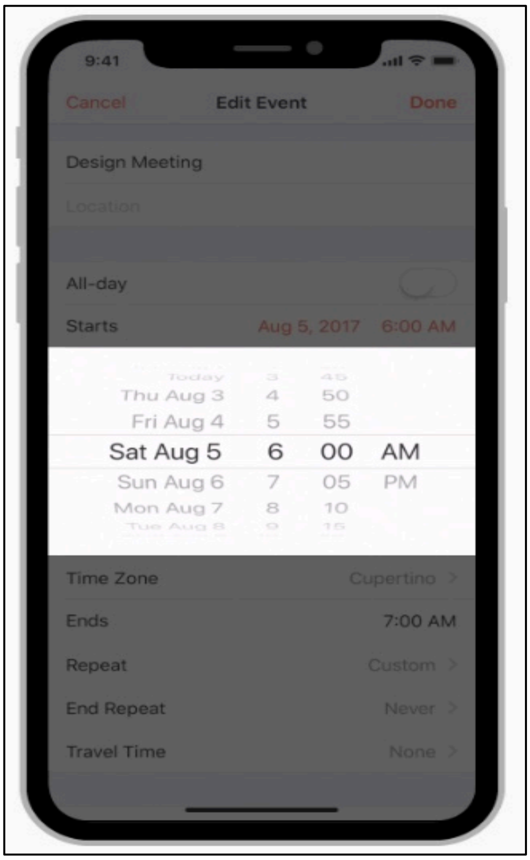

Figure 1.1: A DatePicker displaying the date and time values. (Source: Apple Inc, 2017)

1.1 Research aims

The aim of my research is to design and develop a mobile app, called MyHealthyLivingApp, to allow the older adults to monitor whether they are eating sufficient FV and drinking sufficient liquid. On the basis of two evaluation studies with older adults, I also aimed to develop a set of evidence-based heuristics for the development of apps to support older adults.

I also aimed to investigate methodologies that are appropriate for working with older adults to develop new technologies. I investigated aspects of the size of focus groups and aspects of expert evaluations. In the case of focus groups, the size of the group was investigated; and for the expert evaluations, an existing set of heuristics for evaluating apps for older adults was investigated. On the basis of these methodologies, I provide reflections on how best to conduct focus groups, in terms of the size, with older adults and experts' experiences in using an existing set of heuristics for evaluating apps.

As the result of the first prototype of the MyHealthyLivingApp, I also investigated the older adults' performance of number entry tasks on a tablet computer and a PC. In addition, I am also interested to investigate the older adults' opinions and preferences for the different interaction techniques.

1.2 Thesis structure

The structure of this thesis is as follows:

Chapter 2 presents a review of literature related to malnutrition and dehydration in older adults. This chapter also presents previous research that is relevant to the older adults and their acceptance of technologies. In addition, this chapter also reviews previous research on mobile apps interventions for older adults.

Chapter 3 presents the initial user requirements work for the development of MyHealthyLivingApp. Two focus groups were conducted with a total of 9 older adults, discussing their needs and worries about nutrition and hydration, and their use of technology.

Chapter 4 presents the design of a low-fidelity prototype of an app, MyDrinkApp, to support older adults to monitor their liquid intake for both smartphone and tablet computer platforms. A collaborative heuristic evaluation (CHE) was conducted by four experts to identify potential usability problems of MyDrinkApp. In addition, this chapter also presents the experts' experience in evaluating the heuristics proposed by Silva et al. (2015), which were specifically developed to evaluate smartphone apps for older adults.

Chapter 5 presents the re-design of the MyDrinkApp and the evaluation of the app. Twenty older adults evaluated the usability of the app using a concurrent verbal protocol.

Chapter 6 presents an investigation on the use of the picker as an interaction technique. Three interaction techniques were compared on a tablet computer and a PC: Keypad, Buttons and Number Selector (picker on the tablet, pull down menu on the PC). Twelve older adults' performance of number entry tasks, opinions and preferences for the different interaction techniques were also investigated.

Chapter 7 presents the design of the main app developed in this programme of research, MyHealthyLivingApp, to support good nutrition and hydration in older adults. The app allows them to monitor whether they are eating sufficient FV and drinking sufficient liquid. As a first step, a CHE was conducted by three experts to identify potential usability problems of the app.

Chapter 8 presents the two-week field study of the re-designed MyHealthyLivingApp. Fifteen older adults used the app in realistic setting of use in their own homes. Usability problems were collected via post-study questionnaire and post-study interview.

Chapter 9 presents the analysis of usability problems identified in the user evaluations of MyDrinkApp and MyHealthyLivingApp to support them in monitoring their FV and liquid intake (see Chapters 5 and 8). The problems were categorized and compared with problems identified in the expert evaluations (see Chapter 4 and Chapter 7) as part of two rounds of user-centred designs. The outcome allowed me to develop an evidence-based set of 16 heuristics to assist the development and evaluation of mobile apps for older adults.

Chapter 10 presents the overall discussion of this programme of research, including the contributions, suggestions for future research and conclusions.

1.3 Statement of ethical approval of research

The Physical Sciences Ethics Committee (PSEC) at the University of York approved all studies conducted for this programme of research.

Chapter 2

Literature Review

2.1 Introduction

This chapter presents the review of literature related to the demographics of older adults in the United Kingdom (UK), the characteristics of older adults, the importance of good nutrition and hydration for them and the dangers of malnutrition and dehydration. The chapter also presents research that is relevant to the older adults and technology, emphasizing on research related to engaging older adults with mobile apps.

The structure of this chapter is as follow: Section 2.2 will define the term *older adult*. This section will also discuss the demographics of the ageing population in the UK and the characteristics of older adults. Section 2.3 will present the importance, causes and consequences of malnutrition among older adults. This section will also review how dietary pattern influences later life. In addition, this section will discuss the older adults' attitudes, knowledge, and perception on maintaining balance nutrition. Section 2.4 will present the importance, cause and consequences of dehydration among older adults. Section 2.5 will present research that is relevant to older adults and technology. This section will present the older adults' attitudes, knowledge, and perceptions of using technologies. In addition, this section will also review previous research on mobile apps interventions for older adults.

2.2 Definition of older adults

Defining when one becomes old is difficult. In most developed countries, the chronological age of 65 years or over is often the definition for an older adult because this has been the age when people retire (WHO, 2017). However, with respect with all nations of the world, the World Health Organization (WHO) uses an age of 50 years or over (WHO, 2017) whereas the United Nations (UN) often uses an age of 60 years or over (UN, 2015) to define the older adults in their reports.

However, defining an older adult solely based on retirement age is problematic. This is because the retirement age differs from country to country and has varied across time. In most developed countries, for example the United States, the retirement age is between 62 and 67 years old[3]. In developing countries the retirement age is often earlier; for example Malaysia, it is either 55, 56, 58 or 60 years[4], depending solely on the employee themselves when they want to retire. Moreover, in some countries the retirement age differs between men and women. For example, in Saudi Arabia the retirement age is 60 years for a man and 55 years for a woman[5]. Nevertheless, in the UK, the retirement age was 65 years old for a man and 60 years old for a woman until quite recently[6]. Now, the UK has opted to allow employees to work for as long as they want.

Thus, defining older adults solely based on retirement age is not sufficient. Recent studies on the use of technology by older adults in developed countries have shown inconsistency in the lowest age used in defining older adults, as shown in Table 2.1. As part of the biological process of aging, older adults have different concerns compared to younger adults when using technology Hawthorn (2000). From my analysis, the lowest minimum age for older adults is 48 years, while the highest is 74 years. Nevertheless, the most often used aged to identify the older adults is 65 years old. It is clear that setting a chronological minimum age to define an older adult is difficult.

Table 2.1: Minimum age of older adults in a range of studies related to technology

Minimum age for older adults	**Study**
48	Hardill and Olphert (2012)
50	Burrows et al. (2016) Nicol et al. (2016)
52	Grindrod et al. (2014)
55	Swallow et al. (2016) Dasgupta et al. (2016)
57	Leung et al. (2012)
60	Dalgaard et al. (2013) Chan et al. (2016)

[3] https://www.nasi.org/learn/socialsecurity/retirement-age
[4] http://www.jpa.gov.my/index.php?option=com_content&view=article&id=2662:persaraan-paksa-di-bawah-seksyen-10-1-akta-227-239&catid=532:pencen&lang=ms
[5] http://www.ssa.gov/policy/docs/progdesc/ssptw/2012-2013/asia/saudi-arabia.html
[6] https://www.gov.uk/retirement-age

	Piper et al. (2010)
61	Findlater et al. (2013) Fan et al. (2012)
63	Chang et al. (2013)
65	Vaportzis et al. (2016) Hakobyan et al. (2016) Doyle et al. (2014) Page (2014) Pedell et al. (2013a) Leonardi et al. (2010) Mitzner et al. (2010)
67	Jayroe and Wolfram (2012)
71	Waycott et al. (2012)

However, review papers investigating older adults and technology have used different minimum ages to define an older adult. Hawthorn (2000) identified the minimum age of older adult as 45 years old. However, Wagner et al. (2010) used the minimum age of 40 years old. Joe and Demiris (2013) whom conducted a review on the use of mobile phone for health and Peek et al. (2014) whom conducted a review on the use of technology to support independent living identified the minimum age of 60 years old. In more recent reviews, the minimum age of 65 years old has been used (Dahler et al., 2016; Skjæret et al., 2016). Nevertheless, there are also current review papers that do not specify the minimum age but included older people in their search strategy (Mostaghel, 2016; Yusif et al., 2016).

Researchers in technology and older adults are concerned about other perspective such as the older adults' computer experiences or expertise (Gregor et al., 2002; Redish & Chisnell, 2004) which can be influenced by their psychological age (Dimitrova & Chen, 2006). Psychological aging is how old one feels, acts and behaves and can be influenced by health, lifestyle, personal and environmental factors (Woods, 2011). Psychological aging differs from one person to another. As this research is interested in the older adult population in the UK, the Office for National Statistics (ONS) often refers to an older adult as someone who is 65 and above. In addition, 65 years old is also often used by many current researchers in the UK investigating older adults and mobile technology for example by Vaportzis et al. (2016), Hakobyan et al. (2016), Page (2014) and Barnard et al. (2013). That said, this report will also use this age as the minimum age to represent older adults. The next section will explore the demographics of the older adult population in the UK.

2.2.1 Demographics of the older adult population in the UK

Older adults are a large and fast growing proportion of the UK population (ONS, 2015). At the time of writing in 2016, the overall UK population was 65.1 million (ONS, 2016b). This figure is predicted to rise to 74.3 million by 2039 (ONS, 2015). The ONS (2016b) reports that there are currently 11.6 million older adults. This represents 17.8% of the overall UK population. By the year 2039, the number of older adults is predicted to reach 18 million (ONS, 2015). This represents nearly a quarter (24.2%) of the predicted population in 2039. Figure 2.1 shows the pyramid population in the UK for the years 2014 and 2039.

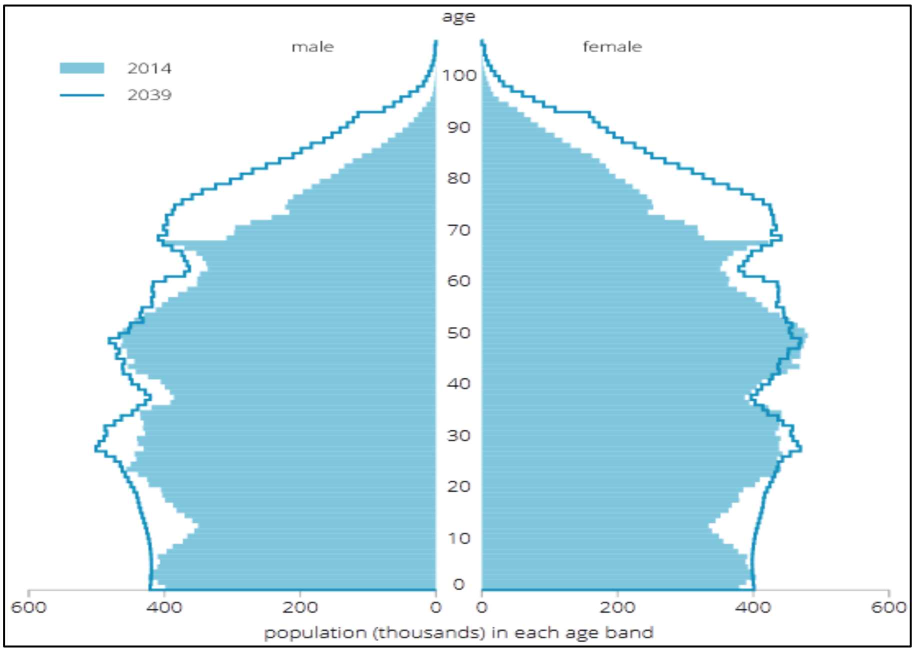

Figure 2.1: Pyramid population, UK, 2014 – 2039 (Source: (ONS, 2015))

Currently, the overall population up to the age of 64 years is 53.5 million. In 2039 it is predicted to be 56.3 million. Table 2.2 shows that there will be an increase of only 2.8 million for people aged up to 64 years between 2015 to 2039. However, there is a far greater increase of 6.4 million for those aged 65 years and over. This prediction explains the fast growing proportion among the older adults in the UK in the next few decades.

Table 2.2: Population, in millions for under 65 years and 65 years and older, UK, 2014 – 2039 (Source: (ONS, 2015, 2016b)

Ages	2015	2039	Increase
Up to 64 years	53.5	56.3	+ 2.8
65 year and older	11.6	18	+ 6.4

From these figures it can be seen that the UK will have many more older adults in the coming years. A low fertility rate contributes to a relatively small increase in the population aged under 64 years in the next two decades (ONS, 2015). With the small increase in the population aged under 64 years and the fast growing number of older adults aged 65 years or more, there is a growing need to support older adults to remain independent. This is because as time goes on there will be fewer younger people compared to the older adults. This is known as the old-age support ratio (OASR). The OASR is a measure of the number of working people to support each older adult (UN, 2015). The OASR is defined as the ratio of the number of working people, those aged 20 to 64 years, to the number of older people of 65 years or over (UN, 2015). Figure 2.2 shows the sharp decline that will occur in the OASR in the UK between 2012 and 2037. The OASR is predicted to decrease from 3.21:1 in 2012 to 3.08:1 in 2027 to 2.74:1 in 2037 (ONS, 2013b).

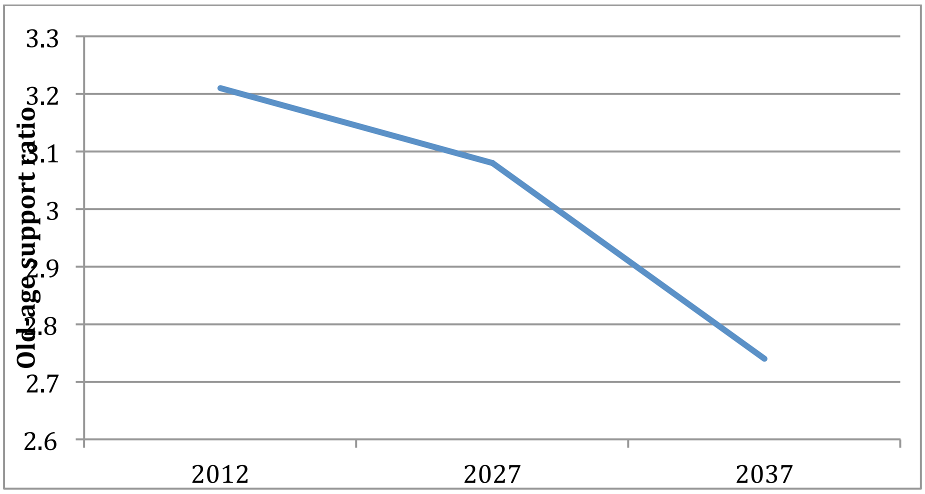

Figure 2.2: Old-age support ratio, UK, 2012 – 2037 (Source: (ONS, 2013b)

The increase in life expectancy is also another factor that will contribute to the high number of older adults in coming years. Table 2.3 shows that in the UK people born in 1917, who turned 65 in 1982, had a life expectancy of 79.2 years for men and 83.0 years for women. These figures are predicted to increase over the next 23 years, with men who turn 65 in 2037 having a life expectancy of 89.1 years and women a life expectancy of 91.7 years.

Table 2.3: Life expectancy at age 65, 1982 - 2037 (Source: ONS (2013a))

Year born	Year at age 65	Life Expectancy	
		Men	**Women**
1917	1982	79.2	83.0
1947	2012	86.2	88.9
1972	2037	89.1	91.7

One factor that relates to the increase in life expectancy is the lower mortality rate (ONS, 2013a) and the increase in healthy life expectancy (ONS, 2016a). Table 2.4 shows that in the UK people who turned 65 between 2009 and 2011, had a healthy life expectancy of 75.4 years for men and 76.5 years for women. These figures increase with men who turn 65 between 2012 and 2014 having a healthy life expectancy of 75.6 years and women a healthy life expectancy of 76.5 years (ONS, 2016a). For both sexes, this presents just under 60 percent of their predicted life expectancy.

Table 2.4: Healthy life expectancy at age 65 (Source: ONS (2016a))

Year at age 65	Healthy Life Expectancy	
	Men	**Women**
2009 - 2011	75.4	76.3
2012 - 2014	75.6	76.5

2.2.2 Characteristics of older adults

As people get older, they change biologically. Biological aging is unavoidable as the aging process, both physically and internally, progresses throughout the lifespan (Magalhães, 2011). The biological process of aging is similar for everyone. This includes changes in vision, hearing or motor skills which tend to be more noticeable at the age of 45 years (Hawthorn, 2000). Victor et al. (2007) highlighted the need to explore the varied characteristics of older adults, especially when conducting a study with them. They noted that as part of the aging process, older adults might have different needs, and wants at different stages of their life. In a review paper on older adults and technology, Arch (2010) suggested age associated decline that can affect older adults in using technology includes declining in cognitive, vision, hearing, and physical ability. The next section will review the changes that people experience as they age and the consequences of these changes in using technology.

Cognitive abilities

There is a considerable literature on the cognitive abilities of older adults. Verhaeghen (2011) defined attention as how the mind can be concentrated towards a particular situation. Verhaeghen (2011) noted that dementia, including Alzheimer's diseases and vascular dementia are common causes of cognitive impairment in older adults. The Alzheimer's Society (2017) reported that in the UK, 808, 000 older adults are living with dementia. The Alzheimer's Society (2017) also reported that dementia increases with age with only 1 person in 14 for those aged 65 to 80 years, to 1 person in 6 for those over 80 to 95 years, to 1 person in 3 for those over 95 years.

Two longitudinal studies Wilson et al. (2002) and Rabbitt et al. (2004) found that, on average, as age increases, cognitive abilities decreases. In both studies, the participants had to do a number of cognitive tests, such as memorising sequences of numbers, arithmetic, story retention, and logic questions. In both studies the authors did not suggest the age when cognitive abilities start to decline, but their findings show that little difference in abilities between age 60 years and 70 years is, but the gap gets wider as older adults enter their 80s.

In related to completing computer tasks, previous research with 10 years apart by Chadwick-Dias et al. (2003) and Findlater et al. (2013), has shown that the older adults have slower cognitive process, poorer attention, and decreases in memory capacity in comparison with younger adults. For these studies, cognitive abilities are often measured by the time taken to complete tasks. Findlater et al. (2013) did a cross-sectional study with

20 young (aged 19 to 51 years) and 20 older (aged 61 to 86 years) adults. 90% of the participants were daily computer users. 60% of the young and 45% of the older participants were daily touchscreen users. The authors measured the speed taken of pointing, dragging, crossing, and steering using a mouse and a touchscreen. They found in all eight tasks, the older participants took, on average, twice the time as the younger group.

Visual and hearing abilities

Literature has shown that as we age, our sensory abilities start to decline. The Royal National Institute of Blind People (RNIB, 2015) reports that more than 2 million older adults in the UK have some form of sight loss which affects their daily life. The prevalence of sight loss increases with age. The RNIB (2015) also reports, of the 2 million, 15 percent are of older adults age 65 years or over. The number increases to 35 percent for those over 75 years and 50 percent for those over 90 years.

Action on Hearing Loss (2016) reports that 8.3 million older adults in the UK have some form of hearing loss. Action on Hearing Loss (2016) also reports that the hearing loss increases as age increases. They reported hearing loss affects 42 percent of people over 50 years old and increases to 71 percent of older adults over 70 years old.

Problems with visual perception are mainly related to poor visual acuity (Bergman & Rosenhall, 2001), either for both distance or near vision, contrast sensitivity, adapting to glare, and colour vision (West et al., 2002). Bergman and Rosenhall (2001) did a longitudinal study with originally 973 older adults. They measured the visual and hearing tests three times at age 70, 81-82 and 88 years. The threshold to define hearing impairment was 30 db HL (decibels Hearing Level). Visual ability was assessed with best-corrected visual acuity. It was not clear in the paper whether they assessed the older adults with distance or near vision. In terms of visual ability, they found that the failure rate increases as age increases. They found that majority older adults at age 70 years still have normal vision abilities. At age 81-82 years, 48.5% of the older adults had normal vision. At age 88 years, it was only 25.5%. In terms of hearing ability, at age 70 years, 72.5% of the older adults had normal hearing. At age 81-82 years, it was only 21.5%. At age 88 years, it was 19%. The authors found that at age 70 years, better hearing was correlated with better eyesight. However, in the remaining two tests, there were no correlations between the vision and hearing abilities.

There is no specific research showed the impact of vision and hearing loss due to ageing affected using technology or specifically in using mobile technology. However, older adults in Demiris et al. (2004) focus group study highlighted their vision loss and hearing impairment as the main reasons that hinders them to using technology at home. Dickinson et al. (2005) also reported that sight loss is the main reason that hinders older adults to use technology due to having difficulty in reading small text and problem with the screen contrast.

In terms of hearing loss due to ageing, older adults are often associated with slow auditory processing and reduced hearing in noisy environments (Bergman & Rosenhall, 2001). To overcome this, older adults often demand for higher frequency (Cruickshanks et al., 1998; Gopinath et al., 2009). Although hearing impairment is not considered as a barrier to using technologies (Hanson, 2001), but with newer designs of technologies including sound effects, this might change.

Physical abilities

Other than being able to see and hear, having the ability to do things physically is important to being independent in old age (Priestley, 2012). The effects of aging can make older adults' physical movements slower and more restricted than those of the younger people (Magalhães, 2011). This can be in conjunction to having multiple impairments such as poor vision and poor hearing (Hawthorn, 2000). Arch (2010) noted that arthritis and Parkinson's Disease are the main ageing diseases that affect the changes in physical abilities. The NHS (2016a) estimated there are 10 million people in the UK suffering from arthritis. Osteoarthritis is the common type of arthritis among older adults (Arthritis Research UK, 2017). Osteoarthritis occurs when the bones become quite fragile, which is a natural ageing process.

Related to mobile technology use, numerous studies have shown that older adults struggle to perform tasks that require them to steer an object in a limited area (Findlater et al., 2013), or to make gestures that require using two fingers, for example rotating and resizing (Piper et al., 2010). Other researchers found that older adults struggle to tap and drag objects (Leonardi et al., 2010) or typing using a built-in keyboard (Jayroe & Wolfram, 2012). Jayroe and Wolfram (2012) also found that older adults have difficulty regarding the sensitivity of a touchscreen, especially in controlling their hand movements. In addition, Hawthorn (2000) found that older adults struggle to move or click using a mouse. A study by Waycott et al. (2012) had participants who had concerns with the weight of an iPad.

In all of the tasks listed in above, the authors focused on the movement of fingers or hands. This is because the main interaction with interactive technologies, particularly mobile technologies, is via the fingers and hands. The main objectives of these studies were to engage older adults using a touchscreen (Waycott et al., 2012), to compare their performance with a touchscreen and a desktop (Findlater et al., 2013; Jayroe & Wolfram, 2012), and to explore the accessibility of a touchscreen for older adults (Leonardi et al., 2010; Piper et al., 2010). To have a variety of types of older adults, the authors included a range of older adults per study, with the age range of 20 years. Some studies included participants with arthritis or severe hand tremors (Jayroe & Wolfram, 2012; Piper et al., 2010; Waycott et al., 2012). In the study by Leonardi et al. (2010), some participant commented on having larger fingers, thus, preferred using a stylus to complete the requirement tasks to explore the accessibility of a touchscreen.

This section discussed the definition of older adults and the characteristics of older adults. This section also included the demographics of older adults particularly in the UK. The statistics show that the older adult population is increasing in a fast pace compared to other age groups. The next section will discuss malnutrition, a health issue for this age group in the UK (AgeUK, 2017; Russell & Elia, 2014)

2.3 Older adults and nutrition

Maintaining balance nutrition is important for older adults. A balance nutrition consists of consuming a balance of fruit and vegetables (FV), starchy food, dairy, protein, fat and drinking plenty of fluids (NHS, 2016b). The UK NHS Eatwell Guide can be found in Appendix 5.

Before I further discuss about older adults and malnutrition, this brief review of literature is for me to understand what are the typical dietary patterns among the community living older adults in developed countries and how it affects their later life. Based on my analysis, most studies are longitudinal which range between 8 to 10 years and allow the older adults to self-report their food daily intake via a food frequency questionnaire (FFQ). The FFQ, which consists on many food groups, was designed to evaluate the style of diet pattern for each participant. Based on the FFQ, the total energy intake per day was estimated and a score is given. A high score represents adhering to the diet-pattern, whilst a low score represents the opposite pattern of the diet. This section will briefly discuss about this analysis.

Older adults adhering to a plant based diet[7] (Bamia et al., 2007), eating healthy food[8] (Anderson et al., 2011), eating according to the national dietary guideline[9] (Gopinath et al., 2014) or eating according to the recommended daily servings of FV (He et al., 2007) is associated with lower mortality rate (Bamia et al., 2007), lowers the risk of coronary heart disease (He et al., 2007), live more years in healthy life (Anderson et al., 2011) and have better quality of life (QoL) (Gopinath et al., 2014) as compared to not adhering to these diets.

A study by Gopinath et al. (2014) aimed to evaluate the relationship between dietary pattern and QoL. They had 1305 community living older adults (aged more than 55 years) living in Sydney. Participants' dietary intake was measured using a 145-item FFQ. The QoL was measured using the 36-Item Short-Form Survey (SF-36). The higher the score represent a better QoL. Each participant answered both FFQ and SF-36 on two occasions, with five years gap in between (year 1997 – 1999 and 2002 - 2004). The analysis of the FFQ ranged between 0 and 20 with the higher score representing adhering to the Dietary Guidelines for Australian Adults[10]. Participants scoring a higher score (score more than 11.12) have higher physical function (71.6%) as compared to the participants with lower score (score less than 8.14, physical function = 66%), P_{trend} = 0.003. Participants with lower score also scored lower in general health (65.2%), and energy and strength (57.0%) as compared to 69.2% (general health, P_{trend} = 0.02), and 62.3% (energy and strength, P_{trend} = 0.001) for participants with higher score.

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7 A PBD is a high combination of intakes of FV, pasta, rice and other legumes but low intake in potatoes, margarine, and non-alcoholic beverages.

8 A healthy food is defined high intake of FV, whole grains, poultry, fish and low intake of meat, fried foods, sweets, and added fat

9 http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/n33.pdf

10 http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/n33.pdf

This brief analysis have demonstrated that consuming well-balanced diet may provide longer survival years and positively affects the QoL among the older adults. However, there are a number of older adults in each study who do not consume a balanced diet or the recommended dietary guidelines (Gopinath et al., 2014). Section 2.3.5 will report older adults' attitudes, knowledge, and perception about healthy eating. Beforehand, this next section will discuss malnutrition, a significant health issue for this age group in the UK (AgeUK, 2017; Russell & Elia, 2014).

2.3.1 Definition of malnutrition

There are numerous definitions of malnutrition. However, for this programme of research the definition of malnutrition developed by the World Health Organization (WHO) will be used. The WHO (2016b) defines malnutrition as *"deficiencies, excesses or imbalances in a person's intake of energy and nutrients".*

From this definition, it is understood that malnutrition occurs as result of the lack of nutrients and energy that a body needs to survive and thrive. This imbalance of nutrients leads an individual to be over-nourished or under-nourished. This current research is primarily focusing on under-nutrition or at-risk of under-nutrition in older adults. Hence, from this point onwards, the term "malnutrition" refers to under-nutrition, unless stated otherwise. The next section will provide an overview on the estimation of malnourished older adults in the UK.

2.3.2 The importance of malnutrition

Elia and Smith (2009) estimated that 1.3 million older adults in the UK aged 65 years and above are malnourished or at-risk of malnutrition. ONS (2009) reports there are 12 million older adults in 2009. Thus, the estimation of a malnourished older adult to the overall older adult population is one in every 9 individuals (11.1%).

In four nutrition screening surveys in the UK[11], with 31, 637 people (mean age of 64.5 years) from 661 hospitals, found that the prevalence of malnutrition increases with age (Russell & Elia, 2014). Of the people, 55% (17 504 people) were older adults age 65 year

[11] The nutrition surveys were conducted in 2007, 2008, 2010, and 2011

and older (Russell & Elia, 2014). Figure 2.3 shows the distribution of malnutrition according to age categories during the four nutrition screening survey.

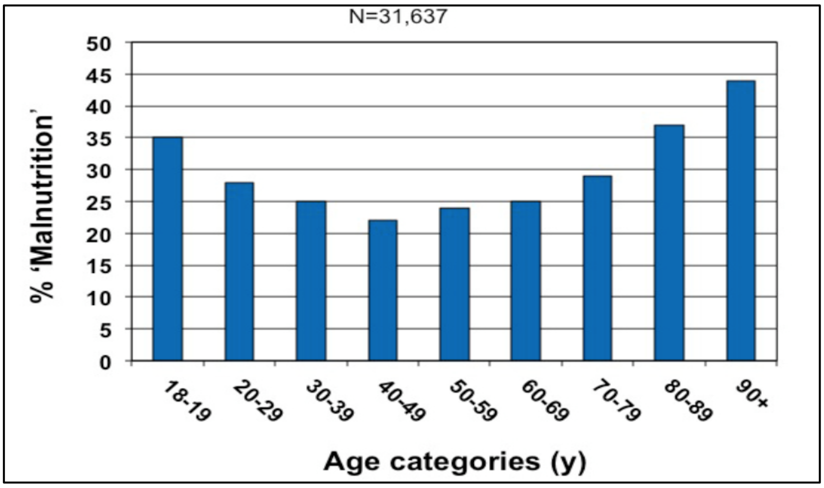

Figure 2.3: Distribution of malnutrition according to age categories. Source: (Russell & Elia, 2014)

In addition, Russell and Elia (2014) also reported that 74% of the people who were malnourished at the time of admission were from the community. Based on the 2011 Census data, ONS (2013c) reported that 4.6 million (52%) older adults have long-term health problems which limits their daily activities, with malnutrition being one of the common health problem AgeUK (2017). The ONS (2013c) also reported that 8.9 million (96%) older adults are living in the community. Of these, 5.2 million are living with a partner or spouse and 2.85 million are living alone. The ONS (2013c) also reports that the number of older adults population in care homes has decreased from 4.5% in 2001 to 3.7% in 2011.

It is worth for me to understand the likeliness of older adults to remain staying in the community despite having health problems. A number of qualitative studies in the UK focus on the community living older adults attitudes of staying at their own home in their later life. Older adults described home in a symbolic term, for example 'love', 'belonging', and 'personal place', rather than just a physical location (Gott et al., 2004) and would prefer to be independent rather than having to burden their family, friends or clinicians (Lloyd-Williams et al., 2007). Older adults would only consider moving into care homes if their health worsen (Gott et al., 2004).

The section above describes the estimation of the incidence of malnutrition among older adults in UK. As the figures show, malnutrition is a health problem especially concerning older adults. To my understanding, there is no later nutrition screening survey done in the UK since 2011 done by Russell and Elia (2011). Literature has also shown that there is a high percentage of older adults in the community who have health problems and older adults prefer to live independently in their later life. However, physical and psychological factors might mean that older adults are not independent in the later life. It is worth understanding what causes older adults to be malnourished, the next section will describe this issue.

2.3.3 Causes of malnutrition

Numerous researchers have focused their effort on studying the causes associated with malnutrition among the older adults. Most researchers who investigated this issue conducted their study in community, care homes or hospitals. Some researchers conducted their study using secondary data for example, Sheiham et al. (2002) and Guest et al. (2011), while some gathered the data on their own, for example Sahyoun et al. (2003) and Callen and Wells (2003). Despite different study fields and methods, most researchers found similar causes associated with malnutrition among the older adults. This section will describe the common causes of malnutrition specifically in older adults in developed countries.

After reviewing 19 papers, it is apparent that there are three major factors that are related to malnutrition among the older adults. See Table 2.5 for the list of references. The first contributing factor is social and environment. The second is psychological and the third is medical or physiological. All three factors are linked to one another resulting malnourishment of the older adults, as shown in Figure 2.4.

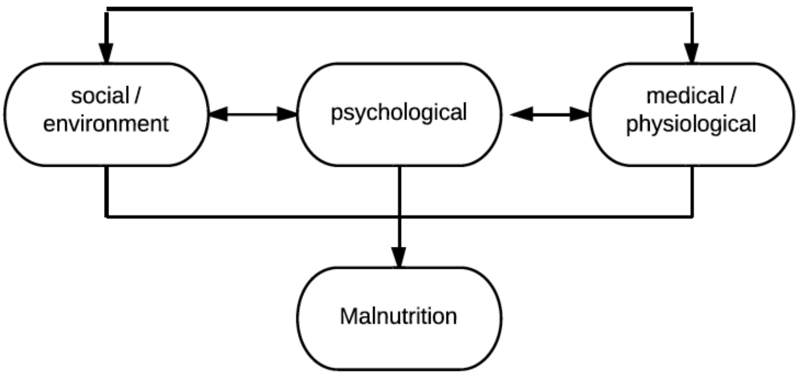

Figure 2.4: Three major factors that cause malnutrition in older adults. (Sources: Table 2.5)

Table 2.5: The references for the major factors that cause malnutrition in older adults

Factor	**References**
Social and environment	Johansson et al. (2009) Bond and Cabrero (2007) Gollub and Weddle (2004) Callen and Wells (2003) Shahar et al. (2001) Christensson et al. (1999) Blaum et al. (1995) Payette et al. (1995) Rosenbloom and Whittington (1993) McIntosh et al. (1989)
Psychological	Callen and Wells (2003) Shahar et al. (2001) Blaum et al. (1995) Payette et al. (1995) Rosenbloom and Whittington (1993) McIntosh et al. (1989)
Medical and physiological	Guest et al. (2011) Johansson et al. (2009) Hickson (2006) Suominen et al. (2005) Wright et al. (2005) Sahyoun et al. (2003)

	Callen and Wells (2003) Sheiham et al. (2002) Christensson et al. (1999) Gariballa et al. (1998) Perry (1997) Blaum et al. (1995) Mack et al. (1994) Schiffman and Gatlin (1993)

From a Human Computer Interaction (HCI) point of view, I am most interested in the social and environment factors as by focusing our attention to this area we can make more of a contribution. It is much less likely that we could tackle the psychological, physiological and medical factors. This is because these factors such as dental and oral status are too related with the human body. From the HCI point of view, this may be beyond our scope to overcome this factor, thus would not be describe in detail in this report. I am interested in factors such as lack of skills, lack of knowledge, or poor social life where arguably technology can help to influence them to have better skills or better social life. The section below will discuss these factors.

Social and environment factors

For this programme of research, social and environment factors are associated with the older adults' living environment, and social lifestyle. A number of studies have been done to show the relationship between these causes that may predict malnutrition. The common causes are loneliness, social isolation, lack of knowledge in cooking, and lack of dependency. These causes have shown to negatively affect nutritional status. The sections below discuss the common findings from the literature.

Loneliness or social isolation

Research has shown that social life is important. Loneliness in community living older adults affects their nutrient intake and eating behaviour (McIntosh et al., 1989; Rosenbloom & Whittington, 1993; Shahar et al., 2001). Older adult who eats alone during meal-time consumed a low dietary intake (McIntosh et al., 1989), tend to lose interest in meal planning, grocery shopping, and meal preparation (Rosenbloom & Whittington, 1993), often feel lonely at mealtimes (Payette et al., 1995), often skip meals, often feel do not want to eat, lose a lot of weight (Shahar et al., 2001) and often eat less (Callen &

Wells, 2003). Callen and Wells (2003) conducted an interview study with 68 community living older adults. Of these, 56 were reported to always eating alone and eating less when compared to eating with companions. A participant who often eats alone states, *"being with somebody to eat, I think it makes a difference"*.

Lack of ability

Lack of ability in this context is referring to the self-ability to eat on his or her own, skills, knowledge or awareness needed to engage in food related activities. Studies in institutions for example by Blaum et al. (1995) and Christensson et al. (1999) found that a lack of help during mealtimes is one of the main reason older adults are malnourished. They found that the limited mealtime duration and lack of staff relates to this factor. Community living older adults also often relied on relatives and neighbours to provide them with food (Callen & Wells, 2003; Payette et al., 1995) due to having lack of ability to prepare food on their own. Payette et al. (1995) found that the older adults do not eat properly is because they struggled to buy groceries and prepare food. Although financial constraint and performing physical activity was not an issue for this group of older adults, 52% of the older adults never do their own groceries shopping and 47.5% of the older adults never prepare their own meal. These older adults often rely on others to provide them with food. However, only 12% of the older adults received community services for food shopping and preparation. In addition, participants reported having low appetite due to fatigue or boredom with consuming similar meals frequently, thus they eat less. Physiological difficulties such as arthritis and poor vision Callen and Wells (2003) or difficulty in walking Gollub and Weddle (2004) are also found to affect the older adults' dietary intake. These difficulties make it hard for them to shop and cook.

Callen and Wells (2003) also found that some of the older adults have lack of nutrition knowledge. Participants reported having poor appetite and boredom with consuming similar meals, thus they tend to skip meals. Another recent qualitative study by Johansson et al. (2009) with community living older adults found that they also have lack of awareness of nutrition. They found 23% (n=23) of the older adults were at-risk of malnutrition. However these older adults do not see themselves as malnourished or were uncertain about their nutritional status. The authors found that these older adults consume fewer servings of FV and protein, and drink less water than the recommended guideline per day.

Psychological factors

Research has shown that bereavement, depression, and stress are the common psychological causes of weight loss and malnutrition among older adults. It has shown that these factors seem to be related to one another, for example the impact of bereavement can cause one to be depressed. As this current research is not interested in these causes, a brief outline on these causes will be presented in the sections below.

Bereavement

Studies from Rosenbloom and Whittington (1993) and Shahar et al. (2001) with equal amount of widowers and married participants shows the mean calorie intake for the widowers was less than the married participants. Both studies showed widowhood cause the widowers to have lack of interest in food, and activities surrounding food such as meal planning, shopping and meal preparation. As a result, it affected their eating behaviours and nutrient intake. Often, widowers also did not enjoy cooking anymore as there is no one to appreciate their cooking (Callen & Wells, 2003; Rosenbloom & Whittington, 1993)

Depression and Stress

Negative feelings, such as depression and stress among the older adults can result in changes in food intake and thus result in changes to their weight. Studies as described above by Payette et al. (1995) and McIntosh et al. (1989) have shown that such negative feelings may decrease diet quality and promote malnutrition or raise the risk of malnutrition. One of the predictors for the reduction of the consumption of regular meals is stressful events from the past including death, illness of a close friend, personal illness (Payette et al., 1995) or by eating alone (McIntosh et al., 1989) or are depressed (Blaum et al., 1995).

Medical and physiological factors

This section describes the causes of malnutrition that are related to medical or physiological factors. The common causes found from the literature are dental, oral status, dysphagia, dehydration, disease and disability, and taste, smell and poor appetite. As this current research is not interested in these causes, a brief outline on these causes will be presented in the sections below.

Dental and oral status

One physiological change is dental or oral problem. Lack of teeth makes it hard to chew. Thus, dental and oral problem can result in one avoiding foods that are difficult to chew and swallow. These impacts may result in consuming a poor diet because of difficulty in chewing nutrient based food such as meats, FV and nuts. Often, individuals with dental and oral problem rely on texture-modified diet (Wright et al., 2005). This is to allow them to chew and swallow food easily. A texture-modified diet can limit the availability of food choice. Indirectly, this influences the nutrient intake. The condition of teeth is also positively associated with nutrients intake where older adults with fewer teeth had lower nutrient intake and are more likely to be malnourished (Sahyoun et al., 2003; Sheiham et al., 2002).

Dysphagia

Dysphagia is associated with dry mouth thus can make it difficult to swallow. Studies by Wright et al. (2005) and Suominen et al. (2005) both showed that dysphagia was one of the causes that lead to poor appetite among the older adults. In Suominen et al. (2005), older adults with BMI less than 17 had difficulty swallowing compared to of those with a BMI more than 23.5, thus consumed less nutrient intake.

Dehydration

Water is essential for life. Literature has shown that aging influences fluid intake. Poor dehydration status among older adults is the main cause of malnutrition in both hospitals (Gariballa et al., 1998) and nursing homes (Blaum et al., 1995; Christensson et al., 1999). Mack et al. (1994) found that older adults (aged 65 years or more) drank less fluid to hydrate themselves in a 3-hours dehydration period as compared to the younger adults (aged 18 to 28 years) after an exercise period. Although dehydration is often seen as a cause of malnutrition among older adults, it is also seen as a health problem on its own (NHS, 2015). For further details on dehydration, its causes and consequences, please refer to Section 2.5 of this thesis.

Disease and disability

Previous studies have found a strong relationship between malnourished older adults and diseases such as gastrointestinal disorders, dementia, constipation, hip fracture, and cancer (Blaum et al., 1995; Guest et al., 2011; Suominen et al., 2005) which leads the older adults to alter their food intake because of their heath condition (Callen & Wells, 2003). Guest et al. (2011) analysed 1000 malnourished patient records and 996 non-malnourished patient records gathered from the Health Improvement Network database. 95% of the malnourished patients had other diseases. The mean age of people suffering from malnutrition with comorbidities is 64.76 years compared to 32.27 years for those who are malnourished but do not suffer from any other disease. Malnourished patients also consumed more medicines compared to the non-malnourished patients (Guest et al., 2011; Johansson et al., 2009) where medicines have side effects that can affect nutrient intake which can influence taste, and smell or through other effects such as nausea, heartburn or malabsorption (Hickson, 2006). Study in nursing homes by Blaum et al. (1995) found that depression among the older adult was one of the main reason they are malnourished. In this study, older adults who are depressed are more likely to have chronic diseases and to be on medication.

Taste, smell and appetite

Older adults are known to having taste and smell impairments. The human sense of taste and smell influence the tastiness of the foods thus makes food more appetizing. Therefore, losing sense of taste and smell plays a role in understanding the cause of malnutrition. Doty et al. (1984) did a smell identification ability with 1955 people ranging from 5 to 99 years old. They found that over 60% of older adults aged between 60 and 80 years have major smell impairments and the number increases to 80% in older adults aged above 80 years. Schiffman and Gatlin (1993) found that to detect the taste of a food, an older adult needs 12 times as much salt and three times as much sugar compared to younger people.

This section has described the common causes of malnutrition among older adults in developed countries. The three major related factors that promotes malnutrition in older adults are 1) social and environment, 2) psychological, and 3) medical and physiological factors. The next section describes the consequences of being malnourished among the older adults.

2.3.4 Consequences of malnutrition

In the previous section explored the causes of malnourishment in older adults. It is essential to also look at the consequences of malnutrition on the older adult. After reviewing 20 papers, a number of repeated consequences have been found. See Table 2.6

for the list of references. The findings include prolonged hospital admissions, prolonged recovery time, increased cost, late receipt of treatment, increased morbidity and mortality, decrease in self-autonomy and poor quality of life, as shown in Figure 2.5. This section discusses the findings.

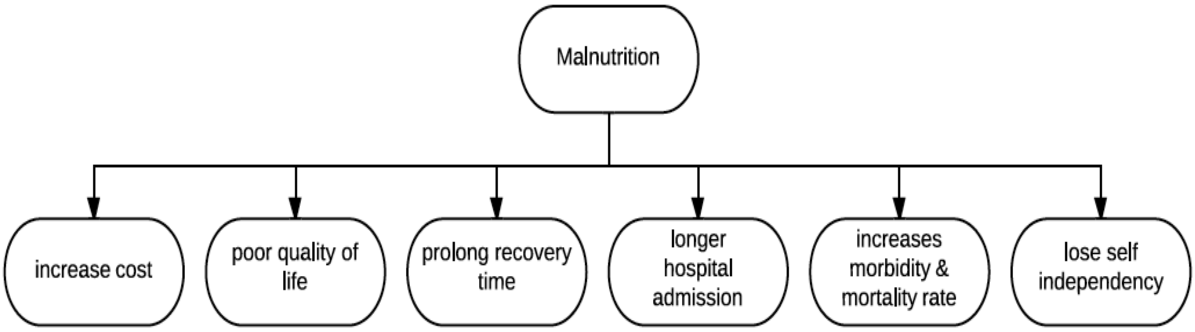

Figure 2.5: Consequences of malnutrition in older adults (Source: Table 2.6)

Table 2.6:Tthe references for the consequences of malnutrition in older adults

Factor	**References**
Increase cost	Guest et al. (2011) Elia and Russell (2009) Elia et al. (2006) Martyn et al. (1998)
Poor quality of life	Olin et al. (2008) Gollub and Weddle (2004) Bowling (2001) McWhirter and Pennington (1994)
Prolong recovery time	Guest et al. (2011) Nieuwenhuizen et al. (2010) Ahmed and Haboubi (2010) McWhirter and Pennington (1994)
Longer hospital admission	Stratton et al. (2006) Kondrup et al. (2002) Elia (2001) Nightingale and Reeves (1999) Perry (1997)
Increased morbidity &	Guest et al. (2011)

mortality rate	Johansson et al. (2009) Olin et al. (2008) Stratton et al. (2006) Martyn et al. (1998)
Lose self independency	Gollub and Weddle (2004) Callen and Wells (2003) Lawton and Brody (1969) Katz et al. (1963)

Cost

Malnutrition is a costly health problem. In 2003, the UK spent £3.65 billion to cover all health and social care related to malnutrition among older adults aged 65 years or over (Elia et al., 2006). Most of this amount is for treatments in hospital, long-term care facilities, GP visits, oral nutritional supplement and tube feeding (Elia et al., 2006). In 2015, nearly £10 billion was spent on older adults aged 65 years or over (Elia, 2015).

Cost per patient

Analysing the data from General Practice Research Database (UK), Martyn et al. (1998) found that for patients whose BMI has increased from lower than 20 to more than 20, their consultation and prescription rates have decreased by 7% and 12% per year. On the other hand, they found that patients whose BMI decreased (from more than 20 to less than 20) have an increase in their consultation and prescription rates by 20% and 22% per year. In Guest et al. (2011) study as described above, shows that a 6-month healthcare cost to manage a malnourished patient is £1753, compared to managing a non-malnourished patient (£750). They noted that this figure only covers the costs spent on hospital admissions, referrals, consultations, lab tests, and medical supplies.

Poor quality of life

Research has shown that malnutrition can affect the quality of life (QoL) of an individual. Bowling (2001) defined QoL as in having the finest levels of mental, physical, and social functioning which includes factors from health, fitness, life satisfaction and well being of an individual. Gollub and Weddle (2004) investigated the relationship of malnutrition with QoL with 381 at-risk of malnutrition community living older adults. In the intervention group, they received home-delivered breakfast and lunch meal. Whereas the control group, they were given home-delivered lunch meal only. All participants received the meal 5 times a week for 6 months. They found that the control group had lower nutrient intake and had more depressive symptoms as compared to the intervention group. They found that the control group often feels bored, worthless and believed their situation was hopeless. On the other hand, the intervention group often feels in a good mood and enjoyed their life. In a later study by Olin et al. (2008) with 49 at-risk malnourished community living older adults, also aiming to investigate the QoL and eating habits. They found that the older adults rated their QoL poorly because of they feel less energetic, their physical abilities limits their movements and they feel socially isolated.

Prolonged recovery time

Malnutrition can also cause longer recovery time. In a study by McWhirter and Pennington (1994), they found that after comparing 55 malnourished patients weighed upon admitted and discharge, 75% of them suffered greater weight loss. In a later study, Guest et al. (2011) found that after 6-months' treatment, the mean BMI of the malnourished patients remained significantly lower than the non-malnourished patients. Only 29% of the malnourished patients became well nourished. The remaining 58% remained malnourished after the six-months treatment. A study by Robert et. al. cited in Ahmed and Haboubi (2010) and Nieuwenhuizen et al. (2010) had young and old adults to participate in an experiment to eat less calories (approximately 750kcal / day) for three weeks. The result shows that all participants lost weight throughout the study but the younger adults quickly gain weight after the study ended. The older adults were less able to increase their nutritional intake and regained only 64% of the weight they lost during the experiment period.

Longer hospital admission

Malnutrition can also prolongs hospital admission. Kondrup et al. (2002) did a study with 750 patients and found that malnourished patients stayed in hospital between 5 to 6 weeks longer than non-malnourished patients. An observational study by Stratton et al. (2006) with 150 malnourished patients found that the mean length of stay of malnourished patients is between 2 to 4 weeks with the severely malnourished patients staying longer in hospitals than the low-risk malnourished patients.

Increase morbidity or mortality risk

Malnutrition can increase morbidity and mortality risks. Longitudinal studies by Olin et al. (2008) and Johansson et al. (2009) investigating the relationship of malnutrition and older adults show a high number of participants had to withdraw because of comorbidity or frailty. In Guest et al. (2011) study, they found that 95% of the malnourished patients had comorbidity as compared to just 81% to the non-malnourished patients.

In terms of mortality risk, Martyn et al. (1998) found that malnourished patient have higher chance of dying earlier compared to the non-malnourished patients. In Stratton et al. (2006) study, they found out of 150 malnourished patients that they screened, 14 died within the first three months. Another 25 died in the next 6 months. The majority who died were severely malnourished. In Guest et al. (2011) study, malnourished patients have six time the risk of death compared to the non-malnourished patients.

Loss of self-independence

Literature have shown that older adults with poor physical abilities often have difficulties in managing their activities of daily living (ADL) or instrumental activities of daily life (IADL). Katz et al. (1963) suggested that ADL includes bathing, toileting, eating, and dressing. On the other hand, Lawton and Brody (1969) suggested IADL includes shopping, food preparation, and housekeeping. ADL and IADL can be measured via questionnaires and used to measure the independence level of an older adult (Katz et al., 1963). The higher the score means the lower independence level of the older adult. Studies by Callen and Wells (2003) and Gollub and Weddle (2004) found that participants who scored higher in IADL score and have lower BMI rate requires more help.

This section describes the consequences of malnutrition among the older adults in developed countries. To further understand the older adults in developed countries attitudes, knowledge and perception on maintaining balance nutrition, a literature review have been conducted. The next section will report my findings.

2.3.5 Older adults attitudes, knowledge, and perception on maintaining a balance nutrition

This section will discuss the older adults' attitude, knowledge, and perception about maintaining balance nutrition, particularly in eating the recommended amount of FV. The

WHO (2016a) and the NHS[12] recommends eating 5 servings of 80 grams of FV a day. A 4-year (2009 - 2012) NDNS by the Public Health England and the Food Standard Agency found that the older adults, aged more than 65 years, mean for FV intake is only 320 grams per day (Bates et al., 2014). As discussed in Section 2.3, inadequate consumption of FV increases the risk of coronary heart disease (He et al., 2007), increases mortality rate (Bamia et al., 2007), and lowers quality of life (Anderson et al., 2011; Gopinath et al., 2014). Most of the studies in this section aimed to assess the participants' knowledge on the recommended servings of FV per day. It should be noted that these studies are from the developed countries.

Baker and Wardle (2003) conducted a survey with 963 older adults aged between 55 to 64 years across the UK. The aim of the study was to assess participants' nutrition knowledge on FV, and their FV daily servings. 45% of the participants correctly estimated the health recommendation servings of FV to be 5-a-day. 32% of the participants were aware of the relationship between low FV consumption and disease. However, only 25% of the participants reported consuming the recommended serving of FV in a day. In average, the participants in this study consumed only 3 serving of FV per day.

Unlike Baker and Wardle (2003), Hughes et al. (2004) interviewed and conducted a survey with 39 older men, aged between 62 and 94 years, in north west of England to investigate their FV daily intake, the barriers to healthy eating, and their cooking skills. Majority (92%) of the participants were living alone retirees. All participants own kitchen facilities and could prepare their own meal by themselves. The analysis showed only 13% of the participants consumed the recommended 5 serving per day and 15% consumed less than one serving in a day. Reasons to not consuming FV varied, for example, due to health, dislike, or lack or interest to change eating habits. In terms of cooking skills, participants self-reporting themselves with good cooking skills consumed more FV than the participants with poorer cooking skills. In terms of nutritional knowledge and awareness of the recommended serving, there are mixed views among these participants. The authors noted that some participants are aware and motivated to follow a healthy diet and some participants are not interested in FV. They concluded that the nutritional knowledge, and the knowledge of consuming 5 servings of FV a day were poor among these participants.

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12 http://www.nhs.uk/Livewell/5ADAY/Pages/5ADAYhome.aspx

Almost a decade later, Saba and Vassallo (2012) conducted a survey study with 258 older adults living across urban cities in Italy. Participants aged more than 60 years (mean age was 68.1 years) and were recruited randomly via telephone interviewing. All participants contributed to groceries shopping and food preparation in their daily life. The aim of this study includes measuring FV intake and to measure their knowledge of the recommended 5 servings of FV per day. Only 9% of the participants in this study knew the right servings of FV in a day. 31% thought it was between 3 to 4 servings a day and the remaining 60% thought it was just 1 to 2 servings a day. In terms of FV intakes, only 46% of the participants consumed FV everyday. However, of these, only 3.1% consumed over 5 portions a day. Majority (90%) of the participants consumed only 1 to 2 servings of FV a day. It is interesting to investigate why the participants do not consume FV in their diet when they found at least 40% of the participants thought the daily recommendation was 3 or more servings but a massive 90% of the participants consumed only 1 to 2 servings a day.

Power et al. (2014) did a survey study to assess the dietary intake with 208 community living older adults aged between 64 to 93 years living in southern of Ireland (mean age was 75.1 years). Participants were excluded if they were an alcoholic or reported participating in a medical trial. The dietary intake was measured via a 147-item FFQ. The frequency of intake was measured with a 10-scale categories ranging from 'never' to 'six times a day or more'. The Food Safety Authority of Ireland Irish food-based dietary recommendation guideline was used to evaluate the group food intakes. The group food include Bread, Cereal and Potatoes (BCP) with 4 servings a day; FV with 5 servings a day; Milk, Yogurt and Cheese (MYC) with 3 servings a day; Meat and Fish (MF) with 2 servings a day; and Fat and Sugar (FS) with less than 3 servings a day. 78% of the participants consumed the recommended servings of BCP. Only 52.9% of the participants consumed the recommended servings of FV. Only a low percentage (5.9%) of the participants consumed the recommended servings of MYC. Majority (68.1%) consumed less than the recommendation servings of MYC. Only 41.2% of the participants consumed the recommendation servings of MF. 15% of the participants consumed the recommendation of FS. However, the mean serving of FS for these participants is more than double than the recommended servings (6.4 servings a day).

These examples of studies show that older adults in the developed countries do not consume the recommended servings of dietary intake, have mixed knowledge in nutrition, have poor cooking skills and lack of motivation in changing their diet plan to eating healthy. Although these participants were not malnourish, some of these findings were similar to the causes of malnutrition as discussed in Section 2.4.2 in above. The next section will discuss dehydration, also a significant health issue for this age group in the UK (NHS, 2015).

2.4 Older adults and dehydration

2.4.1 Definition of dehydration

From the literature, there are numerous definitions of dehydration available. For this programme of research the definition of dehydration by NHS will be used which define dehydration as *"a state in which a relative deficiency of fluid"* (NHS, 2015).

From the definition, it is understood that dehydration occurs as a result of when fluid output exceeds the fluid input. The causes of dehydration in older adults may include lack of knowledge of hydration, lack of pleasure to drink, physical changes, and lack of dependency or help to drink. Further details of these causes are described in Section 2.5.2 below. Beforehand, I will explain the importance of dehydration in older adults in the UK.

2.4.2 The importance of dehydration

The NHS (2015) reports that although dehydration is a common health problem among the older adults in the UK, however the scale of dehydration is unknown. Nevertheless, numerous study has shown that the prevalence of dehydration increases with age (El-Sharkawy et al., 2016; Hooper et al., 2016). El-Sharkawy et al. (2016) analysed 42, 553 patients aged 65 years or more data from a teaching hospital in the UK. Each data represented the patient identification, demographics, diagnoses related to admission between 1 April 2011 and 31 October 2013, and the date of death whether the patient died in the hospital or in the community. 2, 932 of the patients were dehydration upon admission. Furthermore, the authors found that the prevalence of dehydration increases with age. They found patients with dehydration had higher mean age, 81.4 years vs. 78.6 years than those who were not dehydrated.

A four year survey by Public Health England and the Food Standards Agency found that the average daily non-alcoholic liquid intake of people aged 65 and above in the UK was only 1.2 liters for men and 1.3 liters for women (Bates et al., 2014). This is well below recommendations provided by the British Nutrition Foundation (BNF) that men drink 2 liters of non-alcoholic liquids per day, and that women drink 1.6 liters (BNF, 2017). The mentioned average daily non-alcoholic liquid intake shows that drinking might be a complex behavior that involves physical and psychological factors. Thus, making dehydration can be a serious health problem, especially for older adults. It is worth for me to understand what causes older adults to lack drinking liquids. The next section reports my findings.

2.4.3 Causes of dehydration

Water is essential for life. Most researchers who investigated hydration care and older adults conducted their study in care homes and hospitals. Literature has shown that aging influences fluid intake. Below reports the common causes of dehydration in older adults.

Lack of knowledge of the importance of hydration

Godfrey et al. (2012) aimed to explore the hydration care of older adults in a hospital and care home in South West England using a multi-method design. They conducted interview sessions with 11 older adults aged 68 to 96 years, focus group discussions with 9 nursing staffs, and six 2-hours observation of hydration practice of 13 older adults. The observations included lunchtime, afternoon tea and evening meal. The analysis shows that older adults have limited knowledge on proper hydration care. Although water was freely available, some older adults did not like the taste of water. Some older adults viewed drinking water as a burden, that it has to be done, rather than drinking because they enjoy drinking. A number of older adults would prefer to only drink hot fluids. Thus, if the fluid is serve warm, they tend not to drink it. Some of these older adults also were less aware that certain food like soups is also sources of fluid.

Lack of thirst and physical changes

As we age, the physiological changes influence our fluid intake. In Godfrey et al. (2012) study, some older adults avoided drinking due to not feeling thirsty which is a natural process of aging (El-Sharkawy et al., 2016). Amabebe et al. (2013) investigated the changes in thirst perception in 10 younger (aged 22 years) and 10 older women (aged 52 years) after moderate exercise. The moderate exercise was a 15 minutes walk on a treadmill at a speed of 4.2km/h at 27 degrees Celsius. The thirst rating was self-reported based on a 10-item likert scale labeled “not thirsty” to “very thirsty”. After the exercise routine, the younger women reported their thirst rating at 6.5 (with 10 being very thirsty), whereas the older women only rated themselves at 3. The same results shown in Mack et al. (1994) where older men felt less thirstier than the younger men after performing exercise. These results show that the thirst sensation decreases with ageing and older people do not hydrate themselves as younger people following water deprivation.

Disease and disability

Older adults with diabetes, dementia and kidney problems are at most risk of dehydration (El-Sharkawy et al., 2016). The use of medicines, such as laxative and diuretics, which are common among older adults, can also exacerbate dehydration (Kenkmann et al., 2010).

Lack of dependency or help to drink

The size, weight and type of drinking vessel influences one to drink (Godfrey et al., 2012). Many older adults in Godfrey et al. (2012) study reported their frailty affected their ability to drink independently. These older adults needed someone to assists them to drink. The thought of burdening someone be it to drink or to use the toilet, hinders the older adults to ask for help. Some of these older adults have dry lips and sunken eyes reported always feel sleepy and tired, which are the signs of dehydration.

This section has described the common causes of dehydration among older adults in developed countries. The causes can be related to other factors. It is necessary to understand the consequences of dehydration on the individual and its impact on their life. The next section describes the consequences of being dehydrated among the older adults.

2.4.4 Consequences of dehydration

In the UK, according to the NHS, dehydration is often associated with other health problem such as malnutrition (NHS, 2015).

Lose self-independency

Dehydration caused one to loose self-independent (Bunn et al., 2015; Campbell, 2016; Marshall et al., 2016). These studies, which are often conducted in, care homes or hospitals shows that dehydrated people often rely on others to assists them in their daily activity such as eating, drinking and toilet visits.

Poor mental performance

Masento et al. (2014) did a review paper on 26 studies on the effects of hydration status and cognitive status. They found that severe dehydration cause cognitive deficits. Dehydrated people often having short-term memory and lacking the ability to focus in one situation. In a review paper by Frangeskou et al. (2015) found that older adults do not drink enough due to they do not re

Prolong hospital admission

El-Sharkawy et al. (2016) found that dehydrated older adults stayed in the hospital 4 to 9 days longer than non-dehydrated older adults. Dehydration, which is often associated with other health problems (Marshall et al., 2016), also shows that dehydrated older adults often requires higher healthcare cost than the non-dehydrated older adults Frangeskou et al. (2015).

Low quality of life

Dehydrated is often associated with having a low quality of life. Lack of proper hydration can cause older adults feel fatigue, physical weaknesses, and dizziness (Godfrey et al., 2012). Masento et al. (2014) as reported above also found that dehydration negatively affects the mood. Masento et al. (2014) also reviewed studies were participants reported feeling calm and less confused when giving water after a period of time without drinking water.

Increase morbidity and mortality

Frangeskou et al. (2015) reviewed 15 studies on dehydration and older adults. They found that dehydration are associated with a higher rate of health diseases such as falls, fractures, heart disease, confusion, heat stress, constipation, and kidney failure. In El-Sharkawy et al. (2016), study described in above, found that older adults who were dehydrated had a 44% chance of dying within a year as compared to just 25% of older adults who were not dehydrated. In addition, El-Sharkawy et al. (2016) found that older adults who were admitted due to dehydration were twice more likely to die in hospital than the one admitted due to other disease.

This section describes the consequences of dehydration among the older adults in developed countries. The impact of dehydration can be related to one another, for example longer hospital admissions can increase the cost and furthermore can decline the quality of life of an individual. The next section will review the literature on technologies, in particular literature related to older adults.

2.5 Older adults and technologies

Technology is changing at a very fast pace. Currently, commercial developers have shifted from the web-based application towards mobile technologies. Mobile technologies such as smartphones and tablet computers are small, portable, and easy to carry compared to other technologies such as laptops or personal computers. Furthermore, mobile technologies may be used as *persuasive technologies* that serve people of all ages in many ways though mobile applications (apps). Fogg (2002) defined persuasive technology as technology can change a person's attitude or behaviour. Fogg (2002) noted that for a persuasive technology to be successful, the changes of attitude and behaviour among the users should be voluntary. Klasnja and Pratt (2014) reported that mobile apps might be used as a tool to support the users' health by involving the user. They also noted that mobile apps could increase users' self-management capabilities, as mobile apps can track health-related behaviours and provide feedback on those behaviours. Research focusing on older adults and health has shown that mobile apps can potentially change their attitudes and behaviour to improve their health status, (see Section 2.8.3 – 2.8.4 for further discussion).

2.5.1 Usage of mobile technologies by older adults in the UK

Use of mobile technologies by older adults is growing rapidly in the UK. In 2015, 83% of adults aged 65 to 74 years and 50% of adults aged 75 years or more use mobile phones of some kind. In addition, the use of tablet computers among older adults aged 65 to 74 years has increased to 26%, compared to just 5% in 2012 (Ofcom, 2016). For adults aged 75 years or more, the use of tablet computers has increased to 14%, compared to just 1% in 2012. These increases in the use of mobile technologies show that older adults in the UK are not alienate towards these technologies. However, rather than just giving the statistics, it is also important to understand older adults' attitudes towards mobile technologies. The next section will discuss research that investigated these topic.

2.5.2 Older adults' perceptions, attitudes, and knowledge of technologies

Studies on older adults perceptions, attitudes, and knowledge of technologies have revealed a number of interesting themes: 1) feel comfortable and in control to use technology, 2) interested to use technology in the future, 3) Concerns about the ease of use of technology, 4) concerns about their privacy and security when using technology, 5) lack of knowledge and low self-esteem, 6) various learning attitudes to using technology, and 7) positive engagement in participatory design studies. The sections below will present the findings in relation to each of these themes.

2.5.2.1 Feel comfortable and in control to use technology

Piper et al. (2010) conducted a study with 20 older adults (aged 60 to 88 years, mean age 73 years). Ten of the participants had arthritis, one participant had severe hand tremor and 18 participants had corrected vision. All participants had computer experience but none had experience with touch-based systems. Their aim was to investigate the attitudes and the ability of older adults in relation to touch-based system. Participants were given a set of tasks that include selecting, resizing, rotating, and entering text. The results showed that a majority of the older adults (89%) did not have problems completing the tasks. Interestingly, three participants (aged 60, 75 and 77 years) rated themselves as monthly computer user, yearly computer user and non-computer user had no errors to complete the tasks. One participant (age 64 years) commented *"I would say extremely easy. It's like finger painting" p.913* about learning touch gestures. To assess their attitudes to the touch-based technology, a short questionnaire was given to participants. The findings showed that the older adults enjoy, feel comfortable, and feel in control of this technology. The older adults also reported that touch-based systems are less intimidating and less frustrating than a traditional computer.

Jayroe and Wolfram (2012) did a study with 10 older adults (aged 67 to 87 years). Participants had basic computer skills and used the Internet on a weekly basis. Several participants had hand tremor. Their aim of the study was to investigate the attitudes of the older adults towards searching the World Wide Web using an iPad tablet computer. Participants had four Web searching tasks to complete. The authors noted that due to hand tremor, most of the participants struggled to use the features of the iPad, such as the lack of a tactile keyboard and the sensitivity of the screen. However, by familiarising themselves with the built-in keyboard and the screen, all participants managed to complete all of the tasks. Participants were interviewed to investigate their experience with using the iPad. Participants acknowledged the advantages of the iPad because of its portability, efficiency and ease of use in comparison to a personal computer. The older adults agreed that they struggled to use the iPad, but they noted that this could be overcome with experience.

Hardill and Olphert (2012) interviewed 12 older adults (3 men, 9 women, no age range given) from the East Midlands in the UK. These participants were a sub-set of a larger scale survey of 308 participants (age between 48 years – 90 years, mean age = 70 years) on investigating the older adults mobile devices usage. Majority of the participants were from the Over 50s Forum, a local community group. The participants were predominantly female and from high socio-economic groups. A majority of the participants were retirees but remained active in part-time voluntary work. The findings show that there is an increasing number of older adults who like to explore the functionality of mobile devices. The findings were classificed into three types of mobile device users: pervasive, episodic, and fossilised. They found that the older adults in their 60s are typically pervasive users. This type of users is likely to be confident with mobile devices. They explore mobile device functionality and are up-to-date with the technology, for example of wanting to use the latest smartphones. One participant noted that her mobile device *"is part of me (it is) always in my pocket" p.1309*. The remaining two types of mobile device users: the episodic and fossilized are described in Section 2.8.2.5, below.

2.5.2.2 Interested to use technology in the future

Demiris et al. (2004) presented the topic of smart home technologies to three focus groups involving a total of 15 adults aged more than 65 years. The great majority of the participants (97%) were computer users. Little explanation was provided about the other characteristics of the participants. The aim of their study was to explore the perceptions and expectations of adapting smart home technologies such as mobile apps, web-apps, and sensors to improve older adults' quality of life and to monitor their health status. The participants were positively interested in the idea of smart homes.

Mitzner et al. (2010) conducted 18 focus groups with 113 older adults (aged 65 to 85 years). The majority of the participants lived independently and were healthy. The aim of the study was to investigate the older adults' attitudes towards technology. The authors defined technology as any "electronic or digital products". The results showed that older adults are interested in technology if it supports them in their daily life, is convenience, and contains useful features. The results also showed that participants are less interested in technologies if they fail to provide lack of security, reliability and ease of use. Overall, the participants in this study noted that they prefer technologies that can make them more efficient and dislike technologies that reduced their efficiency.

Fan et al. (2012) conducted a study on older people's attitudes toward mobile apps to encourage them to be physically active. They used think-aloud sessions with 11 physically active and inactive adults aged between 64 and 94 years. Little explanation about the ratio of active and inactive adults was given. They developed eight low-fidelity prototypes, such as an app that keeps track of the number of steps walked and an app that can display the route while walking. Some participants liked to use the proposed apps. One participant (age 63 years) noted *"if [older adults] were more aware, they'd probably use it more. I think the biggest problem is letting people know the potential and what the technology can do for them so it is worth the effort to learn it, and it isn't so complicated sometimes" p.38*. This view was supported by another participant (age 67 years) who noted that for them to accept technology, it should be implemented in such way that it is easy, simple, or integrated into an existing device so that they will not be afraid of using such technology. The authors concluded that the attitudes of older adults towards mobile app interventions are positive for those who are currently inactive, but are motivated to change.

2.5.2.3 Concerns about the ease of use of technology

Sensory and physical abilities play an important role to using mobile devices. Some participants in Demiris et al. (2004) study, study described in previous section, were concerned about the ease of use of the smart home technologies. Participants raised the issues of how functional limitation that older adults have, (e.g. such as vision loss, hearing impairment, memory loss) can hinder their acceptance of technology. The participants in this study noted that often the technologies that are available do not take these functional limitations into consideration, thus making the technology difficult for them to use.

In Fan et al. (2012) study as described in the previous section also found that older adults are concern about the ease of use of the proposed apps. One of the apps requires users to carry a tablet computer while walking. With the tablet computer, users can point at buildings and learn about the history about the buildings through audio clips. User can also take notes about the buildings and share it in a social site. The older adults were concern about to carry the tablet around because of its weight and the possibility that people can steal it.

The participants in Malik and Azuddin (2013) study with arthritis, large finger size and poor eyesight noted that these aspects hinder their likelihood towards using mobile devices. These participants noted that mobile devices often have small icons which make it hard for them to use the device. Participants also highlighted the difficulty of using some functions such as speed dialing. One participant found that situations in which a keypad can do two functions, for example changing from alphabet to numbers, are annoying and a waste of time. Overall, the participants in this study preferred a mobile device that is less complicated and easy to use.

The ease of use factor of using mobile technologies is also well reported the other studies for example by (Hill et al., 2015; Mallenius et al., 2007; Parker et al., 2013).

2.5.2.4 Concerns about their privacy and security when using technology

Some older adults in Fan et al. (2012) study are also concern about their privacy and security to use the apps in the future. For example, one of the proposed apps allows finding walking friends around the neighbourhood. Users are required to enter their preference time and street location to meet up before the walking session. The older adults are concern about entering their details and meeting someone they do not know. The users also negatively accepted the idea of another proposed app showing the current location of the user when walking. Studies by (Carpenter & Buday, 2007; Lian & Yen, 2014; Trocchia & Janda, 2000) also reported that older adults in their studies also raised concerns in terms of privacy and security whilst using technology especially the Internet.

2.5.2.5 Lack of knowledge and low self-esteem

Kurniawan (2008) used a multi-method approach including interviews, focus groups and an online survey to investigate the use of mobile devices among older adults (aged 60 to 80 years) in the UK. The majority of participants were from middle to upper social classes and were well educated. All participants for the focus groups and online survey were mobile device users. The findings show that the participants lack of knowledge and low self-esteem to using mobile devices. The participants were found to be passive users of mobile devices. Kurniawan (2008) defined passive users as someone who is not actively engaging themselves in the use of mobile devices. In addition, the older adults in this study were more likely to use mobile devices in emergency cases than for casual conversations and experienced a fear of consequences of using unfamiliar features of the mobile devices, for example video calling. The older adults in this study were also concerned about the addictive nature of using mobile devices and the effect on losing face-to-face interaction.

Bhachu et al. (2008) presented older adults (aged 60 to 80 years) in Scotland with five mobile devices: a smartphone, a tablet device, a PDA, an iPod Touch and a digital photo frame. Participants explored the devices and discussed their thoughts afterwards. Participants included professionals and also people who had never worked. Some participants had hand tremors and poor eyesight. The authors did not specify the total number of participants or the gender composition. Bhachu et al. (2008) found that the participants often thought that mobile technology was not suitable for them. Participants commented about how their lifestyle was affected by the time period in which they grew up, and how they struggle to adapt to concepts of new technologies. Some participants experienced fear in using the devices. Although some participants owned smartphones, they often used them just to call and send text messages. One participant commented, "*It's just a phone. It's not to take photos or anything"* p.63. This finding is similar to that by Kurniawan (2008), as discussed above. The authors also found that some of the participants, who were experienced in using mobile devices, explored the devices extensively. One participant suggested making the icons bigger for others with vision problems to be able to see them clearly. Overall, the authors noted that this group of older adults preferred a mobile device that is easy to carry, portable and provides them just enough functionality, for example the iPod Touch.

In Hardill and Olphert (2012) study, as described in Section 2.8.2.1, found that older adults in their 80s are typically episodic users. They found that older adults at this age hardly use mobile devices other than for making voice calls. They found that most of these older adults see a mobile device as the complement to a landline. For example, to make phone calls, the episodic adults dialed the phone numbers rather than using the contact book. However, the older adults in this group are still interested in learning how to use a mobile device, especially to connect with family members. The authors defined older adults in their 90s as fossilised users. This type of users is likely to use a landline phone in comparison to using a mobile device. The authors reported that this group prefers to use mobile devices for emergency cases only.

2.5.2.6 Various learning attitudes to using technology

Older adults learning attitudes on how to use technology have been repeatedly reported in the literature (Barnard et al., 2013; Kurniawan, 2006; Leung et al., 2012). Researchers have investigated the learning attitudes or by allowing the older adults to practically experience the technology on their own, and then report the findings based on their observations, interviews, or surveys. The analysis of the literature identified three main learning attitudes, which are relying on others, trial and error and reading instructions. The section below describes the finding.

Kurniawan (2006) conducted a field study with seven older women aged more than 60 years. Six of the participants had several years' experience of using mobile devices. Only one participant had only one year of experience. The characteristics of the participants were quite homogenous. All of the participants were highly educated women, middle to upper class and generally able-bodied. The aim of this study was to investigate the style of learning to use a mobile device. The participants received a mobile device, an LG C3300, and a list of tasks to complete. The tasks included making and receiving phone calls; taking, sending and deleting photos; sending and receiving text messages; setting an alarm and changing the date and time. The findings showed that the older adults preferred to explore the mobile apps via trial-and-error compared to referring to the LG C3300 manual. Kurniawan noted that the manual was used only if the trial-and-error exploration failed.

However, a study by Leung et al. (2012) found different results on attitudes to learning technology. Leung et al. (2012) worked with six older adults aged between 57 to 76 years. Only one participant (aged 66 years) used a smartphone. The others used a basic mobile phone. The participants did not have any abnormal declines in cognitive or physical abilities. To assess their attitudes to learning, each participant was given a HTC Google Nexus One smartphone and a list of tasks to complete. The tasks were create new contact; mark a contact as favorite; edit details of a contact; set a ring tone for a contact; answering and rejecting calls; change call volume; and lock the home screen. In general, the authors found that all except one participant (who was aged 66 years) preferred learning alone rather than with a companion. The authors also found that the three younger participants (aged 57, 60 and 66 years) preferred trial-and-error learning compared to referring to the smartphone manual. While the three older participants (aged 67, 69 and 76 years) preferred referring to the manual rather than exploring via trial-and-error. One of the participant, age 67 years, noted that if she did not refer to the manual, she feared damaging the smartphone or incurring extra charges on the service plan. Some participants also highlighted that it is hard to replicate trial-and-error behaviour because of their inability to remember the steps taken.

Older adults in Fan et al. (2012) study, described in Section 2.5.2.2, were concern about the number of features per each proposed apps. Some of these older adults prefer having an instructor to teach them to using the apps.

In Barnard et al. (2013) study, they conducted an interview study with 13 older adults to investigate their learning preferences on using a tablet computer. The authors identified three main preferences, which are relying on others, trial and error and reading instructions. In terms of relying on others, the older adults in this study felt more comfortable to use the new technology or device when someone is there to assist or instruct them on how to use the new technology or device.

Malik and Azuddin (2013) conducted 10 focus groups with 40 older adults aged between 60 to 78 years. All participants were mobile phones users. A majority of the participants had arthritis and poor eyesight. The aim of their study was to investigate the attitudes of older adults towards mobile devices. In terms of exploring new mobile devices, the participants did not like learning using the manual for the mobile device. Participants noted that manuals are very complicated and include jargon terms that are hard for them to understand.

2.5.2.7 Positive engagement in participatory design studies

As far as HCI is concerned, it is well known that user-centred design lifecycles greatly helps to overcome the ease of use of the system by involving the users engaging in all stages of the design process. Charness and Boot (2009) noted that one reason that might prevent older adults from accepting particular technologies is because the technology is poorly designed in relation to their particular needs. Charness and Boot (2009) recommended designing technologies to suit the particular needs of older adults, particularly in relation to sensory and physical abilities. Studies by Hakobyan et al. (2013), Abdul Razak et al. (2013) and Pedell et al. (2013a) have shown that older adults attitudes' towards mobile technologies can changed by involving them early in the design lifecycle. The iterative user-centred design lifecycle in developing the mobile apps towards the older adults expectations, changes their attitudes at the end of the study compared to the first design the authors developed for the older adults.

Abdul Razak et al. (2013) developed a calendar reminder app to allow the users to create events. The design lifecycle involved three usability studies with 14 older adults. The first study was with six older adults (3 men, 3 women, aged 55 to 60 years). Half of the participants were working, two were retirees and one was a housewife. All of the participants were mobile phone users with more than five years experiences. The participants were given two tasks: to create and delete an event. The authors observed the participants while they perform the tasks. After the task completed, the authors interviewed the participants to evaluate the usability of the app. The analysis of the interview reveal that the participants wanted a simpler app with less buttons, no scrolling features, and bigger button and font size. The author re-developed the app and conducted the second usability study with a different eight participants. Little information was given about these participants except that they have similar age and background as the participants in the first study. To evaluate the usability, participants were asked to rate the ease of use of user satisfaction of the app using a rating scale and an open-ended question was given to allow the participants to further comment about the app. Participants rated the ease of use positively but they were not satisfied with the design. The analysis of the open ended question real that the participants wanted a bigger button, simple words, different background colours and all buttons should be placed at the bottom of the screen similar to the nature of reading, from top to bottom. The author re-developed the app and conducted the third usability study with the similar eight participants from study two. To evaluate the usability, participants answered the same questions as in the study two. At this stage, participants rated the interface easier to use and were more satisfied. The older adults' attitudes changed to liking to use the app when their ideas to have a simple design, appropriate functionalities were taken into consideration into the final app.

In Pedell et al. (2013a) study, the authors engaged with older adults to design and evaluate three touch-based games for an iPad. It took the authors 10 weeks with 10 visits with 32 older adults (aged more than 65 years) to explore their needs and to develop the three games. Some of the participants had vision and hearing problems. Most of the participants had no or little computer or mobile phone experience. None of them had any experience with an iPad. The authors focused on creating simple games involving reminiscing about the early lives of the older adults. To attract the older adults to engage with the games, the authors used photos of celebrities who were famous during the times when the older adults grew up. All games were created according the participants design ideas and interest. The result shows that the older adults enjoyed playing the games and got very engaged and competitive in playing the game. The older adults commented that the game was very easy to use and they liked the feeling of having control of the iPad while playing the game. The authors concluded that involving the older adults in the design of the games contributes to the positive feedback from the participants.

Hakobyan et al. (2013) conducted a participatory design study with four older women (aged from mid-60s and above) in eight design sessions. The aim of the study was to design a self-monitoring app for people with age-related macular degeneration (AMD) to support their diet. All four had AMD. Two participants had experience with computers, but the other two had no experience. The app was designed using a low-fidelity prototype. Participants commented and contributed ideas on how to improve the prototype. Changes to the design were updated for each session for another round of evaluation. All participants commented that they felt delighted and satisfied by taking part of the design of the app. They also felt pleased and proud when their suggestions were considered in the final version of the app. Hakobyan et al. (2013) validated the prototype with six other older adults (ages not given). Three of the participants liked the idea of the app and say they would use the app to support them to monitor their diet. The remaining three participants felt reluctant to accept the idea of using the app to monitor their diet, as they do not think that any changes to their diet would improve their eyesight. The participants in the design stage also highlighted this issue, but were keen to identify means that could help future generations to avoid the vision loss they encountered.

This section has described numerous studies about older adults' perceptions, attitudes, and knowledge of technologies. From the research that I have read, there is a huge variation of the number of participants in studies, from 6 to 100 over participants, and with an age range from 48 years to 93 years. There is also a wide range of the characteristics of older adults, ranging from able-bodied to older adults with disabilities such as tremors, arthritis, and partial vision loss. Some studies also focus solely on one gender, for example having all female as the participants; yet others did not report their gender composition. Some studies recruited participants from different career backgrounds, from professionals to non-workers. The findings from the research show that older adults have both positive and negative attitudes towards mobile technologies. One factor that hinders the acceptance of technology by older adults is that their attitudes may be influenced by how they grew up (Bhachu et al. (2008). Victor et al. (2007) noted that age and cohort effects are two important factors that need to be considered in understanding older adults. Aging, as noted in Section 2.2 is more than chronological age. Cohort effect is the influence of the time a particular group of people was born and the experiences they had through their lives. For example, the so-called *baby boomers*, those born between 1945 and 1965, with the youngest being 52 years and the oldest 72 years old as of 2017 (Leach et al., 2008), and *Generation Y*, those born between early 1982 and early 2002, with the youngest being 15 years and the oldest 35 years old as of 2017 (Leask et al., 2013), are two different cohorts of the population. They have each experienced different lifestyles, experiences and surroundings as they grew up.

2.5.3 Research on mobile apps for older adults

Thirteen studies engaging older adults with mobile apps were analysed, as shown in Table 2.7. I analysed these studies based on three main criteria: 1) participants, 2) the design of the app and 3) study design and results. In related to participants, I analysed the age group, mean age, number of participants, the gender balance, and the characteristics of the participants. I then analyse the design of the app. In related to study design, I analysed the method, study duration and procedure of the study. Lastly, I analysed the efficacy of the app interventions used in these studies.

Table 2.7: The studies for research on mobile apps for older adults

Author (year)	**Participants**	**App description**
Self-monitoring dietary intake		
Atienza et al. (2008)	Age (a): > 50y; mean 63.2y Total (t): 20; 14w / 6m Characteristics (c): All participants were healthy, although little explanation was given on the definition of 'healthy'; mean BMI 26.5	app consisted of 43 questions questions include the servings, types of food, time and location of meal app provided feedback for improving dietary intake
Fukuo et al. (2009)	a: 20 to 65y; mean 52.8y t: 16; 3w / 13m c: all were overweight and diabetic; mean BMI 25.5; no severe visual problems, chronic disease or psychiatric problems; 15 participants were mobile phone users and 6 were PDA users	app consisted 423 photographs of food and drinks participants selected a photo to update intake no information whether the app provided any feedback about the data participants had updated
Spring et al. (2013)	a: 28 to 86y; mean 57.7y t: 69; 10w / 59m c: overweight and obese; no psychiatric hospitalisation, substance abuse, eating disorder or severe mood disorder; 9 participants had computer experience;	app designed as a decision support tool to self-monitor food intake and to measure physical activities calorie and physical goals were tailored for each participant depending on baseline weight physical activity goals increased gradually until the criterion of an equivalent of 60 minutes per day of activity was reached
Hakobyan et al. (2016)	a: 65-89y, mean 77y t: 9; 6w / 3m c: all participants had previously been involved in the design and pilot study of the app; all participants had been diagnosed with AMD between 2 -10 years; five participants had computer experiences	app included the ability to record dietary intake, to monitor progress and to view recommendation meals to update intake: select the food from a list of options, enter quantity, and select 'save'

Author (year)	Participants	App description
Engaging in physical activity		
Faridi et al. (2008)	a: > 18y; mean 56y t: 30; 19w / 11m c: mean BMI was 35.6	participants given pedometer and entered the number of steps taken to the app daily; and received tailored messages based on their uploaded data little information about these messages
Liu et al. (2008)	a: 40 – 80y; mean 72.1y t: 48; gender composition not given c: all chronic obstructive pulmonary disease patient; mean BMI of 23.2; participants were excluded if they experienced difficulty in operating mobile devices, had impaired hearing or vision, or had disease limiting exercise	app recorded how long the participants had walked participants turn on the app each time they went for a walk on completing the walk, participants would turn off the app the duration of the walk was then automatically sent to a website for the authors to monitor walking adherence
King et al. (2008)	a: > 50y; mean 60.8y t: 19; 8w / 11m c: all free from any medical condition and were interested in learning ways to increase physical activity (i.e. walking) by using a PDA app; 63.2% reported having excellent or very good health status; 93% were novice PDA users	participants given pedometer and entered the number of steps taken to the app daily participants set own daily and weekly physical activity goals the app consisted of 36 questions, including the type of physical activities undertaken, location, and duration of the activity the inputs were recorded twice a day, at 2pm and 9pm; app alerted the participants if they did not answer the questions at this time app provide daily and weekly cumulative feedback on the reported physical activity
Fan et al. (2012)	a: 58 – 71y; no mean age t: 3; 1w / 2m c: all participants were physically active and reported doing exercise for	the app used Fitbit's API to track the number of steps the app provided daily feedback by using abstract visualisations of the number of steps

	at least 30 minutes a day; two participants were married couple	the abstract animates using different colours and shapes; more colour and different shapes displayed on the tablet screen means the more steps taken for the day
Games		
Grimes et al. (2010)	a: > 18y; no mean age; 2 aged more than 55 t: 12; 10w / 2m c: All participants were mobile phone users;	restaurant based game app participants served healthy food to ten customers; the healthier the food they served, the more points and time they were given to play the game a traffic light metaphor was used as feedback about the served food
Chang et al. (2013)	a: 63 – 85y; mean 74.4y t: 10; 4w / 6m c: four participants had computer experience; one had tablet computer experience; four participants had some hearing problems; one participant had cataract	a 30-level buying and selling game app the app was designed to be simple as the it should be easy of use, not confusing and not require too many inputs, as older adults are known to have declined physical capabilities the app was designed to be meaningful, in the sense that it helped the older adults to maintain or improve their cognitive and memory abilities
Self-monitoring wellness		
Doyle et al. (2014)	a: 65 – 77y; mean 70.6y t: 7; 2w / 5m c: four participants own iPad; three participants reported self-monitoring their health status manually using paper-based recording; no participants reported using a technology-based self-monitoring system	web-app focused on three wellbeing areas: mood, sleep and social interactions participants answered 8 to 10 questions a day regarding their wellbeing; in return, they received three feedbacks daily first feedback was in form of an illustration, using the traffic light metaphor to demonstrate the status of the wellbeing; second feedback was in the form of a graph that display the daily self-reported data; third feedback was in the form of tips which advice on how to improve wellbeing

Author (year)	Participants	App description
Improve cognitive performance		
Chan et al. (2016)	a: 60 – 90y; mean 74.9y t: 18; 13w / 5m c: all participants had limited experience with computers and no experience with tablet computers; participants had no severe eyesight problems and no history of psychiatric disorders	iPad installed with existing apps e.g. Twitter and Words with Friends
Vaportzis et al. (2016)	a: 65 – 76y; mean 68.4y t: 22; 15w / 7m c: all participants were free from neurological and psychiatric conditions	iPad Mini 2 installed with existing apps e.g. YouTube

The primary aim of engaging older adults with technology is to improve their daily lives. Most research done on mobile apps and older adults has focused on older adults with health problems. This could be in terms of being overweight or obese, having chronic diseases, being diabetic, or having early-stage dementia. Most studies which focus on being overweight or obese aim to reduce their participants weight either by self-monitoring their diet or by engaging physical activities. Most studies on chronic diseases aim to remind the participants to consume medicine or by having reminders or by playing mobile games. Most studies on early-stage dementia aim to delay the decline of cognitive abilities by introducing game apps to the older adults. There are also some studies which aim to provide education or to improve social connections with family and friends. The analysis below describes a range of studies using mobile apps to support older adults.

Participants

The total number of participants ranging from three (Fan et al., 2012) to 69 (Spring et al., 2013) participants. Six other studies recruited between 10 to 20 participants, three recruited 20 to 48 participants and the remaining two studies recruited than 10 participants. The mean was 22 participants per study. All of the studies recruited both genders, however none had a balanced number of participants per gender per study. Seven of the studies had

50% more participants than the other gender. For example, Fukuo et al. (2009) had three women and 13 men in their study. However, Grimes et al. (2010) had two men and 10 women. Another imbalance gender representative is by Spring et al. (2013), where they had 10 women and 59 men.

Age

Section 2.2 of this thesis had discussed the factors to define the minimum age to define an older adult. A number of factors were discussed to define an older adult such using as the retirement age or the older adults' computer experiences or expertise which can be influenced by their psychological age. See Section 2.2 for further reading. Nevertheless, in this current review, eight studies recruited participants with the minimum age of 50 years. Of these, five studies recruited participants with the minimum age of 60 years. Of these, three studies recruited participants with a minimum age of 65 (Doyle et al., 2014; Hakobyan et al., 2016; Vaportzis et al., 2016). The remaining five studies recruited participants with the minimum age lesser than 50 years. However, participants in these studies had the mean age of more than 50 years except for Grimes et al. (2010), which did not provide the mean age of the participants.

In related to mean age, the lowest was of 52.8 years (Fukuo et al., 2009) and the highest of 77 years (Hakobyan et al., 2016). In overall, three studies had the mean age of 50 to 60 years; three had the mean age of 61 – 70 years; and five had a mean age over 70 years. Apart from Grimes et al. (2010), Fan et al. (2012) also did not provide the mean age of their participants.

Characteristics

Older adults are known to having different characteristics, as explained in section 2.2.2 of this thesis. In this current review, majority of the studies excluded participants with no severe visual problems or had impaired hearing. Five studies which aim to promote self-monitoring either for dietary intake or engaging in physical activities included older adults who are overweight and obese (Faridi et al., 2008; Spring et al., 2013), diabetic (Fukuo et al., 2009), had been diagnose with AMD (Hakobyan et al., 2016) or chronic obstructive pulmonary disease (Liu et al., 2008). Nevertheless, three other studies that aim to promote self-monitoring either for dietary intake or engaging in physical activities do not recruit participants with a specific characteristic or medical condition. For example, King et al.

(2008) and Fan et al. (2012) aimed to evaluate the efficacy of using an app for increasing physical activities by walking recruited participants who were free from any medical condition were physically active. Two studies to investigate the use of iPad to increase participants' cognitive abilities also recruited participants with no history of psychiatric disorders (Chan et al., 2016; Vaportzis et al., 2016).

Two studies did not specify the characteristic or medical condition of their participants. These studies included Grimes et al. (2010) which aimed to influence participants to eat more healthy using a restaurant based game app and Doyle et al. (2014) which aimed to support participants in self-reporting their wellbeing using an iPad.

Technologies experiences

Only three studies did not specify the technologies experiences of their participants (Atienza et al., 2008; Fan et al., 2012; Faridi et al., 2008). The remaining studies had participants with either computer or mobile technologies experiences.

Study duration

The study duration varied across all studies. The shortest duration was 1 week (Chang et al., 2013; Fukuo et al., 2009), whilst the longest was 1 year (Liu et al., 2008; Spring et al., 2013). The remaining studies were conducted for three weeks, eight weeks, 3 months (two studies each) and six weeks, 10 weeks, and 5 months (1 study each).

Operating system

Only two studies used apps, such as YouTube and Twitter, available on iTunes App Store (Chan et al., 2016; Vaportzis et al., 2016). These studies aimed to investigate the efficacy of an iPad training intervention to increase participants' cognitive abilities.

The remaining eleven studies developed an app for in their studies. Analyzing the literature, there is a pattern of the operating system used to develop the app. The early studies in this review, the ones conducted from year 2008 onwards, developed apps for PDAs or any other cell phones (King et al., 2008; Liu et al., 2008). The later studies, from year 2012 onwards, begin developing apps on Androids and iOS (Fan et al., 2012; Hakobyan et al., 2016). The study by Chang et al. (2013) did not specify the operating system used, but rather noting a general statement that they developed a tablet game. The study by Doyle et al. (2014) developed a web-based app.

App description

Four researchers have put their effort in engaging the older adults to self-monitor their diet. Self-monitoring one's diet can be understood as the means by which a person makes an effort to alter aspects of their food intake to improve their body condition. However, in relation to improving dietary intake among older adults, most researchers have focused on obese or overweight older adults rather than malnourished older adults. All studies reported allowing users to enter their intake via a questionnaire of 43 questions (Atienza et al., 2008), list of 423 photographs of food and drinks (Fukuo et al., 2009), entering their own food intake to the app (Spring et al., 2013) and selecting the food from a list of options (Hakobyan et al., 2016). All studies except Fukuo et al. (2009) provided the ability to view the progress as a form of feedback about the data participants had updated.

Four researchers have also focused on engaging older adults to be physical active by walking. Faridi et al. (2008) and King et al. (2008) measured the number of steps via pedometer whereas Fan et al. (2012) uses FitBit API. Liu et al. (2008) measured the duration of being active via a music app. In Faridi et al. (2008) and King et al. (2008) participants entered the number of steps manually into the app. In Fan et al. (2012), the number of steps were downloaded via the FitBit's API to the app.

All studies except Liu et al. (2008) provided the ability to view the progress as a form of feedback about the data participants had updated. In Liu et al. (2008), each participant was given a Sony Ericsson K600i installed with a music app. The app was designed to record how long the participants had walked. Participants were required to turn on the app each time they went for a walk. On completing the walk, participants would turn off the app. The duration of the walk was then automatically sent to a website for the authors to monitor walking adherence. In Fan et al. (2012), the app provided daily feedback by using abstract visualisations of the number of steps. The abstract animates over the course of the day using different colours and shapes. The more colour and different shapes displayed on the tablet screen means the more steps taken for the day. The lesser colour and shapes represent lesser steps taken for the day.

Games and older adults are becoming an increasing important research topic. Two game apps were reviewed. One study used game to influence older adults' dietary intake (Grimes et al., 2010). The other study was on games for older adults to maintain or improve their cognitive abilities and to improve social connectivity (Chang et al., 2013). In Grimes et al. (2010), to play the app, participants served healthy food to ten customers. For each customer, there were three food options. The healthier the food they served, the more points and time they were given to play the game. A traffic light metaphor was used as feedback about the served food. A green light showed if the participant selected the healthiest food, yellow for something in between healthy and unhealthy and red for the unhealthiest food. In Chang et al. (2013), the authors developed a simple, relevant and meaningful 30-level buying and selling game app. They designed the app to be simple as it should be easy of use, not confusing and not require too many inputs, as older adults are known to have declined physical capabilities. Participants played all 30 levels each day of the study.

In Doyle et al. (2014), the aim of the study was to support older adults in self-reporting their wellbeing using an iPad. The authors developed an app focusing on three wellbeing areas: mood, sleep and social interactions. Participants answered 8 to 10 questions a day regarding their wellbeing. In return, they received feedbacks three times daily. The first feedback was in form of an illustration, using the traffic light metaphor to demonstrate the status of the wellbeing: green for having enough sleep, yellow to indicate medium, red for a bad mood. The other two feedbacks were in the form of a graph and tips. The graph displayed the daily self-reported data. The tips included advice on how to improve wellbeing. For example, if a participant scored red for sleep, they would get a tip how to improve their sleep by avoiding caffeine or alcohol 4 – 6 hours before bedtime.

Study design

All studies encouraged participants to use the app on their own throughout the duration of the studies. However, in five studies, participants also received reminders or were interviewed by the authors to assess their ongoing experiences with the app throughout the duration of the studies. These studies included to influence the participants to walk daily using a music app Liu et al. (2008), to self-monitor dietary intake by Spring et al. (2013) and Hakobyan et al. (2016), and also the two studies to improve participants cognitive performance (Chan et al., 2016; Vaportzis et al., 2016). The latter two studies provided 2-

2.5 hours weekly training sessions to the participants to investigate whether the use of iPad could increase participants' cognitive abilities. In addition, the participants were also encouraged to use the iPad outside the training sessions.

In the Liu et al. (2008) study to influence the participants to walk daily using a music app, the participants received telephone reinforcement everyday if they missed one day of walking for the first three months of the study. The next 9 months was self-management period. In Spring et al. (2013) study, to encourage participants to self-monitor dietary intake, all participants received 90 minutes face-to-face coaching (bi-weekly from Month 1 to 6; and monthly from Month 7 to 12). In addition, participants received an extra 15-minutes coaching phone calls (bi-weekly from Month 1 to 6). In Hakobyan et al. (2016) study, also to encourage participants to self-monitor dietary intake, participants were interviewed to assess their ongoing experiences with the app every 7-10 days.

Dropouts

Only four studies reported participant's dropouts. In Atienza et al. (2008) study, only eight participants (out of 20) completed the 8-weeks study. However, no further explanation of this high dropout rate or what might have contributed to the low adherence to the study. In Faridi et al. (2008), only two out of 15 participants used the app for at least 75% of the 3-months study duration. Five of the participants did not use the app at all; four used it for one week and four used it for 1 – 2 months. In Liu et al. (2008) 1-year study, only a little percentage of 8% of participants (n = 2) did not complete the study. In Doyle et al. (2014) 5-months study, one participant dropped out after two months, noting she did not like the system. Adherence to the app was the highest during the first month (79.2%), dropping to 63.1% in the second month. The authors noted that the adherence level remained low until the end of the study. However, they gave no further adherence values.

App acceptability and efficacy

Four studies reported positive results in self-monitoring dietary intake. Measurement was either from self-reporting on the apps or through questionnaires. In Atienza et al. (2008), although there were high dropouts, the authors found that using a PDA app did improve participants' dietary intake. At Week 1, participants' mean energy intake was 1813 ± 775 kcal, and at Week 8 it was 1679 ± 541 kcal. In Fukuo et al. (2009), there were no significant differences between the PDA app with food photography and 24-hour food recall. Therefore, the authors suggested that PDA app with food/drink photographs may be helpful in assessing the individuals' long-term dietary habits and could help clinicians to give nutritional guidance. In Spring et al. (2013), the participants lost a mean of 4.9 kg. The authors noted that the participants were motivated to self-monitor food intake. 80% of participants attended the coaching sessions throughout the study. The authors concluded that the use of a PDA app and coaching could contribute to weight loss among obese individuals.

In Hakobyan et al. (2016) study to evaluate the usability of a self-monitoring app to support diet for people with age-related macular degeneration, all participants maintained or increased their food entries. The interview sessions showed that all participants felt the app was easy to use, efficient and portable in comparison to a paper-based diary. The progress option helped the participants to raise their awareness to eat according to their diet. The app was also found to facilitate participants to self-monitor their diets, thus encouraging them to positively change their diet. In addition, the app was found to motivate learning, particularly in using technology. Participants commented about enrolling in computer classes, and making enquires at local libraries for courses on using technology. Overall, participants found the study enjoyable to be able to learn about healthy lifestyles and improving eating habits.

Four studies targeted performing exercise by walking as a primary measure (Fan et al., 2012; Faridi et al., 2008; King et al., 2008; Liu et al., 2008). All except Faridi et al. (2008) and Liu et al. (2008) reported increases. In Faridi et al. (2008), the authors noted that one reason there were no improvements in terms of physical activities might be because of the high dropouts.

In Liu et al. (2008), the walking duration increased from 1887 ± 221 sec in month 1 to 2083 ± 230 sec in Month 3. However, the walking distances for this group dropped from Month 3 (324.2m ± 22.5m) to Month 12 (306.7m ± 21.2m). The authors noted that the music app captured the duration of walking, but it was not clear whether the participants are walking whilst the music app is on. It was not clearly stated in the paper whether the mobile device had to be held or could be placed anywhere while the walking begin. This might be the reason why the results show that the walking duration increases (captured from the music app) but the walking endurance dropped.

In King et al. (2008), the participants performed more physical activity in Week 8 compared to at the beginning of the study. At the end of the study, the participants completed a questionnaire evaluating the acceptability and utility of the PDA using 6-point Likert items (1 – strongly disagree to 6 – strongly agree). The participants enjoyed using the app to improve their physical activities and rated the app as feeling comfortable responding to the questions (mean = 5.3, SD = 0.6), having a reasonable number of questions (4.2, SD = 1.3), and motivating to complete the questions (4.2, SD = 1.6). The authors concluded that the use of PDA app could promote exercising among the participants in this study.

Positive results were also found in Fan et al. (2012) study. The post-study interviews sessions found that all participants enjoyed using the app and noted that the app raise their awareness and motivated them to walk each day. The married couple competed with each other to perform more exercise. The other participant was motivated to walk to fill up the tablet screen with more colours and shapes every day and that the app made him aware of how much walking he did on a daily basis.

Two studies reported positive results in using mobile app games. Grimes et al. (2010) aimed to influence participants to eat more healthily using a restaurant-based game app. Eight participants reported that the app corrected their previous understanding of eating healthily. However, the traffic light metaphor was not enough for some of the participants to understand which food option was the healthiest. Related to participants' eating habits, most participants noted that the app made them re-consider what to eat and made them discuss the importance of nutrition with others, especially family members. The authors concluded that the app helped the participants in initial steps to increase wellness. Chang et al. (2013) aimed to investigate the usage of a tablet computers game app to help maintain or improve older adults' memory and calculating abilities. The average success rate in the game was low at the beginning of the study, but increased as the participants became familiar with the game interface, particularly from Day 3 onwards. Each participant's success rate became stable in the last four days. However, no figures or percentages were given to support these findings. The authors also found that participants' previous career also influenced their success rate in completing the game. One participant was a retired mathematics teacher. He completed all 30 levels with almost no calculation errors. The post-study survey showed that most participants enjoyed playing the game as it connected them with the past. Most of the participants also liked the app as it was easy to use, and its operation was simple. Overall, eight participants enjoyed using the game app, the remaining two participants preferred outdoor activities.

One study targeted self-monitoring wellness (Doyle et al., 2014). However, there was a low adherence towards the app until the end of the study. Post-study interviews showed that the participants found the app was useful to monitor their wellbeing. However, they did not find the app enjoyable or fun to use. There was no elaboration on this. Five of the participants did not understand the traffic light metaphor. Only three participants reported that they read and follow the tips. Some of the participants did not like the repeating daily questions and messages (n=5), and the lack of ability to change the answer when answering questions (n=2). However, in overall all participants noted that the app increased their awareness of their wellbeing.

Two studies to investigate whether the use of iPad could increase participants' cognitive abilities also found positive results (Chan et al., 2016; Vaportzis et al., 2016). Both studies provided weekly training sessions to the participants and also encourage the participants to use the iPad on their own. For both studies, to measure cognitive ability, the participants did pre- and post-study cognitive and psychosocial tests. In Chan et al. (2016), the results showed improvement in verbal memory recall and processing speed. The authors also conducted a post-study survey. All participants noted that their overall experience towards iPad was positive. However, in Vaportzis et al. (2016), the results showed improvement in terms of processing speed but did not differ in verbal comprehension or working memory. In both studies, the authors concluded that with iPad training and productive engagements, it improves cognitive performance of the participants in this study.

There are other studies that have yet to be evaluated by the older adults[13]. For example a smartphone app for detecting falls (Tacconi et al., 2011), and app that encourage learning (Takagi et al., 2014). There is also work in progress on a medication reminder app

[13] Studies not shown in Table 1

(Dalgaard et al., 2013). In Tacconi et al. (2011) study, user wears the smartphone on a waist belt. Using the belt will allow the app to provide information on body movements based on the accelerometer data near to the center of the body mass. The app is also connected to a web management application that is monitored by clinicians. When a fall is detected, an alarm is generated. If the user is conscious, they can press the "Stop Alert" button which will stop the alarm. If the user does not press the button, assuming they are unconscious, an automatic text is sent to the clinicians to start sending help. The authors noted the app is in its early stage of development. Study by Dalgaard et al. (2013) proposed a medicine reminder app for older adults. They tested a high-fidelity prototype with one 87 year old woman who had no experience with tablet computers. They found that she did not notice some elements of the app which requires the participant to scroll for further information about the medicines. She focused on other elements of the interface such as the buttons. She noted that the app has a lack of content, especially about the dosage for medicines. However, overall she noted *"I think that this is very good even though I am against technology"* p.41. The authors concluded that further design and an extensive evaluation was needed. Anand and Jalal (2014) proposed an interactive social connection app to be used by grandparents and grandchildren. The aim of this app was to promote storytelling sessions between these two target user groups. They have yet to finalise the app but have shown two interfaces in their paper that might be used in the application. A current review of literature found no further publications for these research.

2.6 Conclusion

The demographic of the older adult population in the UK is increasing in a fast pace compared to other age group. The increase in the older adult population and change in balance between younger and older people will place many stress in the society. There will also be fewer people of working age to care for older adult. This means older adults will need to be more independent. Part of the solution to these stresses is to provide older adults with technologies to support them in being independent. This is a considerable challenge for the current cohort of older adults, who grew up before the introduction of computers and smartphones, but for coming cohort of older adults, this will seem quite natural.

The literature review focusing on mobile devices and health has shown that mobile devices can potentially change the older adults' attitude and behaviour to improve their health status. However, studies have mainly concentrated on adults who are overweight or obese.

Little work has focused on exploring the use of mobile technologies to reduce the risk of malnourishment or dehydration in older adults living in the community, both importance health problems for older adults.

Thus, for the remaining studies for this programme of research, I will explore about healthy living, in particular on drinking liquid and eating FV, with mobile technologies.

Chapter 3

Study 1: Focus Groups on Older Adults' Concerns about Healthy Living, Internet and Mobile Technologies

3.1 Introduction

This chapter presents the first study in my programme of research, which investigated ways to help older adults to maintain healthy living when living independently by using mobile technology. For this programme of research, I defined healthy living as maintaining balanced nutrition and drinking sufficient liquids. As a first step to achieve this aim, I conducted two focus groups to investigate older adults' attitudes and concerns about healthy living and the use of the Internet and mobile technologies. In addition, I also investigated the issue of the size of focus groups with older adults and how this affects the quantity and quality of information elicited.

3.1.1 Focus groups as a data collection method

This section will describe the focus group method, the advantages and disadvantages of using focus group as a data collection method, and the mixed views in the literature about the number of participants to have in each focus group.

Focus groups are a very common method to elicit requirements and ideas for new technologies with users (Preece et al., 2015). Krueger and Casey (2014) described the focus group as a *"planned series of discussions designed to obtain perceptions on a defined area of interest"* (p.2). The common practice is for focus groups to be conducted with a number of people led by a skilled moderator (Stewart & Shamdasani, 2014). Usually, the moderator is someone who is familiar with the topic of discussion (Krueger and Casey (2014). This is because the moderator plays an important role in ensuring the discussions are conducted in a controllable and systematic way. For example, the moderators in Lines and Hone (2004) study, aimed to elicit user requirements for an alarm system with 12 older adults (aged more than 65 years), found it difficult to conduct the discussions when the moderators were not familiar with the topic of discussions.

The role of the moderator also needs to ensure that the discussions remain on track while the participants are potentially voicing a wide range of opinions. In addition, an assistant moderator may be used to set up the tape recorder, handle logistics, respond to unexpected interruptions and take notes during the discussions Krueger and Casey (2014).

To avoid fatigue among the participants, the duration of a focus group is usually between 1 to 2 hours based on the complexity of the topic to discuss, number of questions, and the number of participants (Lazar et al., 2010). A proper discussion procedure, a list of appropriate topics to be covered in expected order, and the time duration per topic is often used to control the discussion (Stewart & Shamdasani, 2014). In Lines and Hone (2004) study, the moderators found it hard to control the discussions when the procedure of the discussions was poorly designed.

Advantages of focus groups

One of the major advantages of focus groups as a method of data collection is that it can generate a large amount of data in a short time span as compared to one-to-one interviews (Abd Malik, 2011; Preece et al., 2015). Abd Malik (2011) aimed to investigate the effectiveness of focus groups and one-to-one interview sessions on the topic related to mobile phone. Based on the analysis of the total contributions and time duration for both methods, the author found focus groups elicited more contributions than interview session.

Mora et al. (2012) suggested that the participants are selected based on the discussion topic. This process of selecting participants is important as the participants have knowledge or experiences that are helpful for the discussions (Krueger & Casey, 2014). Furthermore, focus groups questions are often open-ended thus allow participants to express their views and opinions about the issues in their own words (Stewart & Shamdasani, 2014) which can build a consensus view of the topic of discussions (Preece et al., 2015). Focus groups also allow the researcher to interact directly with the participants to clarify their views and opinions (Lazar et al., 2010; Lines & Hone, 2004).

In a focus group, when one participant proposes an idea, there are chances that the idea has never been thought of by other participants, thus further discussion on that idea can be elaborated (Lunt & Livingstone, 1996). Focus groups are also good at obtaining agreement on ideas and highlighting areas of conflict or disagreement among the participants

(Brondani et al., 2008; Preece et al., 2015). Furthermore, Gibbs (1997) noted that with focus groups, what people say and what people actually do can be better understood. For example, in a focus group study by Lankshear (1993), she found a gap in between nurses' attitude in real life in comparison what is written in papers about the qualities of a nurse.

Disadvantages of focus groups

Apart from the advantages, there are some disadvantages of using focus groups. Focus group recordings are often transcribed word-by-word (Preece et al., 2015) which is very time consuming. The analysis process, for example using thematic analysis (Braun & Clarke, 2006), grounded theory analysis (Grindrod et al., 2014) or content analysis (Krippendorff, 2012), are often used to identify the themes of the discussions. The analysis process requires a lot of time involving first transcribing the recordings, then reading and re-reading the transcripts, and coding the responses into similar themes (Thomas & Briggs, 2014). In addition, a second or third coder may be used to ensure all themes are identified from the transcripts (Lyons et al., 2013; Thomas et al., 2014). Brondani et al. (2008) found it challenging to transcribe the audio recordings especially with incomplete sentences, interruptions and silences that were assumed filled with nonverbal communications.

An uncontrolled focus group session may mean that participants have side discussions (Lines & Hone, 2004; Lyons et al., 2013) or discussing unrelated topics (Buykx, 2013; Lines & Hone, 2004). Lines and Hone (2004) found that working with 12 participants per focus group tended to allow the participants to discuss unrelated topics and to have side discussions among themselves. This led to difficulties for the moderator in managing the sessions. Buykx (2013) investigated meal planning, shopping and cooking habits of 15 participants in four focus groups. Buykx (2013) found that 33% of the time in the focus groups was spent on discussing topics that were not related to the goal of the discussions.

The characteristics of the participants can also influence the discussion negatively and make it hard for the moderator to manage the session (Hawthorne et al., 2006; Inglis et al., 2003; Kitzinger, 1995). Hawthorne et al. (2006) conducted focus groups to explore the quality of life issues among older adults. Participants were grouped by age, either aged less than 80 or more than 80, and by health status, either healthy or unhealthy. Little information was given on how they defined the health status. Most participants with age-related health problems required constant care during the discussion. In addition, focus groups may also compound difficulties in communication among the participants with different disabilities. In Kitzinger (1995) study with older adults in a residential home, found a severe restriction communication problem with participants with dementia, impaired hearing, and partial paralysis. These two studies, of course, are extreme examples of participants having difficulties which may interfere with the progress of a focus group and interviews may have been more appropriate in that instance.

Another disadvantage of focus groups is that often particular participants dominate the discussion (Brondani et al., 2008; Kitzinger, 1995). In Kitzinger (1995) study, she noticed that some participants tried to prevent other participants from criticising the residential staff, becoming agitated and repeatedly interrupting the discussion. Brondani et al. (2008) conducted six focus groups with 5 to 9 participants discussing topics related to dentures for approximately 75 minutes per group. In one of the discussions, one participant continuing talking for 10 minutes. The authors noticed tensions between the other participants and probed other participants to give opinions about the participant's ideas. However, none of the other participants would agree or disagree with that participant's statements.

Number of participants per focus group

There are mixed views in the literature about the optimal number of participants to have in a focus group. Carlsen and Glenton (2011) reviewed 220 focus group research publications where almost half failed to mention the minimum and maximum number of participants. Carlsen and Glenton (2011) found papers that did report numbers of participants showed a great range in these numbers, where the minimum numbers of participants was 1 to 13 and the maximum was 3 to 20 per discussion.

Guides to focus groups written from a general social science perspective, such as Stewart and Shamdasani (2014) suggested six to 12 participants per group. They noted having up to 12 participants per group may produce a lot of ideas and having lesser than six may make the discussion dull. However, another guide by Krueger and Casey (2014) suggested having five to eight participants per group. They noted having more than eight participants may produce a lot of ideas, but may limit the chance for each participant to elaborate their ideas, especially if the groups includes one or more dominant participants.

HCI texts, for example Adams and Cox (2008), suggested between three to eight participants. They explained that having a large number of participants might allow the participants to have side discussions or leave some people out of the discussion. They also noted having less than three participants might make the discussion dull. Other HCI researchers have suggested different numbers of participants. Lazar et al. (2010) suggested having eight to 12 participants per discussion. Their concern is if the discussion is conducted with fewer than eight participants, the chances of having more ideas and opinions is reduced. However, Preece et al. (2015) suggested having three to 10 participants per group. They did not explain why they proposed these numbers. Blandford et al. (2016) suggested recruiting at least 10 participants to ensure a saturated return in measurement validity and reliability in HCI qualitative studies, be it for observation, interviews, focus groups or diary studies. No upper limit of the number of participants is given in the text.

However, even with all these suggested number of participants, the literature has shown that focus groups have been conducted with as little as two participants (Goodman et al., 2004; Lyons et al., 2013) or three participants (Inglis et al., 2003) and as many as 23 participants (Braithwaite et al., 2004) or 31 participants (Gloet, 2002) per group. Studies within HCI have also conducted focus groups with various numbers of participants. For example, there were 4 participants in (Massimi et al., 2007a), 7 participants in (Kurniawan, 2008), 11 participants in (Hitchens & Lister, 2009; Martín-Duque et al., 2016), and 13 participants in Scanniello et al. (2016) per group.

To the best of my knowledge, after reviewing the literature, there is no definite number of participants for focus groups in relation to the age of participants, especially with older adults. Many researchers found it difficult to conduct focus groups with older adults either with a small (n = 2) or large (n = 12) number of participants per focus groups. I will elaborate some of the studies, below.

Inglis et al. (2003) found that working with more than three participants aged between 54 to 86 years per group were hard to manage. They reported that some of the characteristics of the older adults, for example having poor hearing, or a poor ability to follow a discussion, could influence the session negatively. In another study with older adults, Lines and Hone (2004) aimed to elicit user requirements for an alarm system. They found that when working with 12 older adults aged more than 65 years per focus group participants tended to discuss unrelated topics and to have side discussions among themselves. This led to difficulties for the moderator in managing the sessions.

In Hawthorne et al. (2006) study as described in above, found that discussing quality of life issues with four to six participants aged more than 80 years was difficult to control. Brondani et al. (2008) conducted focus group discussions with five to nine older participants, aged between 64 and 93 years, per discussion. They found some participants made a few attempts at dominating the discussion. Finally, Lyons et al. (2013) conducted focus groups of two to ten participants aged more than 65 years, (mean age 75.2 years), and found that the participants often discussed irrelevant topics amongst themselves. As with the study by Brondani et al. (2008), they had particular participants who tended to dominate the discussion.

This study investigated older adults' attitudes and concerns about healthy living and the use of Internet and mobile technologies. The mixed views on the optimal number of participants per focus group particularly in relation to the age of participants prompted me to explore the issue of the size of focus group with older adults and how this affected the quantity and quality of information elicited. I also hoped to provide reflections on how best to conduct focus groups with older adults.

3.2 Method

3.2.1 Design

The discussions were about older adults' attitudes and concerns about healthy living and the use of Internet and mobile technologies. The discussions were also about the possible use of mobile technologies for older adults in relation to maintaining balanced nutrition and to drinking sufficient liquids. Two sizes of focus group were conducted: small focus group with three older adults, and large focus group with six older adults. Both focus groups were moderated by the same person. The moderator was experienced at focus group moderation.

To investigate whether the size of focus group with older adults affected the information elicited, the analysis of data elicited from four focus groups. Two of the focus groups (one small, one large) were for my programme of research. The other two focus groups (one small, one large) were about the possible use of technology for older adults in relation to mobility and wellbeing, and conducted for a different research project being conducted in the HCI Research Group (Bevan et al., 2016; Swallow et al., 2016), (hereafter "Co-Motion"). Further details on Co-Motion are available at Appendix 1.

3.2.2 Participants

The inclusion criteria for the focus groups was to be 65 years or over and living independently, either alone or with a partner. Nine participants took part in two focus groups, 3 in small group and 6 in the large group.

As there were no definite number of participants for focus groups especially with older adults, I chose 3 for the small group as this is the minimum number suggested in HCI text (Adams & Cox, 2008; Preece et al., 2015) and I doubled the number for the large group.

The participants were recruited via StreetLife[14], a local digital community. Participants did not have to have any technology experience. Table 3.1 summarizes the participants' gender, age, living arrangements, educational level and current employment status.

Table 3.1. Demographics of the participants

Characteristics:	**Large focus group**	**Small focus group**
Gender	3 women, 3 men	2 women, 1 man
Age	65 – 80 years	65 – 70 years
Mean age	75 years	68 years
Living arrangement	All living with partner	1 living alone, 2 with partners
Education level	3 secondary school, 1 Bachelors degree, 3 professional qualification	2 secondary school, 1 Bachelors degree
Employment status	1 working p/t, 5 retired	All retired

14 https://www.streetlife.com

3.2.3 Materials and equipment

The discussion topics emerged from the literature about older adults, malnutrition and technology (Bhachu et al., 2008; Callen & Wells, 2003; Fan et al., 2012; Payette et al., 1995; Shahar et al., 2001). The discussion topics are listed in Table 3.2.

Table 3.2: Discussion topics for the focus groups

Healthy Living
• Eating habits
• Healthy eating
• Drinking habits
Technology
• Internet
Mobile Technology
• Smartphones and tablet computers
• Mobile apps

Each participant completed an informed consent form (see Appendix 2) and a background information questionnaire. The questionnaire consists of three sections:

1) about the technologies they use; which asked them about the brand / model, how long they have been using it, how often they use per week if they are still using it and reasons if they no longer using it
2) about their attitudes to mobile phone and computer technology; which asked them reasons for which technologies that they used find most useful and fun, and how comfort and expert feel they were in using the technologies (on a five point scales)
3) about their personal information; which asked for the marital status, living arrangement, highest education, employment status, age and gender.

See Appendix 3 for the copy of the questionnaire.

They also received an A4-sized food pyramid diagram and the NHS Eatwell Guide[15] to stimulate the discussion (see Appendices 4 and 5 respectively).

[15] http://www.nhs.uk/Livewell/Goodfood/Documents/The-Eatwell-Guide-2016.pdf

The focus groups were audio recorded using the Voice Memos application on two iPhone 5s, running on iOS 8. One iPhone acted as a backup for the sessions.

3.2.4 Procedure

The focus groups were audio recorded and were conducted in a meeting room in the Department of Computer Science. Participants sat around a large round table. Tea, coffee and biscuits were available throughout the session.

Both focus groups were moderated by Dr. Blaithin Gallagher, an experienced focus group moderator and researcher on the problems of older people. I was the assistant moderator.

The moderator started by introducing the objectives and procedures of the focus group. Participants were asked to read and sign the informed consent form and complete the background information questionnaire. The moderator then guided the participants through the discussion topics on their concerns about eating, and drinking. Participants also discussed their use of and attitudes towards technology, including mobile technology.

At the end of the discussion, the moderator summarised the key points mentioned by the participants during the discussion and debriefed them. Participants were offered a Mark & Spencer gift voucher worth £25 to thank them for their time and efforts. The time taken for the large focus group was 97 minutes and for the small focus group was 109 minutes.

3.2.5 Data Analysis

The audio recordings were transferred to Express Scribe[16] software for transcription, organization, and analysis of the data. The audio recordings were transcribed using Microsoft Word within 72 hours of the actual recordings.

Content analysis (Krippendorff, 2012) was conducted using the transcripts, identifying topics related to older adults' attitudes and concerns about healthy living and technologies, including mobile technologies.

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[16] http://www.nch.com.au/scribe/

This was achieved following typical content analysis methods. Initially I listened and re-listened to the audio recordings to ensure that I have a broad overview of what the discussion was about. I compared the audio recordings to my handwritten notes taken during the focus group if I was confused on any part of the discussion. Next, I transcribed the recordings. My supervisor helped me to transcribe the recordings in cases that I could not understand the word or phrases.

To avoid losing any information related to the interest of this study, I repeated the transcription process twice. To ensure I adapt and understand the information told by the participants, I reviewed the transcriptions many times line by line.

Then, I analyzed using an open coding technique (Mora et al., 2012) until appropriate topics were found. To establish inter-coder reliability of the categorization, a second coder went through all of the topics and any disagreements were resolved.

3.3 Results

3.3.1 Older adults' attitudes and concerns about healthy living

Two main topics relevant to older adults' attitudes and concerns about healthy living were asked during the discussions. The topics were: older adults' attitudes and concerns about (a) maintaining balanced nutrition, and (b) keeping hydrated. I will discuss the results of each of these topics in turn.

Older adults' attitudes and concerns about maintaining balanced nutrition

Participants had knowledge about maintaining balanced nutrition, as it was repeatedly mentioned in both focus groups. Some participants maintained their nutrition as to how they thought and were trained when they were young. They commented on consuming fresh food and eating proper portions of food:

> *we would basically shop one main shop a week and one small shop in the mid week for fresh fruit and vegetables p7*

> *I think when we were young and during the war you went out everyday and you bought fresh food I think that people were healthier then and with smaller portion p5*

to think about it our meals will always include vegetables and fruit and really thinking back as a child that's how my mother always used to prepare food for us it was always made from scratch it makes me laugh now when I see programs on television and they talk about have you made meal from scratch I mean for us I think it's just normal we've always done it that's how our mothers did it well my mother did my mother once said a fantastic cook by any means but it always meat potato and two vegetables and that's the way it was p7

I was sportsman so I always take advice as I was playing sports basically for quite a few years my main meal then was actually depend[ing] the time of the year and mainly the winter early spring my main meal in breakfast it was fresh grapefruit steak eggs tomatoes followed by tea and coffee then I would go out for training for 5 to 6 hours so that was the culture now it has changed completely because all carbohydrate or whatever but I've come from those day I was quite aware of what I need and didn't need and what was good for me and what was not good for me p8

In addition, some participants maintained balanced nutrition by being conscious about eating processed foods. Some participants tend to minimise buying processed foods or meat. Some participants only buy raw food and make their own food from scratch. Some participants plant their own fruit and vegetables (FV) at home. For example:

occasionally fish and chips yes what we call a treat but normally speaking no we don't use any fast food at all p1

well for me it's not just about that it's the ingredients the additives for example like yesterday we had those pasta with spinach in but the list of additives in that was just amazing what actually went into it … I do have a problem with the additives p2

you can make a lot [soups] and put it in the refrigerator or freezer and it's lovely that you have some in the freezer and you don't feel like cooking and you can get something out freezer and it's fresh and you know what's in it p7

I eat fresh food rather than stuff that has been processed away altered and changed before you get into it p4

yes you need salt for taste but you don't need more salt to be health reason p1

we grew traditional potatoes but mainly raspberries leeks onions garlics rhubarb broccoli and herbs p8

Some participants maintained balanced nutrition by making changes to their diet and eating habits. To avoid eating the same FV, some participants eat according to what is in season. Some participants tend to eat more fibre, and change their main meal to lunchtime, particularly to ease the digestive system or to avoid interfering with their sleep. For example:

I don't eat as much sweet stuff now I am more into savories p9

we try to make it healthy the cereals are wholegrain the toast usually rye or whole meal bread p1

what we do is if we can we eat what is in season p8

I steam most of my vegetables p9

in my case I find that that eating in the evening can often interfere with my sleep and so it is preferable for me to eat my main meal during lunch time p1

I'm conscious that you do need fibre for instance because basically it's for your bowel movement and I have for breakfast is cereal oats or toast or things even sandwiches something like that I think is it essential that you make sure you need a form of fibre p8

Although some participants do not know how to prepare large healthy meals, yet they know how to prepare simple meals like eggs and toast, sandwiches or salads with lots of healthy ingredients to maintain balanced nutrition:

I don't do that [cook large meals] very often I like doing salad yeah I think I do like salads what I do with salad is maybe not just lettuce and cucumber and tomato or onions but you've got radishes pine nuts walnuts sultana currants and all that and croutons as well and that is a meal p8

no I don't like to cook but very small things you know I can't do a roast or a very big meal but I can do very small things like scramble eggs and toast not like big proper meal no I couldn't p3

just a normal sandwich cheese and tomato or cheese and onion tuna either open sandwich or wraps or soup that type of sandwiches it's not a lot but it's sufficient p8

The participants have also thought on how to manage their future independence in terms of eating healthily. The participants acknowledged that ageing affects their capabilities to buy or prepare their own food. However, the participants were still conscious about eating processed foods even when it gets difficult for them to buy or prepare their own food. Quotes from some of the participants include:

I would I think I'll ring up Tesco and Waitrose and give them the order p1

one of the things that I invested in when I bought my bungalow and people laugh at me is a 3 foot chest freezer … I batch cook I make my own soups and I make my own ready meals just in case you get a bad winter you don't want to go out to the shops the furthest I got to walk is to go to the garage again if you're not very well you get a cold or something there's nothing more comforting … a good home made soup p9

if I were to be alone and I don't drive I'll have a shopping trolley and take a bus so I can manage p5

well you have to adapt according to your capabilities if I were to come to a stage were I couldn't do I would have to resort to certain supermarket that sells chopped carrots or whatever I would go down to that route rather than buying pre prepared food p2

One participant was aware that the support that social services could provide to older adults particularly with grocery shopping. That participant noted:

> *social services are pretty good in one way for the elderly particularly with food shopping because a friend of mine was in incapacitated she's 80 something she couldn't get up and shop don't know about computer didn't want to know about technology ... they will order online for anybody that hasn't have a computer that need access to food shopping and can't get there ... social services will telephone that person and take their shopping list they'll go to either Sainsbury or Tesco p9*

Some participants listen to the news and read recommended eating guidelines from government departments about maintaining balanced nutrition. Some participants were also aware of the food pyramid or the NHS Eatwell Guide[17]. For example:

> *there's a plate like this one [referring to NHS EatWell Guide] p5*

> *it's on the news p6*

> *you read about it it's always been bombarded by doctors government ministers of what we should be eating p1*

However, some participants are not aware about the food pyramid or the NHS Eatwell Guide. Some participants lack knowledge about the recommended servings of each food group, particularly the amount of FV they should consume each day. These participants commented by eating FV or a bit of everything, assuming that will give them the required nutrition:

> *I was just looking here [at the food pyramid diagram] so many five servings a day what size servings I would really like to know fruit group 5 servings a day what how much is one serving what is there you know fruit and vegetables but you can have 25 grams of carrots or is it 25 grams of spinach is it cooked spinach or raw spinach p7*

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[17] http://www.nhs.uk/Livewell/Goodfood/Documents/The-Eatwell-Guide-2016.pdf

a bit of everything p5

well I think if you're getting your fresh fruit and your fresh vegetable you're getting your fibre anyway p9

it always meat potato and two vegetables and that's the way it was [referring to her/his eating habits] p7

One participant attended cooking classes when she/he was younger to about nutrition. She/he said:

my mother absolutely loathed cooking she hated it she could have eating all raw food she [unintelligible]… [comments from moderator] so it was a case of I don't like this if is food I don't like it and something inside said that it should be better than this which is why when I was 18 I decided I going to be a chef and I took myself to Leeds p9

Older adults' attitudes and concerns about keeping hydrated

The participants had concerns about drinking sufficient liquid especially water:

I drink under sufferance p2

yes but not a lot I know I should drink more p6

I drink 6 mugs of tea a day 2 in the breakfast 2 lunch and 2 in the evening meal I have 2 cups of coffee in a day 1 at 10am and one at 330pm and that's it p6

Some of the participants stop drinking at a certain point in the day. This is probably to try to avoid having to get up during the night to go to the toilet:

I don't drink anything after 8 o'clock p9

my last drink is with my evening meal at 6:30pm I don't drink after that p3

One participant only drinks water due to health reasons. This participant commented:

I developed a kidney problem which the consultant said that it was a direct result of dehydration which is kidney … so now I have to make sure I drink I *hate drinking water but I really have to make sure I drink 2 litres of fluid a day p7*

In addition, some of the participants lack knowledge about the recommended amount of liquid they should drink a day, the importance of drinking plain water, and appropriate choices of liquids to drink:

what you're saying the amount of liquid we're supposed to drink is p3

I like water actually but the fact that I've drink tea and coffee I just don't feel thirsty that I need to drink water very often p3

what about drinking bottled water p1

3.3.2 Older adults' attitudes and concerns about the Internet and mobile technologies

Three main topics relevant to the Internet and mobile technologies were asked during the focus groups. These topics were older adults' attitudes and concerns about using the Internet, using mobile technologies, and suggestions for mobile app development.

Older adults' attitudes and concerns about the Internet

participants clearly have knowledge of using the Internet. A majority use the Internet in their daily life for various activities:

I use the internet for banking I use it for information I like looking at historical facts on different thing and recipes to do that and to do read the news I do email p7

I use email keep in touch with people and I'm a writer so I use it for research p9

I often see what you know the finance side is currency rate and I look at the sport results mainly the sports that I'm more interested in and to see what's the rugby is in Australia and NZ cause my son lives there so those type of things P8

A majority of the participants are aware of the advantages of using the Internet. The ability to get up-to-date news, keep in touch with friends and family members were frequently repeated comments from the participants:

> *news update it's so interesting to see it's updated itself p8*

> *I email most days to friends is that it is so easy so you sit down you type your letter well typing it starts off of being difficult but it becomes fairly easy you type your letter you press a button and its gone p1*

> *it's great that you could chat with your friends you know without writing a letter I don't want to be on it all day but perhaps check it once a day and reply quickly like you know this study happens really useful p5*

> *I'm always astonish with the wealth of information that you can tap in to it I find computer fascinating I always have p9*

However, some participants were not interested in using the Internet in their daily lives. Some participants raised concerns about privacy and security issues of using the Internet. Some participants had virus attacks on their computers so they minimized their Internet usage.:

> *I'm so far detached from everything in many years my son trying to get me involved I just cannot find any I can live my life without it I don't need it there's nothing p3*

> *I just don't like it I just feel like a fool once there's a lady showing to me at the library but I wasn't just clicking into it p6*

> *I used to use Facebook I had an account on there for quite sometime but my computer got hacked and it was a particularly nasty one because it left the key logger and I get in touch with one of my friends in IT and it took us 2 days to clean the computer and get rid of it so I have never been on Facebook again p9*

> *I got a virus when ever we went to Google and put in the site that you want to go to through Google it went straight through a pornographic site it was awful p7*

Older adults' attitudes and concerns about mobile technologies

Note: In this context, the *mobile technologies* refers to both smartphones and tablet computers

Some participants are reluctant to use mobile technologies in their daily lives. Although some participants have tried or seen other people using mobile technologies, they still do not wish to use them, for a variety of reas:

> *I just don't have any interest p5*
>
> *I'm not bothered with it I'm just not interested in it you know p3*
>
> *I have seen my children and grandchildren but I'm not interested p6*
>
> *I've tried but I just find it ponderous and slow and I assume that I just dial a number and speak and if they are not there it's fine I don't mind p1*

In particular, the cost of mobile technologies was raised as a concern:

> *it's expensive p6*
>
> *it's the cost we talking about smartphone ... I manage to get it down to 7 pound a month so but you have to buy your own phone but when I look at some of these contract I mean it's ridiculous some of them are like 30 pound a month that would be quite a high percentage of my weekly income p7*
>
> *it's something I'll think long and hard before I expand the expense at the moment I am on the pay-as-you-go not a contract I maybe put about 20 pound a year in it because I purely use it for texting p9*
>
> *[if cost is not an issue] I wouldn't mind a nice Apple Air the little MacBook p7*

Some participants do not see the necessity of using mobile technologies because they are comfortable with the technology (e.g. mobile phone or laptop computer) that they are currently using. In addition, some participants prefer using a desktop computer due to it having larger screen compared to a smartphone or tablet computer.

> *I'm comfortable with what I've got I've got a computer I've got access to the Internet I've got a very basic mobile phone and at the moment that's all that I need to do thing that I need to do so I'm not tempting to buy anything else p2*
>
> *I am using the technology I like I don't see the need of it I can communicate you know very well with the telephone emails with the equipment there's no need for us p8*
>
> *well I carry a mobile phone with me for emergencies only if I'm stuck somewhere I can call for help or I can text people I very very rarely use it actually as a phone p9*
>
> *I know why I prefer a desktop to having a smartphone or a tablet I got a nice big screen p7*

Another barrier to adopting new mobile technologies is a preference for more traditional forms of communication, for example making voice phone calls rather than texting, communicating face-to-face rather than chatting online, or reading books physically rather than relying on reading them on screen:

> *we have a daughter in Edinburgh University and she tends to text rather than speak on the phone I always come back to the idea that speaking on the phone is much more intimacy p1*
>
> *yes but chatting with your friends you say you don't chat with your friends actually that's what you've been missing there isn't the same communication everybody becoming into it because of this technology that's what I think it's not chatting p6*
>
> *I've should have said it that I still like the feel of books so I won't want a tablet to read a book p2*

Lack of knowledge is another barrier to using mobile technologies. Some participants rely on others, for example family members or friends, to learn how to use mobile technologies. In addition, two participants took tablet computer courses for six weeks to improve their knowledge in this area. They acknowledged that they liked the course and were willing to learn more in the future:

> *my daughter showed me how to text oh mother look you can do this and I thought that's great so then I said to my friends do you know you can send messages then we all started sitting in the same room sending each other text p7*
>
> *my wife and I just went to a six weeks course just over at Rowntree Centre with an instructor with a tablet and what we had to do was write a story ... and then we had to put it ... on the tablet then we had to select photographs to illustrate our story ... well all of these have been done under instruction p4*
>
> *yeah with the screen and he'll say press button b and that's it we learn better p6*
>
> *we don't have enough time it was a very short time that 6 weeks but we did learn things we only use thing that we need not everything but if you could tell us that there's a lot of other things that we could do with that p6*

However, some participants acknowledged the advantages of using mobile technologies in their daily lives.

> *it's great that you could chat with your friends you know without writing a letter p5*
>
> *this [texting] is quite a good idea and it's cheaper than a phone call p7*
>
> *I think technology can help us when we get older the tablet for instance for reading books because my sister in law has really bad eyes she just got a tablet .... because larger technology is good for her p6*
>
> *and you can enlarge the font on those quite easily p9*

Interestingly, as technology is rapidly advancing, some participants acknowledged that they could see themselves using mobile technologies in the future:

I'm sure yes well 10 years ago we didn't thought we're going to get a laptop p5

it's going to get built-in into your cars your clothes now isn't and eventually maybe stuck into your chest somewhere p1

However, there some participants did not see themselves using mobile technologies in the future or who raised concerns about having to accept the use of mobile technologies:

I've been thinking about this while you were talking but I cannot really think about I can say that it wouldn't benefit me at all or benefit anybody p3

we have the choice I think the message you get across is that you don't have to because so many people think they have to and I don't think people should think that way like myself I want to embrace technology fine but equally you should not feel embarrassed for not doing it p2

it's take it or leave it p3

One participant is looking for a new mobile technology (a smartphone) at the moment:

well this phone is almost past its use by so I think maybe the next one might be a smartphone I have no objection to them it's just that I have got no time to get doing it p9

Only one participant currently owns a tablet computer. She noted that her husband bought the device, as he felt left out by not owning one. However, she also noted the advantages of using the tablet computer:

it's my husband who bought it I was quite surprised about it he's been going around with it it's my husband I think he just felt missing out a bit because we haven't got one I think we've been pushed into it actually [by] the society the media you know you can always get the phone number or the email address or some information and things p6

Older adults' attitudes, concerns and suggestions about the development of future mobile apps for older people

Some participants have a positive attitude about possible future use of mobile apps to improve their healthy living:

> *now I suppose in having to revert to shopping in supermarket because they are people who deliver or maybe farm shops may deliver then maybe we can think of an application that helps us to plan our food because we can no longer get to the shop p7*
>
> *particularly for medical care apps at home where you get reminder of when you get a bit of reminding where you forget to take your tablets for example I think that would be useful for myself p2*

However, some participants raised concerns about using mobile apps in the future. There were a number of reasons mentioned: not using technology when they were younger, the fear of losing memory capabilities if they were to rely on technologies, and their preference for bigger screens:

> *well yes I think you could have a variety of apps that could support people and then it's take it or leave it p2*
>
> *it wouldn't enhance my life by having one you look today you coming from a bus in town some guy would say I'm on the bus coming up to you or keep on texting what line what route well 20 years ago how did they manage how did they get back p3*
>
> *I'm doing a sort of re think we are entering a seriously dangerous territory here if we going to have these little things reminding us of everything what's going to keep our memory to keep on going p9*
>
> *I just thought of something actually I know why I prefer a desktop to having a smartphone or a tablet I got a nice big screen ... I really can't be doing looking at a screen that size you know if I'm reading a recipe lets have it on a big screen with big font and it's great p7*

Nevertheless, some participants also suggested features they would like to see included in apps in the future:

yes [to having a reminder text to remind them to drink] it could be a good idea if you've been busy and you haven't been thinking about drinking p5

yes [to having a reminder text to remind them to drink] it could be but I might find it irritating p2

portability and useful apps like that ... something that could give the availability of say fresh fish and the prices because that fluctuate p9

I just discovered from a friend that he's been doing the wrong thing he was running until he's exhausted but the friend explain that you're supposed to run for a minute and then walk for a minute ... and slowly build it up now that's some sort of information that could be put on an app isn't p1

I would really like some simple information like this that says I was just looking here [the food pyramid diagram] so many five servings a day what size servings I would really like to know ... how much is one serving ... you can have 25 grams of carrots or is it 25 grams of spinach is it cooked spinach or raw spinach p7

no I don't know about that that will be too complicated [to providing nutrition facts about the food in the app] p5

3.3.3 Effect of the number of participants on the total of information elicited in focus groups

To ease the analysis, the information from the focus groups for the current study is labelled "Healthy Living".

The total number of contributions were counted based on the three topics of information relevant to the development of apps to support nutrition and hydration for Healthy Living and based on the eight conceptual design solutions for Co-Motion.

Contribution was defined as either 1) participant presents a unique idea or opinion on a topic, and when 2) another participant further elaborates on this idea or opinion on a topic. However, confirmatory comments such as *"Yes, I agree"* without a further elaboration of an idea or opinion were not considered as a contribution.

No statistical test was conducted between the number of contributions per participant and the size of the focus groups or between the number of contributions per 10 minutes of discussion and the size of the focus groups due to the small number of data.

Table 3.3 shows the total number of contributions made in each focus group and the number of contributions per participant and per 10 minutes of discussion time. As can be seen, there are very big differences between the groups, which is not surprising given individual differences between people in their willingness to contribute to a group discussion, their interest and knowledge on a topic and the dynamics of the group. It is perhaps not surprising that the larger focus groups produce less contributions per participant, as there are more people competing to add something to the discussion. But it is interesting that for both topics and overall, the number of contributions per 10 minutes of discussion is substantially higher in the larger groups than in the smaller groups. So it does not seem that the larger groups of older adults has any difficulty generating contributions than the smaller groups.

Table 3.3 Total number of contributions, contributions per person and per time for the four focus groups

	Small Focus Group	Large Focus Group
Healthy Living	Participants: 3 Total time: 109 minutes Total contribution: 188 23.0 contribution per participant 11.5 contribution per 10 minutes	Participants: 6 Total time: 97 minutes Total contribution: 218 14.3 contribution per participant 18.5 contribution per 10 minutes
Co-Motion	Participants: 4 Total time: 80 minutes Total contribution: 92 62.0 contribution per participant	Participants: 7 Total time: 54 minutes Total contribution: 100 36.3 contribution per participant

	17.25 contribution per 10 minutes	22.5 contribution per 10 minutes
Overall	42.5 contribution per participant 14.3 contribution per 10 minutes	25.3 contribution per participant 20.5 contribution per 10 minutes

3.4 Discussion

This study conducted focus groups with older people to provide information about the attitudes and concerns about healthy living in terms of consuming balanced nutrition and keeping hydrated. This study has also provided information about the attitudes and concerns about the use of Internet, and mobile technologies among this sample. In addition, this study has provided the analysis of conducting focus groups with two group sizes.

In relation to older adults' attitudes and concerns about maintaining balanced nutrition, the main findings were that older adults:

- Have knowledge about maintaining balanced nutrition
- Are conscious about not eating processed and fast food
- Make changes to their diet and eating habits for example by eating more fibre as get older
- Have thought on how to manage their future independence in terms of eating healthily
- Are aware of the support available from social services to buy groceries
- Listen to news or read recommendations about guidelines for eating healthily
- Lack knowledge about the recommended serving sizes of the food groups, particularly the amount of FV they should be eating

These findings are in agreement with previous research. The participants demonstrated their understanding of the importance of consuming balanced nutrition, and do eat healthy most of the time. Although some participants do not know how to prepare complex healthy meals, they know how to prepare simple meals with healthy ingredients to maintain balanced nutrition. A preference for consuming balanced nutrition is associated with ageing, with older adults making changes to their diet and eating habits for example by eating more fibre. Hughes et al. (2004) and Saba and Vassallo (2012) found that some older adults in their studies had knowledge about eating healthily and activities related to food preparation. Older adults in Lane et al. (2014) focus group study were also aware with the physical changes of ageing, and made changes to their eating habits and activities related to food preparation. These older adults also commented that they cooked in large batches and froze food to ease situations in which they cannot do grocery shopping or cook. They also changed their diet to eat more healthily and relied on social services to provide food if they could prepare food by themselves (Lane et al., 2014).

Although the participants in the current study reported they do eat healthily, some participants lack knowledge about the recommended servings of the different food groups, particularly the amount of FV. These participants commented by eating a bit of everything they believe they are getting balanced nutrition. Although I did not specifically asked the participants about their dietary intake for each food group, this finding shows that these participants have concerns about eating the right portions of FV. These findings support previous studies on older adults and their attitudes on eating healthy. Studies by Baker and Wardle (2003) and Power et al. (2014), with 10 years apart, have also shown that some of the older adults in these studies also have mixed knowledge in consuming balance nutrition and do not consumed the recommended servings of dietary intake. A more recent survey study by Bates et al. (2014) and Gille et al. (2016) have also shown that older adults are not consuming balance nutrition. Older adults in the UK are eating less than 400grams of FV a day (Bates et al., 2014), the amount that is recommended by WHO (2016a) and the NHS[18]. In Gille et al. (2016) study with 632 older adults, only 71% knew about the food pyramid, but only 38% said they refer to it to eat healthy.

In related to older adults' attitudes and concerns about keeping hydrated, the main findings were that older adults:

- Have concern about drinking sufficient liquid especially water
- Tend to stop drinking liquids later in the day
- Lack knowledge about the recommended amount of liquid to drink per day, the importance of water, and choices of liquid to keep hydrated

The findings indicated that this group of older adults does have concerns in drinking sufficient liquid intake, particularly water. Interestingly, participants were aware that they were supposed to drink more water, but were reluctant to do so. They prefer drinking other

[18] http://www.nhs.uk/Livewell/5ADAY/Pages/5ADAYhome.aspx

liquids, especially coffee and tea, which may lead to further dehydration. Most participants stopped drinking later in the day. In addition, some of the participants lack knowledge about the recommended amount of liquid to drink per day, the importance of water, and choices of liquid to keep hydrated. These findings support current research on older adults' attitudes to keeping hydrated. For example, Godfrey et al. (2012) found that older adults know the importance of drinking water, but some of them do not like to do so. Some of the older adults in this study also refrain drinking to avoid using the toilet too frequently and only drink water for heath reasons. The older adults in this study also prefer drinking coffee and tea to quench their thirst.

Three main topics relevant to older adults' attitudes and concerns about using the Internet, using mobile technologies, and suggestions for mobile app development were asked during the discussions.

In relation to older adults' attitudes and concerns on the Internet, the major findings were that older adults:

- Have knowledge about using the Internet
- Acknowledged the advantages of using the Internet
- Lack of interest in using the Internet
- Have concern about privacy and security issues

These findings are in agreement with previous research. A number of studies have shown that older adults see advantages in using the Internet in their daily life and tend to predominantly use the Internet for communication (Carpenter & Buday, 2007) and information seeking purpose (Vroman et al., 2015). However, there are concerns for some participants in the current study about using Internet. Two participants clearly noted they do not like using Internet or any such technologies. These participants have tried using the Internet, but they are not interested in using it in their daily life. Carpenter and Buday (2007) found a lack of interest as the most reported reason (nearly 60%) for not using Internet and technology by a majority of the older adults in their study. Hope et al. (2014) also found lack of interest as a common reason to not using the Internet as a form of communication among older adults.

Three other participants raised concerns about the privacy and security issues of the Internet, especially virus attacks. These three participants still acknowledged the advantages of using the Internet and still use the Internet in a daily basis. Studies by (Carpenter & Buday, 2007; Lian & Yen, 2014; Trocchia & Janda, 2000) also reported that older adults raised concerns about privacy and security of the Internet.

In related to older adults' attitudes and concerns on mobile technologies, the major findings were that older adults:

- Lack of interest in mobile technologies
- Have concern about the cost of mobile technologies
- Do not see the necessity of using mobile technologies
- Prefer traditional forms of communication
- Lack of knowledge about mobile technologies
- See the advantages of mobile technologies
- See themselves using mobile technologies in the future
- Have concern about having to accept the use of mobile technologies especially in the future

These findings indicated that participants were reluctant to use mobile technologies. Although some participants have tried mobile technologies, they were still not interested in using them. These findings supports previous research where older adults are not interested in using mobile technologies in their daily lives to promote physical activities (Fan et al., 2012).

The cost of the mobile technologies was also a concern to using them. However, if the financial element was not an issue, some participants in this study would not mind getting themselves a new mobile technologies. This financial elements as a barrier to using mobile technologies are well established in the literature (Mallenius et al., 2007; Parker et al., 2013).

Other concerns raised by the participants include the necessity of having the mobile technologies. Participants noted by having laptops and desktop computers are enough for them to use the Internet. In addition, the cost to invest on new technologies burdens the participants. Furthermore, participants, especially the one with poor eyesight, preferred having bigger screens when they access the Internet. The necessity factor of having the devices as a barrier to using mobile technologies supports the findings from previous research with older adults such as by (Hill et al., 2015; Mallenius et al., 2007; Parker et al., 2013).

The findings of the current study also indicated that some participants preferred traditional methods of communication. This finding is also in agreement with previous research. Yuan et al. (2016) found that majority of the older adults preferred the face-to-face communication compared to other methods of communication such as via telephone. Hope et al. (2014) found that older adults were concerned about texting as a way to communicate as text messages can be interpreted incorrectly. Other research has also show that older adults feel uneasy about using the Internet (Melenhorst et al., 2001; Trocchia & Janda, 2000)

Lack of knowledge is another concern in relation to using mobile technologies for some participants in the current study. These participants relied on others, such as family members, to learn how to use mobile technologies. In addition, some participants attended courses to learn about mobile technologies and were willing to learn more in the future. Older adults relying on others to learn new technologies has been repeatedly reported in the literature (Barnard et al., 2013; Kurniawan, 2006; Leung et al., 2012). Barnard et al. (2013) identified three main preferences amongst older people in learning new technologies: relying on others, trial and error and reading instructions. In terms of relying on others, the older adults in this study felt more comfortable to use a new technology or device when someone is there to assist or instruct them.

A majority of the participants in the current study saw the advantages of using mobile technologies, especially for making phone calls and texting, even to family members living overseas. Keeping connected with family members and for emergency cases are the main reasons to use the call and text functions. Studies by (Dhukaram et al., 2011; Kurniawan, 2008; Melenhorst et al., 2001) reported similar findings. Participants in the current study who have used tablet computers found them interesting with the ability of the tablet computer can do. Some participants keep their mobile phone close to them at all time. This supports findings by (Hardill & Olphert, 2012; Kurniawan, 2008).

Although older adults in the current study raised many concerns about using mobile technologies, they acknowledged that technology is changing rapidly and they do see themselves using mobile technologies in the future. Nevertheless, some participants were firm in their thoughts and concerns about using mobile technologies in the future. These mixed findings support those from previous research, in particular in focus groups discussion with older adults about technology usage (Fan et al., 2012; Mitzner et al., 2010)

In relation to older adults' attitudes, concerns and suggestions about mobile app development, the main findings were:

- Positive attitudes about possible future use of mobile apps to improve healthy living
- Concerns about using mobile apps in the future
- Suggestions for the features of mobile apps

The findings indicated that the majority of participants had positive attitudes towards using mobile apps in the future to improve healthy living. However, some participants were firm in their thoughts and prefer to say that it is up to the individual whether they want to use a technology or not. Participants had concerns about using apps in the future for a number of reasons. In particular, they were concerned about not having experience in using them, and the fear of losing memory capabilities, if they were to rely on technology and their preference is for using bigger screens. This fear of using new technologies is well documented in the literature, for example in the studies by (Barnard et al., 2013; Bhachu et al., 2008).

This study has also provided suggestions for future apps to improve healthy living. The most suggested feature is a reminder to remind them to drink and also tips and information, especially on food related topics. Participants also preferred an app that is easy, simple, and straightforward. Some participants acknowledged that ageing has influenced their mental capabilities thus a reminder text to remind them to drink might be helpful for them. Tips can increase their knowledge to live a healthier life. These positive suggestions about using mobile apps for maintaining healthcare in the future is consistent with the findings in studies by Dhukaram et al. (2011), Parker et al. (2013) and Silveira et al. (2013).

The findings indicated that focus groups are a suitable and effective methodology for involving older adults to elicit ideas and opinions on healthy and the use of Internet and mobile technologies and also possible use of technology for older adults in relation to mobility and wellbeing.

In terms of conducting the focus groups with both large and small groups the moderator had minimum difficulties. The moderator allocated each participant in both groups to speak and share their thoughts for each topic in an approximately same time lengths. The moderator also attempted to ensure that each participant had an opportunity to speak and share their thoughts, drawing more reticent participants into the discussion when necessary especially when some participants who were more forthcoming than others.

The moderator also made sure that the discussions kept reasonably close to on the topic of the discussion. With these groups there was little diverging from the topic by the participants, and very few examples of participants having side discussions. Participants in both groups were quite firm with their thoughts and ideas. The moderator also made sure that short breaks were given. The participants were asked to freely help themselves to coffee, tea and biscuits throughout the focus groups.

For this study, although I did not specifically ask the participants about their health status, none of the participants in either groups showed any lack of ability to follow the discussions as reported in Hawthorne et al. (2006) and Inglis et al. (2003).

In terms of the size of focus group with older adults and how this affected the information elicited, the findings showed that the smaller focus groups elicited more information per person but the larger groups elicited more information per unit of time of the focus groups. These results are logical in terms of people's opportunity to express their views.

3.5 Conclusion

The findings indicated that participants in this study do have knowledge and enthusiastic about food preparation, and eating healthy. However, some participants were confused about the amount and type of FV we should consume each day. These participants also have concern in drinking sufficient liquid intake particularly water. Although they acknowledged the importance of drinking water, some participants prefer not to consume it in their daily life. In related to mobile technology, participants agreed with the fast changes of technologies and do see themselves using mobile technologies in the future. As a conclusion, I would like to explore more about self-monitoring FV and liquid intake with mobile technologies. The next study will design and evaluate a low-fi paper prototype of a mobile app to support older adults to monitor their liquid intake based on the suggestions given by the participants in this study and from literature on mobile app design guidelines for older adults.

Chapter 4

Study 2: Design and Expert Evaluation of a Low-Fi Prototype of the MyDrinkApp App for Liquid Monitoring

4.1 Introduction

The results from Study 1 (see Chapter 3) showed that older adults have concerns about drinking sufficient liquid, particularly water. Although the participants acknowledged the importance of drinking water, some participants did not like to do so. In terms of accepting new technology, the participants did have positive attitudes towards the Internet, computers, laptops, and mobile phones. The participants also see themselves using a tablet computer or a smartphone in the future.

As a common practice in user-centered design lifecycle (Nielsen, 1993) and to avoid fatigue among both experts and older users (in Study 2 and Study 3) to conduct usability evaluations on similar design prototypes, I decided to design a low-fi paper prototype of a mobile app designed to support older adults to monitor their liquid intake first. There are very few guidelines and heuristics relevant to the design and evaluation of apps for older adults (Al-Razgan et al., 2014; Kobayashi et al., 2011; Silva et al., 2015; Watkins et al., 2014). A background literature review on these guidelines and heuristics is provided below.

Kobayashi et al. (2011) touchscreen guidelines were developed from direct empirical evidence, an evaluation with 20 participants in their 60s and 70s. The participants were required to perform tap, drag and pinch tasks on a tablet computer. They performed each tasks twice, separated by a week. During the one-week period, they were asked to practise their hand gestures. The analysis of the tasks allowed Kobayashi et al. (2011) to develop a set of four touchscreen guidelines to design better interfaces for the older adults. The guidelines cover only the interaction with the touchscreen, so are useful but limited in scope for the development and evaluation of apps.

Calak (2013) proposed a set of 19 heuristics based on literature of older adults' characteristics as part of his Master research. The heuristics were validated through interviews (n = 10) and online survey (n = 170) with older adults aged more than 50 years old. The study only managed to validate 9 of the proposed heuristics. The remaining 10 of the proposed heuristics such as the use of colours and animations were not validated in the study.

The set of 13 heuristics proposed by Al-Razgan et al. (2014) was developed based on existing heuristics for older Web users (Chisnell et al., 2006), literature on usability testing of mobile application (Zhang & Adipat, 2005) and existing heuristics for game design for the general population (Pinelle et al., 2008). The heuristics were validated by a group of four undergraduate students (as experts) evaluating six Android launchers. The experts rated majority (61%) of the usability problems found were rated as "no problem", indicating that the existing Android launchers suit the older adults. All experts found the heuristics were understandable, easy and simple. These heuristics limited in scope, covering only Android app launchers, meaning the interface to the smartphone or tablet, not the apps themselves.

The set of 14 heuristics proposed by Watkins et al. (2014) was built on both heuristics developed for the general population (Apple Inc, 2017; Nielsen, 1994) and heuristics developed for older Web users (Chisnell & Redish, 2005). The heuristics was developed specifically to evaluate iPad apps for older adults. The heuristics by Watkins et al. (2014) were validated with a group of three experts evaluating five health and well-being iOS apps. Eight usability problems were found relating to six of the proposed heuristics. The authors further proposed eight design guidelines to design tablet apps for older adults.

The set of 35 heuristics proposed by Silva et al. (2015) was built on existing known guidelines designed for older Web users (Chisnell et al., 2006; Kurniawan & Zaphiris, 2005) and a Master thesis developing heuristics for smartphone apps older adults (Calak, 2013). The heuristics by Silva et al. (2015) were validated with a group of 10 experts (5 experts for the iOS and 5 experts for the Android platform) to find its usefulness, strength and gaps to suit the context of designing mobile apps for older adults on two apps promoting physical exercise. A post-evaluation survey was conducted for supplementary feedback of the heuristics. In terms of the strength of the heuristics, all experts mentioned at least one strength. For example, the experts commented the good balance between concreteness and flexibility, and the heuristics consisted of a good initial point for the evaluators. In terms of the limitation of the heuristics, two experts found the length of the heuristics might make it hard to handle, one expert stated he lacked knowledge on what mental models and standards for older adults, and one expert query the purpose of the heuristics itself. After analysing the results of the evaluation and the feedback from the evaluators, a new set of 33 heuristics were proposed.

Considering how these sets of guidelines and heuristics were developed and validated, for the current study, I designed a low-fi prototype of a mobile app, MyDrinkApp, following the heuristics by Silva et al. (2015) and Watkins et al. (2014), as these heuristics are for the design and evaluation of apps for health and well-being. I also designed the app based on information gathered in the focus groups (see Chapter 3).

MyDrinkApp is designed to support older adults to monitor their liquid intake. The Apple iOS platform is chosen because it account for the leading mobile operating system in the UK[19]. As a preliminary step, to investigate common features of current health-related apps, I analysed popular 20 nutrition apps on Apple's UK App Store.

The aim of the current study is to identify potential usability problems of the MyDrinkApp using collaborative method for heuristic evaluation (CHE) Petrie and Buykx (2010) as the method and the heuristics developed by Silva et al. (2015).

CHE is a variation of the well-known expert evaluation method, heuristic evaluation (HE) developed by Nielsen (1994). In an HE, three to five experts are asked to work through a system, looking for problems that users might have, guided a set of heuristics. Heuristics are short, easy to remember guidelines of good interface design. After the experts have worked through the system, they come together and discuss all potential problems they have found and come up with an agreed list of problems, and rate them for severity. However in CHE, experts work together as a group to identify potential usability problems,

[19] https://www.statista.com/statistics/262179/market-share-held-by-mobile-operating-systems-in-the-united-kingdom/

but rate the problems privately. This creates a more interesting experience for the experts, means they are exposed to a wider range of problems and allows experts with different area of expertise to work together.

In addition to the expert evaluation, I also took the opportunity to evaluate the heuristics proposed by Silva et al. (2015) which were specifically developed to evaluate smartphone apps for older adults.

4.2 Analysis of 20 nutrition app

To investigate the common features in nutrition-related mobile apps, 20 apps available in the Apple's UK App Store were analysed. The number of apps reviewed is similar to Martínez-Pérez et al. (2013) study on analyzing apps on depression and diabetes. A content analysis (Krippendorff, 2012) was then used to categorise the features.

4.2.1 Method

An initial search of the Apple's UK App Store online store for apps using the term "nutrition" on 16th December 2014. The search returned 100 apps. To reduce the number of apps, I ignored magazine apps, apps that needed to be purchased, or apps that were developed for a specific target user group (e.g. children or pregnant women). I downloaded the first 20 apps from the search list (see Appendix 10). I used each app for a week to familiarise myself with them and to understand the features.

4.2.3 Results

A total of 26 features were identified. The three main categories that emerged from the content analysis were: Settings, Main Functions, and Additional Features. The Main Functions was the largest category with 15 features, followed by Additional Features with nine features and Settings with two features. Table 4.1 shows the three main categories of features and the frequency of specific features found within each of the categories.

Settings are features that are required in order to use the app. For example, creating a user profile. In Settings, creating a user profile and setting one's own goal (e.g. to gain, lose, or maintained weight) are the two features that repeatedly occurred in the apps. Main Functions are the main interactions between the user and the app. The user interacts with the app by entering data and in return, the app displays information associated with the data. For example, by adding daily food intake the user can see their total intake of calories for the day. Additional Features are features that support the app's functionality. This means that the user can still interact with the Main Functions of the app even though if they do not use these features (e.g. reading tips). In Additional Features, the ability to interact with other users through the app, share their progress (e.g. calories burned) via social medias or email, read tips, set reminders and do quizzes on nutrition are the features that were provided by the apps.

Table 4.1: Categories of app features and frequency of specific features

Category	**Features**	**No of Apps N (%)**
Settings	Create user profile	11 (55)
	Set own goal	9 (45)
Main Functions	View history	9 (45)
	Add food intake via database	8 (40)
	Provide recipe	7 (35)
	Calculate calories intake or calories burned	6 (30)
	Add own exercise type and duration	6 (30)
	Add food intake via barcode	5 (25)
	Add own liquid intake	4 (20)
	Add grocery list	3 (15)
	Add recipe	3 (15)
	Auto calculate steps	2 (10)
	Provide feedback (e.g. message) on user input	2 (10)
	Add own calorie count for the food intake	2 (10)
	Add menu planner	2 (10)
	Add food intake via photo	1 (5)
	Provide meal suggestions	1 (5)
Additional Features	Provide nutrition facts	10 (50)
	Provide tips (on nutrition and weight loss)	9 (45)
	Ability to link to other device, app, or web (e.g. blog)	9 (45)
	Ability to share app content (e.g. calorie burned)	6 (30)

	through email or social websites	
	Ability to communicate with other users within the app	6 (30)
	Provide reminder option	2 (10)
	Provide tips (how to use the app)	2 (10)
	Provide quizzes on nutrition	1 (5)
	Ability to change font size	1 (5)

In Main Functions, viewing performance and the ability to add food intake by searching within the app are the two most frequent features occurring in the apps. In related to the ability to add food intake, other features that were also found is adding food intake via barcodes, photos, and by providing own calorie intake. Other features related to monitoring food intake are providing recipes and meal planners, the ability to add one's own recipes, and create shopping lists. In terms of monitoring physical activities, six apps allowed the user to add their exercise routine manually (e.g. brisk walk for 60 minutes), and two apps auto-calculated the number of steps per day. Six apps provided the ability to calculate the calorie intake or calories burned based on the data added to the app.

Only four apps included monitoring liquid intake by allowing the user to manually add the volume of liquid consumed or by a defined volume (e.g. user presses buttons labeled with the volume). None of the apps allowed the user to set a daily goal for the amount of liquid they should drink. In the nine apps that provided the ability to set one's own goal, have goals to gain, lose, or maintain the current weight only.

4.2.4 Discussion

This analysis reports the 26 features in 20 nutrition apps available on Apple's UK App Store. Although the apps analysed were not for specific target users, the features in Main Functions and Additional Features, such as view intake history or provide tips on nutrition, could overcome the causes of malnourishment in older adults.

As reported in Chapter 2 Section 2.3.3, studies include those by Gollub and Weddle (2004) and Christensson et al. (1999), found a lack of nutrition knowledge, low awareness in food related activities, lack of physical movement, and dehydration as some of the causes of malnourishment in older adults. Only eight apps analysed had a feature to monitor food intake by any means for example via searching the database or by taking photos. Only nine of the apps provide knowledge on nutrition, particularly on how to lose weight. Although the apps for chosen for nutrition, seven apps included a feature to monitor physical activities. Six of these apps provided the ability to calculate the number of calories burned by performing the physical activities. Little attention was given in these apps to monitoring liquid intake, for example by allowing the user to set a daily goal for liquid intake. Of the two apps with reminders, only one app had a reminder to remind the user to drink.

4.3 Method for the Expert Evaluation of the MyDrinkApp

4.3.1 Design

Paper based low-fidelity prototypes of MyDrinkApp to support older adults in monitoring their liquid intake were evaluated by four experts using the CHE method. The number of experts is as suggested by Nielsen (1992), to have three to five experts per heuristic evaluation.

MyDrinkApp were designed for both iPhone and iPad platforms. A content analysis (Krippendorff, 2012) was conducted to categorize the usability problems identified by the CHE. In addition to the expert evaluation, I also took the opportunity to evaluate the heuristics proposed by Silva et al. (2015) which were specifically developed to evaluate smartphone apps for older adults.

4.3.2 The MyDrinkApp

Paper based low-fidelity prototypes of the MyDrinkApp were designed for iPhone and iPad platforms based on Apple's design conventions[20], heuristics developed by Watkins et al. (2014) and Silva et al. (2015), the information gathered in the focus groups reported in Study 1 (see Chapter 3, section 3.3.2) and the analysis of 20 nutrition apps (see section 4.2).

[20] https://developer.apple.com/ios/human-interface-guidelines/

The app was designed using Lucidchart[21]. The features of the app consist of the ability to set a user profile, to update the amount of liquid consumed, view one's progress, set reminders to remind user to drink, and read tips, in particular about keeping hydrated.

To add the amount of liquid consumed, two options were designed. Prior to adding a liquid intake, the user would have to set their daily goal and the default volume of the glass (see Figure 4.1a). The first option to add liquid intake consists of a with sixteen glasses (see Figure 4.1b). To update an intake, user would have to tap on each glass. A "tick" on the glass will be used to represent the fact that liquid has been added (see Figure 4.1c).

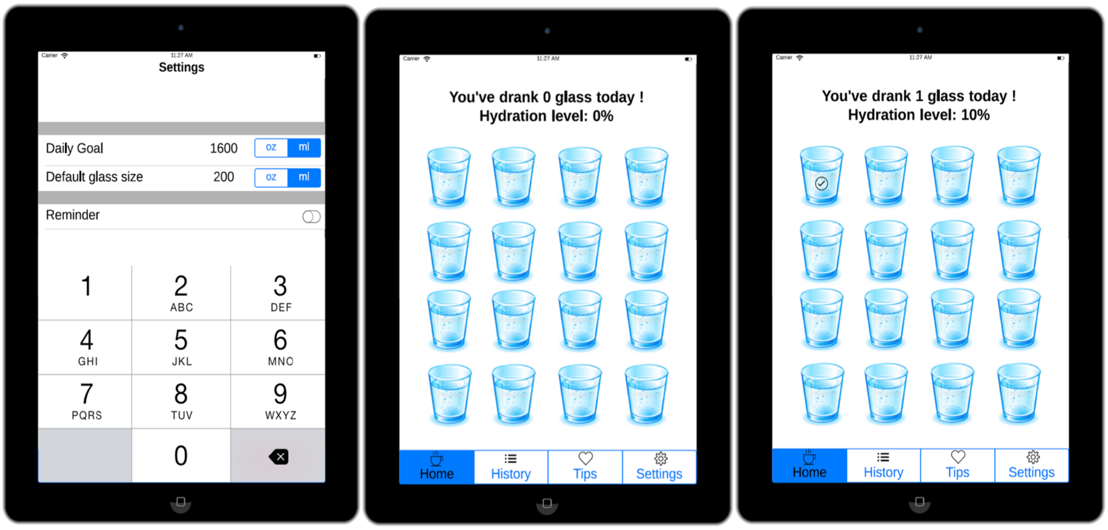

Figure 4.1. (From left): (a) the Settings screen (b) the add intake screen with sixteen glasses, and (c) a "tick" to represent that liquid has been added

The second option to add liquid intake consists of a screen with an empty bottle (see Figure 4.2a). To update liquid intake, user would tap on the green "Add Liquid" or the red "Remove Liquid" button. Having tapped the "Add Liquid", the user can update their intake via three options. The first option is tapping on the defined volume (see Figure 4.2b). The second option is by entering the number of glasses of liquid they had (see Figure 4.2c). The third option is by entering their own volume either in fluid ounces or millilitre (see Figure 4.2b, below). Having adding the intake, user would have to tap on the Save button (see Figure 4.2b-c). This will show an increase level of liquid in the bottle to represent the intake has been added (see Figure 4.2d). To maintain consistency, avoid confusion and

[21] https://www.lucidchart.com

reduce mental demand (Silva et al., 2015), the design to remove a liquid intake was similar.

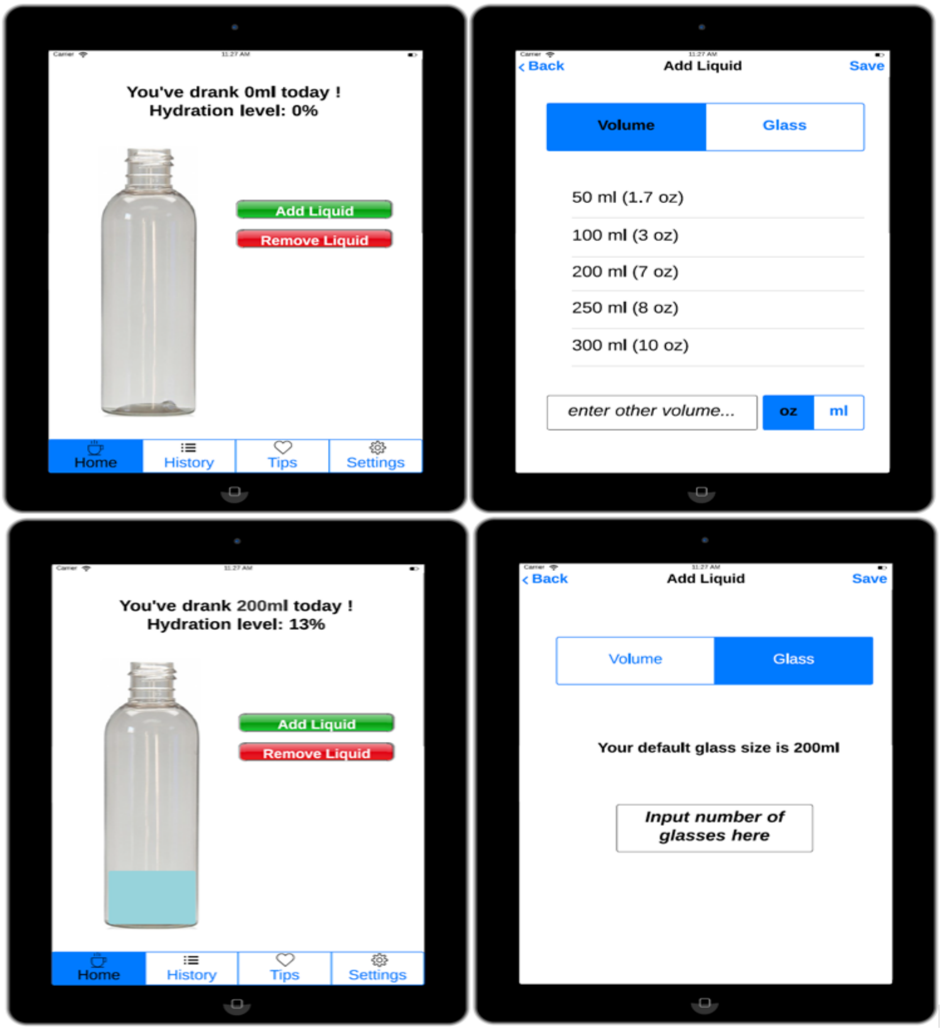

Figure 4.2. (Clockwise from top left): (a) the add intake via an empty bottle (b) add intake by defined volume and own volume, (c) add intake by entering number of glass, and (d) an increase level of liquid to represent that liquid has been added

There are two options to view one's progress. On the top of the progress screen, there is a coloured chart of the last seven consumptions (see Figure 4.3). On the bottom of the chart, there is a coloured list showing all consumptions. The traffic light metaphor (Doyle et al., 2014; Grimes et al., 2010) was used to represent progress, red represents the fact that the user has only achieved 0% to 50% of their daily target, amber represents that they have achieved 51% to 70% of their daily target, and green represents 71% of the daily target or more.

Figure 4.3. The progress screen

To set a reminder to remind users to drink, user would have to set the start time, end time and the interval they want to have the reminder messages (see Figure 4.4). Reminders were to help users consume enough liquid, particularly early in the day, and to update their intake in the app.

Figure 4.4. The set reminder screen

There were two designs for presenting tips about hydration to users. The first design consists of reading tips via multiple screen. The main tips screen consists of having several topics about tips on liquid consumption. To read the tips, the user taps on a topic, which brings them to a new screen. To avoid scrolling, the "Back" and "Next" buttons are provided to navigate between screens (see Figure 4.5a-c). The second design consists of having all the tips on one screen. To read the tips, the user scrolls up and down the screen (see Figure 4.6). The tips used in the prototypes were from reliable sources in the UK, such as the NHS[22] and British Nutrition Foundation (BNF)[23].

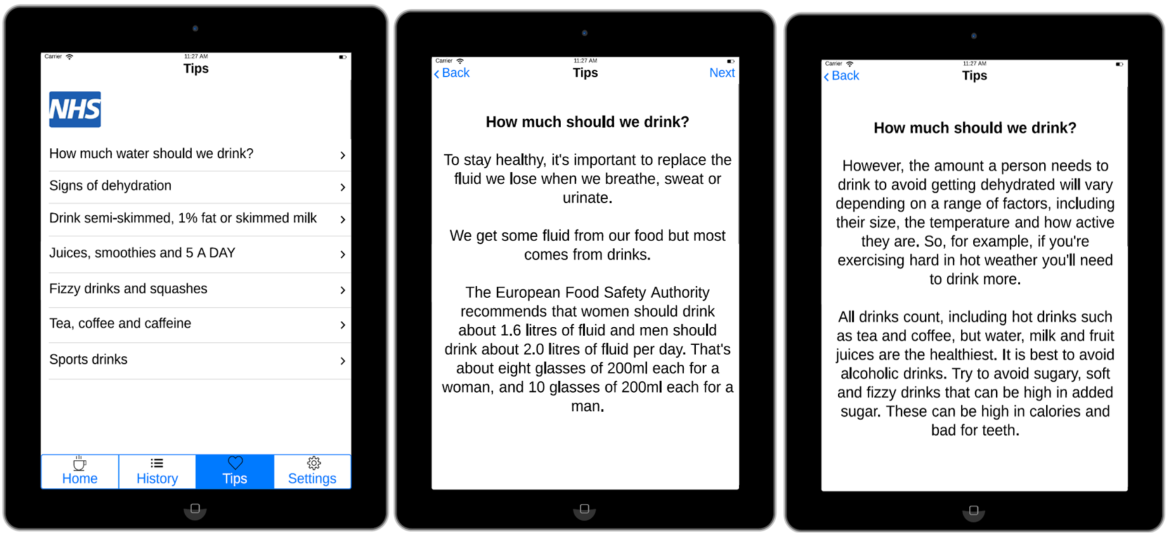

Figure 4.5. Reading tips via multiple screens

22 http://www.nhs.uk/pages/home.aspx

23 https://www.nutrition.org.uk

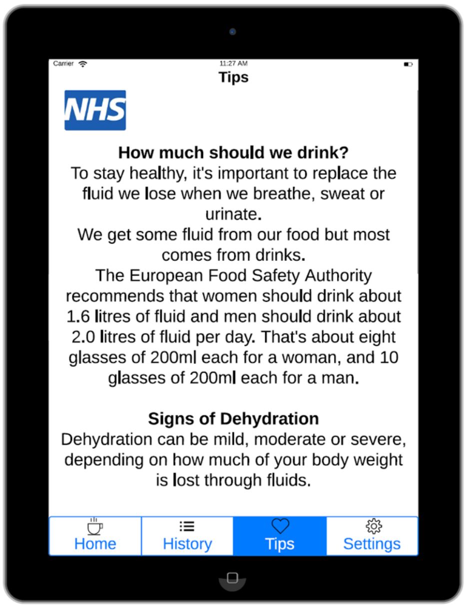

Figure 4.6. Reading tips via scrolling in one screen

To maintain consistency, avoid confusion and reduce mental demand (Silva et al., 2015), the design for adding a liquid intake, viewing progress, and reading tips were similar for both the iPad and iPhone prototype. Figure 4.3 shows some screens of the iPhone prototype.

Figure 4.7 (From left to right): (a) add intake via an empty bottle, and (b) add intake via glasses

4.3.3 Experts

Four experts participated in the CHE sessions. All experts in the current study were from the HCI Research Group in the Department of Computer Science, University of York. Two experts were professionals and two experts were postgraduate students in the department. All experts have experience with CHE and with interactive systems for older adults. Three experts are Apple users and one is an Android user.

4.3.4 Evaluation Tasks

Two tasks with two alternative options were designed for the experts to use in the evaluation. Each task was situated within a realistic scenario of use. The tasks and scenarios can be found in Appendix 11.

Each time an expert proposed a potential usability problem, all experts would then match the potential problem with the heuristics developed by Silva et al. (2015). All experts would then privately rate its severity using a five-point scale of 0 = not a problem, 1 = cosmetic, 2 = minor, 3 = major, and 4 = catastrophic (Nielsen, 1994).

4.3.5 Materials

Each expert was given the list of scenarios with the tasks (Appendix 11), and the heuristics developed by Silva et al. (2015) (Appendix 12).

4.3.6 Procedure

Three CHE sessions were conducted. Two CHE sessions were to evaluate the iPhone prototype and one session was to evaluate the iPad prototype. Experts worked as a group. Each CHE session was audio-recorded for later detailed analysis. During each CHE session, I guided the experts through the prototype. One expert recorded the potential usability problems raised by the experts. The problems were projected onto a wall so that all experts could see them clearly. The heuristics relevant to each problem were also recorded. The experts individually rated the severity using a five-point scale. Each CHE session lasted approximately 75 minutes.

4.3.7 Data Analysis

A separate list of usability problems identified in the iPhone and iPad prototypes was created. The mean severity ratings were calculated for each usability problems. A content analysis (Krippendorff, 2012) was conducted to categorize the usability problems with a priori set of categories, those developed by Petrie and Power (2012). The Petrie and Power (2012) categorization of usability problems was used as both Watkins et al. (2014) and Silva et al. (2015) did not provide the categorization of usability problems before proposing their heuristics. However those categories were developed with younger users and for interactive websites, so I was very open to the need for new or different categories. To ensure the reliability of the categorization, a second coder went through all the usability problems and any discrepancies were resolved by discussion.

4.4 Results

The experts identified 54 usability problems in the iPhone prototype and 19 in the iPad prototype.

Table 4.2 shows the categorization of usability problems identified in the iPhone prototype, their frequency and their mean severity ratings. Only three of the four major categories from the Petrie and Power (2012) categorization were found in this set of problems. These were Physical Presentation, Content and Interactivity. The major category that was not identified was Information Architecture. Over two thirds of the problems (68.5%) were found in the Interactivity category, and 22.2% were found in Physical Presentation. Less than 10% were found in the Content category.

Six sub-categories of the usability problems had a mean severity rating as major, which were “content not detailed enough”, “concerns about how to proceed”, “input format is unclear”, “options not logical / complete”, “interactive functionality expected is missing”, and “too many tasks / interactive elements presented in a single screen”. The remaining had a mean severity rating as minor. See Appendix 13 for the full list of problems identified in the iPhone prototype and their individual mean severity ratings.

Table 4.2 Categorization of usability problems identified in the iPhone prototype and the frequency of problem categories and sub-categories and the mean severity ratings of sub-categories

Category	Examples	Mean Severity Rating	% (frequency)
Physical Presentation			**22.2 (12)**
Inappropriate colours / patterns	contrast in image not sufficiently high	1.50	3.7 (2)
Text / interactive elements not large/clear/distinct enough	text at top very small	2.41	14.8 (8)
Screen layout unclear / confusing	so much blank space	1.88	3.7 (2)
Content			**9.3 (5)**
Content not clear enough	input is technical language … not clear for older users	1.88	3.7 (2)
Content not detailed enough	need an information page	2.50	1.9 (1)
Content not suitable for the users	"weight" could be more informative and friendly … for example "my current weight"	1.75	3.7 (2)
Interactivity			**68.5 (37)**
Concerns about how to proceed	what am I supposed to do … no call to action	2.81	14.8 (8)
Labels /instructions /icons on interactive elements not clear	does the set of glasses represent 100 percent of daily intake	2.38	22.2 (12)
Excessive effort required by user to complete a task	is it necessary to have an input field	2.38	3.7 (2)

Input format is unclear	keyboard not complete	2.88	9.3 (5)
Concerns about feedback on user actions and system progress	user probably wants confirmation	2.25	5.6 (3)
Design and sequence of interaction elements illogical	what order will be most natural for older people … units or selecting kg lbs	2.00	1.9 (1)
Options not logical / complete	for UK should include stone lb setting	3.25	1.9 (1)
Interaction not as expected	users might click on "Home" from here … not realizing they are in home	1.50	1.9 (1)
Interactive functionality expected is missing	no "home"	2.88	3.7 (2)
Interactive and non-interactive elements not clearly identified	save not prominent enough	1.88	1.9 (1)
Too many tasks / interactive elements presented in a single screen	too much on the screen, need to split up	2.75	1.9 (1)

Table 4.3 shows the categorization of usability problems identified in the iPad prototype, their frequency and their mean severity ratings. Similar to the iPhone prototype, only three of the four major categories from the Petrie and Power (2012) categorization were found, Physical Presentation, Content and Interactivity. The major category that was not identified was Information Architecture. A majority of the problems (84.6%) were found in the Interactivity category. Very few problems were found in the Content category (10.5%) or the Physical Presentation category (5.3%).

Four sub-categories of the usability problems had a mean severity rating as minor, which were "screen layout unclear / confusing", "content not suitable for the users", "interactive and non-interactive elements not clearly identified" and "too many tasks / interactive elements presented in a single screen". The remaining had a mean severity rating as major. See Appendix 14 for the full list of problems identified in the iPad prototype and their individual mean severity ratings.

Table 4.3 Categorization of usability problems identified in the iPad prototype and the frequency of problem categories and sub-categories and the mean severity ratings of sub-categories

Category	**Example**	**Mean Severity Rating**	**f % (N)**
Physical Presentation			**5.3 (1)**
Screen layout unclear / confusing	a lot white space wasted and is confusing … is something loading	1.75	5.3 (1)
Content			**10.5 (2)**
Content not clear enough	language is too technical and jargon	2.50	5.3 (1)
Content not suitable for the users	no personal or friendly messages	1.75	5.3 (1)
Interactivity			**84.2 (16)**
Concerns about how to proceed	not clear what to do to set a glass size from this screen	2.81	21 (4)
Labels /instructions /icons on interactive elements not clear	"default glass size" is confusing	2.50	5.3 (1)
Excessive effort required by user to complete a task	oz and ml need to go together for all measurements	2.75	5.3 (1)
Input format is unclear	Alice may wish to set a number of cup glass sizes measures	2.75	10.5 (2)
Concerns about feedback on user actions and system	not clear which task will happen if Alice enters a number … relies on her	2.88	10.5 (2)

progress	recalling her tasks		
Interactive functionality expected is missing	no back and cancel option	2.67	15.8 (3)
Interactive and non-interactive elements not clearly identified	oz and ml settings are confusing … you do not change them on this screen these are the set values but look changeable	2.00	5.3 (1)
Too many tasks / interactive elements presented in a single screen	why is daily goal here at all	2.25	10.5 (2)

4.4.1 Experiences in using the Silva et al. (2015) heuristics

Only three usability problems found were not addressed by the heuristics proposed by Silva et al. (2015) (two in the iPhone prototype and one in the iPad prototype, see Appendix 15).

Of the 33 of the Silva et al heuristics, only 20 were used in the evaluations. This is partly because some of the heuristics were not relevant for the prototype. For example, the prototype does not contain any animations or moving objects, so *H3: Avoid the use of animation and fast-moving objects* is not relevant for the prototype. However, the experts had numerous difficulties in using the heuristics, which are summarized in Table 4.4. The experts also commented that the set of heuristics is very long, which adds a further layer of difficulty in using them.

Table 4.4 Experts' comments on the Silva et al. (2015) heuristics

N.B. * = used in iPhone evaluation, ‡ = used in iPad evaluation

Silva et al Heuristic	**Experts' comments**
H1. Focus on one task at a time instead of requiring the user to actively monitor two or more tasks, and clearly indicate the name and status of the task at all times. * ‡	Three different points in one heuristic. One heuristic should be about focusing one task at a time; the other about clearly labelling the task, so the user knows what they are doing; and the third about providing information about the status of the task at all times.
H2. Avoid the use of interaction timeouts and provide ample time to read information.	Contradictory information – if the developer is to avoid timeouts, then providing ample time is not relevant.
H3. Avoid the use of animation and fast-moving objects.	
H4. Leverage mental models familiar to older adults. * ‡	Difficult to know what mental models older adults have. This is not a heuristic.
H5. Reduce the demand on working memory by supporting recognition rather than recall.* ‡	
H6. Aim at creating an aesthetical user interface, by using pictures and/or graphics purposefully and adequately to minimize user interface clutter and avoid extraneous details.* ‡	Two different points in one heuristic. One heuristic should be about using pictures and / or images to create a suitable interface; the other is about to minimise user interface clutter and avoid unnecessary details. Simpler words should be used.
H7. Give specific and clear instructions and make help and documentation available. Remember that it is better to prevent an error than to recover from it.* ‡	Two different points in one heuristic. Providing specific / clear instructions and having help documentations are two different heuristics.

H8. Provide clear feedback and when presenting error messages make them simple and easy to follow.* ‡	
H9. Make sure errors messages are descriptive and use meaningful words and verbs when requiring an action.* ‡	Partly overlaps with H8.
H10. Write in a language that is simple, clear and adequate to the audience.*	
H11. Avoid pull down menus.	
H12. Avoid the use of scrolling.*	Why is this important?
H13. Enlarge the size of user interface elements in general; targets should be at least 14mm square.*	
H14. Keep the user interface navigation structure narrow, simple and straightforward. ‡	
H15. Use consistent and explicit step-by-step navigation.* ‡	
H16. Make sure that the "Back" button behaves predictably.	
H17. Support user control and freedom, allowing or alternative and flexible flows of interaction. * ‡	
H18. Disable inactive user interface objects.	
H19. Do not rely on color alone to convey information. Be aware of color blindness.	
H20. Provide not only visual feedback, but also tactile and auditory.	
H21. Make information accessible through different modalities.	

Silva et al Heuristic	**Experts' comments**
H22. Use lower frequencies to convey auditory information such as confirmation tones and alerts.	
H23. Do not use pure white or rapidly changing contrast backgrounds. ‡	
H24. Make it easy for people to change the text size directly from the screen.	
H25. Use high-contrast color combinations of font and/or graphics and background to ensure readability and perceptibility; avoid using blue, green and yellow in close proximity. *	Two different points in one heuristic. One heuristics should be about not using high-colour contrast combinations to ensure readability and perceptibility. The other heuristics is confusing. The wordings are ambiguous. It is unclear whether they mean avoid using blue and green together, green and yellow together, blue and yellow together or avoid using all three colours all together.
H26. Use color conservatively, limiting the maximum number of colors in use to ~four.	
H27. Make sure text uses types, styles and sizes appropriate to older adults, that is, for instance, but not exclusively: large-sized fonts, sans serif, non-condensed typefaces, non-italic, and left justified. *	
H28. Make links and buttons clearly visible and distinguishable from other user interface elements. *	
H29. Make information easy to read, skim (or) and scan.	

H30. Group information visually (make good use of color, text, topics, etc.).	
H31. Allow sufficient white space to ensure a balanced user interface design. *	
H32. Use user interface elements consistently and adhere to standards and conventions if those exist. *	Two different points in one heuristic. One heuristics should be on having consistent user interface elements; the other should be about adhering to standards and conventions (if those exists)
H33. Use simple and meaningful icons. *	

4.5 Discussion

This study presented the design and expert evaluation of the iPad and iPhone prototypes of an app, MyDrinkApp, to support older adults in monitoring their liquid intake. 73 usability problems were identified in both prototypes and grouped in three major categories: Physical Presentation, Content and Interactivity. Interactivity was the most frequently used category.

4.5.1 Experiences in using Silva et al. (2015) heuristics

In addition, this study also took the opportunity to evaluate the heuristics proposed by Silva et al. (2015) which were specifically developed to evaluate smartphone apps for older adults. Although the experts did find that most of the problems identified could be categorised by the heuristics, the experts struggled to use them. The experts raised numerous concerns about the appropriateness, wording and clarity of the heuristics.

A heuristic should be simple, clear and straightforward, and consist of just one point (Nielsen, 1994). However, Silva et al. (2015) had multiple heuristics consisting of two or more points per heuristic. For example, H1, H6, H7, H25 and H32 had more than one point per heuristic. The experts argued that this was rather confusing than helping them to use the heuristics. In H32, it describes *"Use user interface elements consistently and adhere to standards and conventions if those exist."*. The experts argued that designing user interface consistently and adhering to a specific standards and conventions are two different points and should be separated. Similar to H1, it describes *"Focus on one task at a time instead of requiring the user to actively monitor two or more tasks, and clearly indicate the name and status of the task at all times."*. This heuristics itself carries three points in one heuristic. The experts commented that focusing on one task at a time should be one heuristic. Clearly labeling the task, so the user knows what they are doing should be a different heuristics, and providing information about the status of the task at all times should another heuristic.

In terms of H4, it describes *"Leverage mental models familiar to older adults."*. Silva et al. (2015) noted that they remained having this heuristic, as the concept of mental models should be well understood by an HCI expert. However, the experts in our study commented that it is impossible to understand the concept of mental models that an older adults have. Thus, we argued that this should not be a heuristics itself.

In H2, *"Avoid the use of interaction timeouts and provide ample time to read information."* provides contradictory information. The experts commented if the developer is to avoid timeouts, then providing ample time is not relevant. The experts in Silva et al. (2015) also noted that this heuristic is rather confusing and needs revision, but Silva et al. (2015) did not know how to improve the understanding thus no revision took place, as exemplified in the following text:

"these heuristics could possibly need revision, but as no specific reasons for not understanding the heuristics were provided by the evaluators, the authors did not know how to improve their understanding and no revision took place" p3245

In H12, it describes *"Avoid the use of scrolling."*. The experts raised their concern as Silva et al. (2015) came with this heuristics from their experts' point of view. They did not take in consideration the older adults perspective. In Piper et al. (2010) study, they found that the older adults preferred scrolling using hands gestures as compared to using buttons whilst using a touch screen. We argue that, in order to have such heuristics, we need to include the older adults' perspectives rather than solely what the experts think.

In overall, the experts commented that the set of heuristics is very long and has no high level structure, which adds a further layer of difficulty in using them. The experts also noted that many of the heuristics feature in general usability heuristics and it would be helpful to have a set of heuristics which concentrate on the additional aspects important for older users, and not mix them with heuristics for all users, which people are likely to already be familiar with.

4.6 Re-designed of MyDrinkApp

4.6.1 Experts suggestions to improve MyDrinkApp

Based on the usability problems, the experts suggested some design recommendation to improve the MyDrinkApp based on the heuristics developed by Silva et al. (2015). The explanations of the suggestions are discussed below.

Physical presentation and content

Referring to H31 in Silva et al. *"Allow sufficient white space to ensure a balanced user interface design"*, the experts suggested making the icons, labels and text size bigger especially in screen that have too much blank space *(H13: "Enlarge the size of user interface elements")*. To attract the older adults to use the app, the experts suggested using informative and friendly wordings, such as 'My Weight' rather than 'Weight', as following H10: *"Write in a language that is simple, clear and adequate to the audience"* in Silva et al. They also suggested avoiding using any jargon wordings such as "input" or "settings" in the app.

Options to complete tasks

Another usability problems raised by the experts were the lack of freedom for the users to choose their preferable option in completing tasks. Experts referred these usability problems to H4 in Silva et al. *"Leverage mental models familiar to older adults"*. In few interfaces, such as to enter their weight, I did not cater the possibility of entering 'stone' as an option. The experts noted that in the UK, especially among older adults, 'stone' is often used as compared to the younger people. The experts also suggested providing different measurement options to update the liquid intake. They suggested having the options such as mugs, cups or glasses rather than having a fixed measurement option to add the liquid intake.

Universal design for smartphone and tablet computer apps

The experts also raised their concern of using the universal design principle for smartphones and tablet computers apps. It was my intention to make the app similar between both devices to avoid confusion among the older adults upon using the app. I further read the literature to get more understanding of this matter. Nielsen (2010) found that killing time is a major use of smartphone and tablet computers. However, the context of use between these two devices differs. A participant in his study noted that s/he uses a tablet computer if s/he is not in a rush. Thus, Nielsen justified that if a user were to wait for a few minutes at a train station, they might be wanting to use a smartphone to kill the time. However, during the train journey, they might be wanting to use a tablet computer. Therefore, Nielsen recommends that an iPad app should not be a scaled-up version of an iPhone app as the user interaction and the context of use between these two devices are different.

Moreover, researchers began investigating the use of mobile devices, including smartphones (Choudrie et al., 2014; Hardill & Olphert, 2012; Kurniawan, 2008) and tablet computers (Müller et al., 2012) among older adults. These studies investigated the activities that were commonly used by the users with the mobile devices and also investigated the time when these devices were commonly used. Müller et al. (2012) found that tablet computers were often used at home rather than outside as compared to using a mobile device while they are outside rather than in the home (Kurniawan, 2008).

Thus, the experts in the current study suggested designing an app to suit the context of use in these two devices. The experts suggested the features of updating the liquid intake might be needed when the older adults are both in the home or outside and any other features, for example reading tips or setting daily goals, might be used only when the users are at home.

Input techniques for data entry

Referring to H12 in Silva et al. *"Avoid the use of scrolling"*, the experts were also concerned with the use of scrolling, for example to enter weight, liquid volume or setting time reminder. A picker was designed because of the lack of space, especially on an iPhone, which could bring difficulty among the users to type-in the values in a limited space (de Barros et al., 2014; Longoria et al., 2004). However, the experts were concerned to scroll, for example from 0 to 150 pounds, might be an effort for an older adult to enter their weight. In terms of setting a time reminder, the experts were aware of using the ‘time picker’ is Apple’s design convention (Apple Inc, 2017). However, the experts were still concerned about the spacing in between the ‘hour’ and ‘minute’ of the ‘time picker’ might be too small for older adults.

The type of number keyboard was also a raised as a usability problem. The experts were concerned about the possibility of user wanting to enter a decimal place, for example to enter liquid volumes in litre. Following Apple’s design convention, a ‘Number Pad’ keypad only provides the number 1 – 9, 0 and an ‘X’ button and is used for the iPhone interface. Differently, the ‘Numbers and Punctuation’ keypad provides both numbers and punctuation and is used for the iPad interface. Figure 4.8 shows the difference in these two types of Apple’s number keypad. However, in relation to the small screen of a smartphone, the experts suggested avoiding using keypads as the mean to enter data. They suggested updating the liquid intake via buttons might be preferable by the older adults.

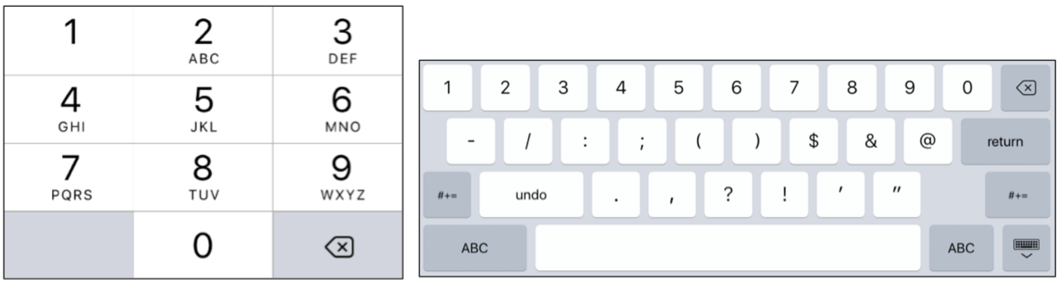

Figure 4.8. (From left): (a) the “Number Pad” keypad for an iPhone interface, (b) the “Numbers and Punctuation” keypad for an iPad interface

The changes in the design for the refined version of MyDrinkApp are discussed below.

4.6.2 Refined version of MyDrinkApp

A low-fidelity paper prototypes of MyDrinkApp had been re-designed. All problems raised during the CHE were taken into consideration during the re-design stage. All design suggestions given by the expert were also taken into consideration. The changes are discussed below.

The experts were concerned about the layout of the app, text styles, images, blank spaces within the app, gaps between the icons, colours and contrast used in the prototype. The experts commented that the design of the screens should be consistent throughout the whole app.

To ease the readability of this chapter, the MyDrinkApp used in the current study will be called "MyDrinkApp_v1". The redesigned of MyDrinkApp will be called "MyDrinkApp_v2".

Features of MyDrinkApp_v2

For the tablet computer prototype, the features consist of the ability to set a profile, add liquid intake, view profile, view intake progress, set reminders and read tips related to hydration. To suit the more limited context of use of smartphones, only the adding liquid intake feature was designed.

Physical presentation

For the tablet computer prototype, the font size for the text was at least 24px. For the smartphone prototype, the font size for the text was at least 16px. The target size for button for both prototypes was at least 1.5cm (height) x 1.5cm (width) each (Kobayashi et al., 2011). The gap in between targets was at least 5mm (Jin et al., 2007). All text for both prototypes was non-italic and black on a white background.

To maintain consistency, avoid confusion and reduce mental workload, there were only one task per page (Silva et al., 2015). It should be noted that certain tasks had a few steps thus were spread over a few screens. Numerous instructions and messages were also given throughout the MyDrinkApp_v2 (Hollinworth & Hwang, 2009). In addition, the design of the features for adding a liquid intake was similar in both prototypes.

The Home Screen

One of the problems highlighted by the experts was the possibility of the user might click on "Home" whilst not realizing they are in the Home screen. The experts were also concerned about the number of options or tasks presented at the bottom of the Home screen. The experts also commented that the wordings used in the app were not informative and friendly for older adults. See Figure 4.9 for the Home screen of MyDrinkApp_v1. It was decided to have a separate screen as a Home screen consisting buttons for all features of the prototype. Experts also suggested having background colours rather than black and white. Verbs were added to make the app more informative and friendly, for example “Tips” to become “Read Tips to Keep Hydrated” (Silva et al., 2015). See Figure 4.10 for the Home screen of MyDrinkApp_v2.

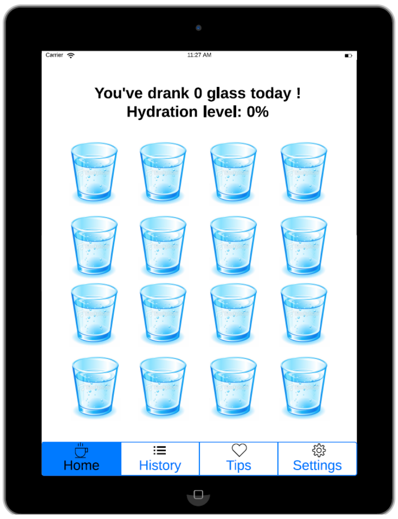

Figure 4.9. Home screen for MyDrinkApp_v1

Figure 4.10. Home screen for MyDrinkApp_v2

The Add-a-drink Screen

The experts repeatedly commented that the MyDrinkApp_v1 had no call to action to most of the tasks and can confuse the user to use the app. For example, in Figure 4.9, the experts raised their concern that the older adults will not know how to add their liquid in this screen. There were no instructions given to add an item. They also commented that the text message and the images used were inconsistent. They highlighted, the text message says “You’ve drank 0 glass today” yet the glasses on the screen are all full. A major re-design was made to the Add a Drink screen for MyDrinkApp_v2, as shown in Figure 4.11. A welcoming message was included. The text message of the liquid consumption tallies with the images of the glasses and an instruction was provided on how to add a drink. Figure 4.12 shows the text messages and changes in instruction after the adding liquids.

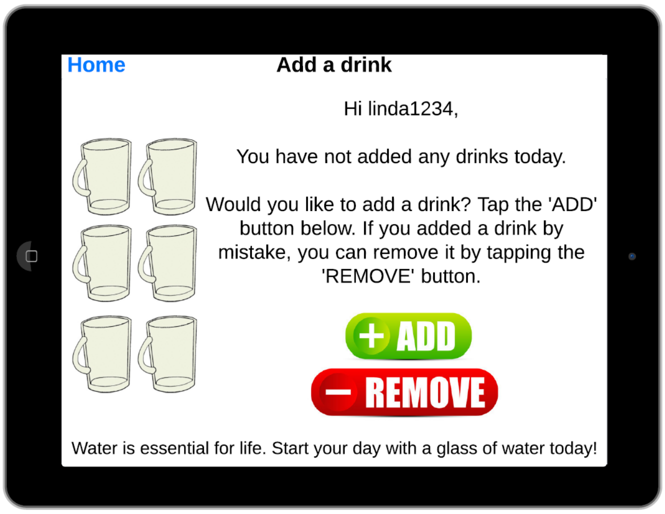

Figure 4.11. The Add a Drink screen for MyDrinkApp_v2

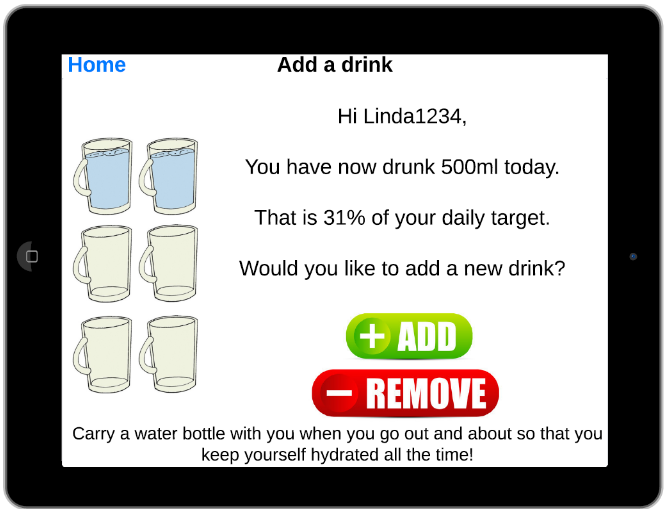

Figure 4.12. The Add a Drink screen (after updating drinks) for MyDrinkApp_v2

To add a liquid intake in MyDrinkApp_v2, three alternative options were offered to users for evaluation. The layout of the options is similar except for the image that represents the intake amount. The first option used is an image of an empty bottle (see Fig 4.13a), which then fills up as the user adds liquid during the day. When the bottle is full, the daily target liquid intake has been reached. The second option consists of a measuring jug with a measuring scale on its side (Fig 4.13b). The third option consists of six mugs, which when full represent the daily intake target (Fig 4.13c).

Figure 4.13. (Clockwise from top left): (a) add intake option 1, (b) add intake option 2, and (c) add intake option 3)

Options to complete tasks

Another usability problem that the experts raised was the limited options available in the app to perform a task, for example to update liquid intakes. Experts commented that users might wish to set a number of cups, glass sizes, or even inputting their own measures. Thus, two other options to add an intake were designed in MyDrinkApp_v2. For both prototypes, the first option uses buttons (Figure 4.14(a) and Figure 4.15(a)). The second option for the iPad only, uses a picker (Figure 4.14(b)). The second option for the iPhone, to suit the small screen, is a keypad on which the user enters the amount of liquid directly (Figure 4.15(b)).

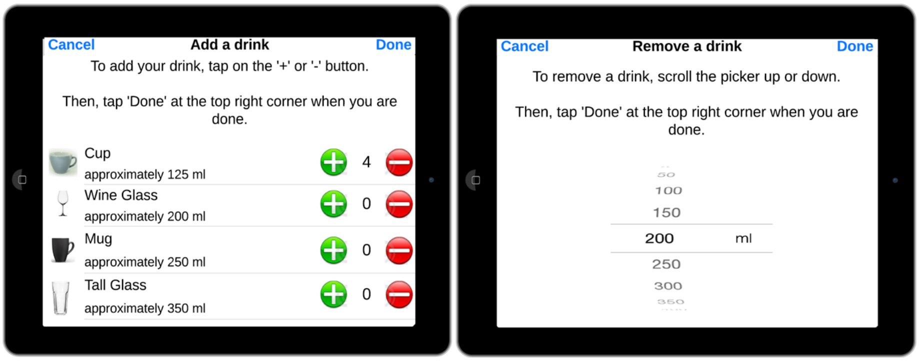

Figure 4.14. (From left to right): (a) add intake via buttons, and (b) add intake via picker for the iPhone prototype for MyDrinkApp_v2

Figure 4.15. (From left to right): (a) add intake via buttons, and (b) add intake via keypad for the iPhone prototype for MyDrinkApp_v2

The Settings Screen

Figure 4.16 shows the Settings screen for MyDrinkApp_v1. This screen requires the users to input all information that is needed to calculate the recommendation liquid per day, for example their weight and physical activity level. Problems with the highest severity that were rated by the experts were that there were no call to action to proceed with any tasks in this screen, the default values were confusing, having too many tasks on the screen and the labels were confusing.

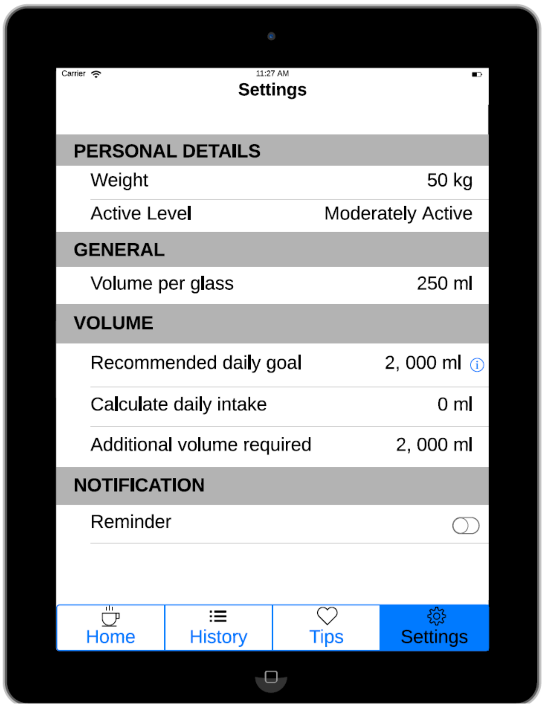

Figure 4.16. Old design for Settings screen

A major re-design was also done for the Settings screen for MyDrinkApp_v2. It was decided to remove the Settings screen due to the possibility of confusion of the name itself. The experts commented that perhaps the user would not know that by tapping "Settings" would take them to a user profile for entering info such as weight. It was decided to have a User Profile screen. The users would have to provide some information, which includes their weight, physical activity level, liquid target, e-mail address and username prior adding the liquid intakes. Rather than having all tasks in one Settings Screen (see Figure 4.16), the MyDrinkApp_v2 consists of having only one task per screen as following the heuristics H1: *"Focus on one task at a time instead of requiring the user to actively two or more tasks"* in Silva et al. (2015). In addition, a plenty of instructions and messages were given (Hollinworth & Hwang, 2009; Watkins et al., 2014) to complete a task. This flow of getting inputs from the users was the same throughout the design of MyDrinkApp_v2. An example to set the Unit of Measurement (UoM) for the liquid is explained below.

Figure 4.17 – Figure 4.19 shows the process to set the UoM for the liquid. This feature is required to allow the user to select a measurement option they prefer to view their liquid intake. The top part of Figure 4.17 provides the explanation of having the UoM. The middle part provides the instruction on how to select a UoM option. The bottom part provides the options to set the UoM for the liquid. The colours of the interactive and non-

interactive buttons are different (H18: *"Disable inactive user interface objects"* in Silva et al.). As such, users cannot proceed to 'Next' if they have yet to set the UoM for the liquid. By default, the 'Next' button is grey. Upon selecting an option, a tick will appear on the right side of the selected option and the 'Next' button will change to blue indicating it is clickable (see Figure 4.18). After tapping 'Next', a confirmation screen will appear to remind and to reduce mental demand workload of the older adults of what option did they selected previously (see Figure 4.19).

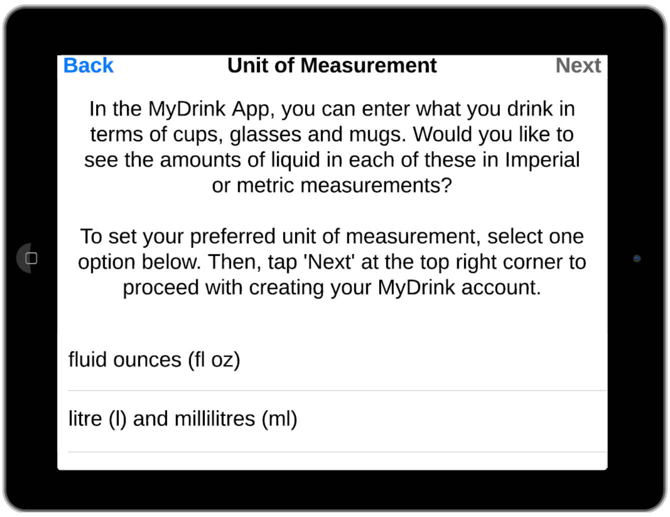

Figure 4.17. The Unit of Measurement for liquid screen before selecting an option

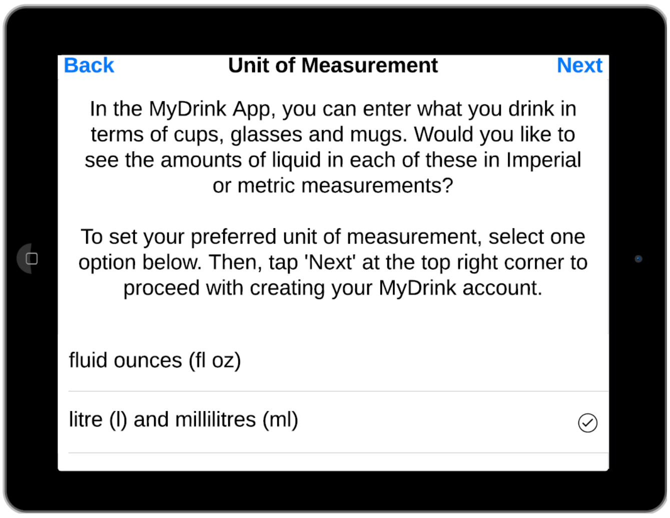

Figure 4.18. The Unit of Measurement for liquid screen after selecting an option

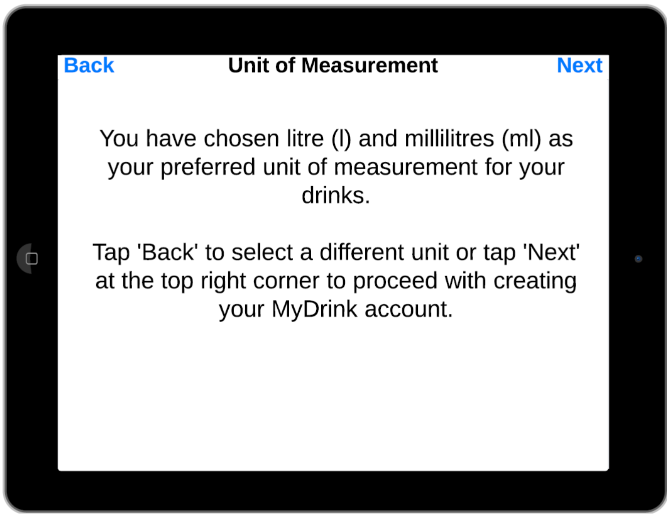

Figure 4.19. A confirmation message after tapping "Next" from the Unit of Measurement for the liquids screen

4.7 Conclusion

This study reports the usability problems found by a group of experts using a low-fidelity MyDrinkApp prototype designed for older adults. Four usability experts found a total of 73 usability problems. After analyszing the problems encountered and the suggestions given by the experts, a major re-design of the app was done to solve the usability problems before proceeding with the user evaluation. This study also reports the difficulties the experts faced in evaluating the heuristics proposed by Silva et al. (2015) which were specifically developed to evaluate smartphone apps for older adults.

As a conclusion, a user evaluation will be conducted to evaluate the refined version of MyDrinkApp. On the basis of the difficulties in using Silva et al. (2015), I planned to develop a refined and shortened version heuristics guideline for mobile apps for older adults.

Chapter 5

Study 3: User Evaluation of a Low-Fi Prototype of the MyDrinkApp for Liquid Monitoring

5.1 Introduction

Many researchers have shown that including older adults early in the design process leads to systems that meet their needs better (Abdul Razak et al., 2013; Davidson & Jensen, 2013; de Barros et al., 2014; Fan et al., 2012; Massimi et al., 2007b; Pedell et al., 2013b). Please see Chapter 2 for further reading on these studies.

Therefore this study evaluated the acceptability and usability of a low-fidelity prototype of the MyDrinkApp to monitor older adults' liquid intake. Both iPad and iPhone prototypes were re-designed based on information gathered in the focus groups reported in Study 1 (see Chapter 3), the CHE evaluation in Study 2 (see Chapter 4), and the literature on mobile app design guidelines for older adults (see Section 4.6.2).

In addition, this study explored the use of verbal protocols. The main two types of verbal protocols are the concurrent verbal protocol (CVP) and retrospective verbal protocol (RVP). CVP is a technique often used to understand users' understanding of and usability problems encountered an interactive system (Lewis, 1982). In this technique, users are given a number of tasks to perform with an interactive system. Users are asked to articulate whatever comes into their mind as they do the tasks. The alternative to CVP is RVP, in which users verbalize their thoughts about the task while watching a recorded video of their task performance (Shneiderman, 2010). It is found that CVP and RVP may elicit different usability problems and RVP may be considered a better option in user studies (Savva et al., 2016). However, in a recent study with 18 older adults to investigate the usability and acceptability of tablet computers, 12 of the older participants preferred the CVP to the RVP (Chatrangsan & Petrie, 2017). On the basis of that result, I am taking this opportunity to use this method with older adults to evaluate the usability of the prototypes.

5.2 Method

5.2.1 Design

Paper based low-fidelity prototypes of the MyDrinkApp to support older adults in monitoring their liquid intake were evaluated by 20 older adults using CVP. The number of participants is as suggested by (Nielsen, 1994; Nielsen, 2012), to recruit 5 to 20 participants for each iterative testing process, as additional participants typically result in a saturated return in measurement validity and reliability. A content analysis (Krippendorff, 2012) was conducted to categorize the usability problems which emerged from the participants' protocols.

5.2.2 The MyDrinkApp

The refined version of MyDrinkApp is explained in Section 4.6.2.

5.2.3 Evaluation Tasks

Twenty tasks were designed to allow evaluation of all the features of the prototypes. Three of the tasks, the add intake, view progress and read tips, included considering the different alternative design options.

Given the number of tasks required to evaluate the prototypes and an evaluation of a reasonable length to ask each participant to conduct, each participant performed only four of the tasks.

See Appendix 16 for the lists of tasks.

5.2.4 Participants

20 older adults participated in the current evaluation. The inclusion criteria for the evaluation was to be 65 years or over and living independently, either alone or with a partner. They were 10 women and 10 men, with a mean age of 71 years (age range 65 – 82 years; sd: 4.7). Six participants lived alone, the rest lived with a partner. Two participants had a highest education level of primary school, seven had secondary school, three had a bachelors degree, one had a post-graduate degree, and four had professional qualifications. Nineteen participants were retirees, one worked part-time. 16 participants were Internet users with experience of using the Internet from 2 years to more than 20 years (mean: 12 years; sd: 7.9). Twelve participants were computer users with experience of using

computers from 5 months to more than 30 years (mean: 12 years; sd: 11.8). Thirteen participants were tablet computer users with experience of using the device from 4 months to 5 years (mean: 2.9 years; sd: 1.4).

See Appendix 17 for the lists of participants together with their gender and age.

5.2.5 Materials

A classical think aloud is restricted to the current thought by the user to solve the test tasks (Ericsson & Simon, 1993). In HCI research, Zhao et al. (2014) found that relaxed think aloud produced verbalizations more valuable to usability testing as compared to classical think aloud. Previous usability studies have also shown that classical think aloud may add little value in usability testing (Olmsted-Hawala et al., 2010; Van den Haak et al., 2004).

Each participant received an information sheet, informed consent form and a demographic questionnaire. A copy of these materials can be found in Appendix 18 (information sheet), Appendix 19 (informed consent form) and Appendix 3 (demographic questionnaire, similar as used in Study 1).

5.2.6 Procedure

Study sessions took place in the Interaction Labs of the Department of Computer Science, at University of York, or at the participant's own home if they preferred. Participants were invited to bring a family member or friend to the session, if they wished.

Participants were first briefed about the purpose of the study and invited to ask any questions. They then completed an informed consent form. I guided the participants through the iPad prototype first, followed by the iPhone prototype (as the iPhone had only a subset of features, and could only be used once a profile had been set up on the iPad). Multiple breaks were given throughout each session, as the participant needed.

Participants were asked to "think aloud" as they went through the prototypes, articulating their thoughts about what they were doing, problems they were encountering and pointing out features they liked. The session followed a relaxed think aloud, which prompted for participants current thoughts, as well as for reflections on their actions (Hertzum et al., 2015) as compared to using the classical think aloud.

Each time a participant proposed a problem, they were asked to briefly explain the problem. For each task with different design options, participants were asked to choose which option they prefer or they could suggest other possible designs. After completing the session, participants were asked whether or not the prototypes would be useful, whether they had any worries or concerns with the prototypes and completed a short demographic questionnaire. Participants were then debriefed and invited to ask any questions about the study. Participants were offered a gift voucher worth £25 to thank them for their time and effort. Each session was audio-recorded for later detailed analysis. Each session lasted approximately 75 minutes.

5.2.7 Data Analysis

The data analysis conducted is as described in Section 4.3.7, apart that there were no calculation for the mean severity ratings for each usability problems, as it was not asked in this study.

5.3 Results

214 usability problems were identified in the tablet computer (iPad) prototype and only 3 problems were identified in the smartphone (iPhone) prototype.

Table 5.1 shows the distribution of problems in the iPad prototype into major categories and specific categories within those major categories, the number of participants who encountered them and the total frequency of each problem. All four major categories from the Petrie and Power (2012) categorization were found, being Physical Presentation, Content, Information Architecture and Interactivity. Over half the usability problems (57%) were found in the Interactivity category, and over one third (36%) were found in the Content category. Less than 10% were found in Physical Presentation or Information Architecture.

Table 5.1 Categories of usability problems identified in the iPad prototype with percentage/number of users who encountered them and frequency of the problem category (f)

Category	**Examples**	**Users % (N)**	**f % (N)**
Physical Presentation (5.1%)			
Inappropriate colours / patterns	the colours for the history page is a bit worrying because my husband is colour blind (P5)	15 (3)	1.4 (3)
Text / interactive elements not large / clear / distinct enough	It's not clear that there are five buttons (P11)	15 (3)	1.4 (3)
Changes to content / interactive elements not noticed	I didn't realize where was the next button (P7)	25 (5)	2.3 (5)
Content (36%)			
Too much content	when I read it I don't know the answer (P15)	40 (8)	6.5 (14)
Content not clear enough	by looking at the name are you looking into all aspects of fluid intake … the name is not clear (P10)	50 (10)	9.3 (20)
Content not detailed enough	asking for weight was a bit confusing as this app is for monitoring liquid intake … why asking for weight (P1)	65 (13)	13.0 (28)
Content not suitable for the users	the image of ice … [we] shouldn't be drinking ice water (P17)	30 (6)	4.7 (10)
Contradictory content	I don't understand the two options because above you talk about the cups glasses and mugs while at the bottom you gave fluid ounces and this is confusing (P12)	20 (4)	2.3 (5)

Information Architecture (1.8%)			
Content not in appropriate order	I actually don't know where is this going … I honestly don't know the measurement of this mug (P18)	20 (4)	1.8 (4)
Interactivity (57%)			
Concerns about how to proceed	adding a drink is confusing for the first time … looking at it I thought that we can only use it once (P6)	70 (14)	13.5 (29)
Labels / instructions / icons on interactive elements not clear	what is removing a drink … [is it] removing the daily target (P2)	80 (16)	12.6 (27)
Excessive effort required by user to complete a task	why do I have to press the plus button 10 times to add 10 cups of tea in a day (P11)	55 (11)	13.0 (28)
Input format is unclear	how many letters are there for the password … do we need alphanumeric (P1)	35 (7)	3.7 (8)
Design and sequence of interaction elements illogical	now it takes me to login and not sign up … (P13)	5 (1)	0.4 (1)
Options not logical / complete	I don't have an email address or password [so I] couldn't do task … I'm lost when it comes to this (P9)	75 (15)	11.2 (24)
Interaction not as expected	even this page is not asking for my weight (P20)	15 (3)	1.9 (4)
Inconsistent interaction between elements/screens	the bottle and jugs just probe me … I didn't know where would I go with the bottles and jugs … that completely threw me (P8)	5 (1)	0.4 (1)

In related to the iPhone prototype, all 3 problems were related to the Interactivity category, in specific to the "Excessive effort required by user to complete a task" sub-category. All 3 problems were found by different participants.

5.3.1 Older adults preferences for key MyDrinkApp features

When asked for their preference for the add liquid intake, 11 participants (55%) preferred the mugs, 6 participants (30%) preferred the measurement jug, and 2 participants (10%) preferred the empty bottle option. One participant (5%) preferred the add a drink via button option (see Figure 4.13 in Section 4.6.2) as the main screen to add a liquid intake.

To read tips, 16 participants (80%) preferred reading the tips based on topic, and 3 participants (15%) preferred reading the tips all in one screen. One participant (5%) did not make a preference and did not make any suggestions to improve the design.

There were not many differences in participants' preferences for the view progress options. Eight participants (40%) preferred displaying the daily liquid consumption and the overall average liquid consumption and 10 participants (50%) preferred displaying only the daily liquid consumption without the average liquid consumption. One participant (5%) suggested displaying a graph of the seven latest liquid consumption only. The remaining two participants who did not have a preference or suggestions were concerned about the usability issues of the screen more than offering a preference, as exemplified by the following comment: *"I'm colour blind ... I can't see the red and green"* (P6).

5.4 Discussion

This study reports on the user-based evaluation with 20 older adults of the MyDrinkApp prototype to support older adults in monitoring their liquid intake. The iPad prototype produced 214 instances of usability problems, a disappointingly large number. The iPhone prototype produced only three usability problems, but had a much more limited functionality compared to the iPad prototype.

Both prototypes were designed following heuristics proposed by Silva et al. (2015) and Watkins et al. (2014), specifically for apps for older people. However, both these sets of heuristics were developed from reviewing the literature rather than on empirical work with older people. It was clear from the comments made by participants and the usability problems they encountered, that my interpretation of some of these heuristics lead to a prototype that was not suitable for this group of older people, who were quite typical of British people in their 60s and 70s living independently.

For example, the first heuristic proposed by Silva et al is "Focus on one task at a time instead of requiring the user to actively monitor two or more tasks, and clearly indicate the name and status of the task at all times" (H1). I followed this heuristic by only presenting one task per screen in the tablet version of app. However, a number of the problems in the category of "Excessive effort required by user to complete a task" related to only having one task per screen (9 problems encountered by 6 of the participants). Participants commented that they were losing their focus in using the prototype because the task was spread over too many screens and there were too many clicks to get through the screens to complete a task.

Another heuristic from Silva et al is "Give specific and clear instructions and make help and documentation available. Remember that it is better to prevent an error than to recover from it" (H7). Of the excessive effort problems, 10 problems (encountered by 7 participants) were related to the effort of reading too many instructions and messages. These participants commented that they did not need so many instructions. In screens that required participants to read text or instructions on how to complete a task, they would just skim the text and not read them thoroughly. This is different from the conclusions from Hollinworth and Hwang (2009) that older adults need more instructions to successfully executive computer tasks.

These two issues mean that the majority of the 28 problems in the category of "Excessive effort required by user to complete a task" could have been avoided if I had put several tasks on a screen and cut down the amount of instructions. In fact, the older participants seemed very similar to younger users, they wanted to get on with things quickly, did not like having to navigate through a lot of screen with a lot of clicks and only skimmed through instructions.

To provide the fundamental task of adding and removing liquid intake, I followed the Silva et al. (2015) heuristic "Use simple and meaningful icons" (H33) and Watkins et al. (2014) heuristic "Use icons with symbols and text that clearly indicate the icon's function" (R1) (see Figure 4.11 in Section 4.6.2). I also labeled the buttons with verbs as recommend by Silva et al. “Make sure they are descriptive and use meaningful words and verbs when requiring an action”. However, all the problems (27 problems encountered by 16 participants) in the specific category of “Labels /instructions /icons on interactive elements not clear” related to this issue. Participants often commented that the labels and icons for the interactive elements were not obvious in their meaning and if the prototypes were to be in a real system, they would need to explore by try-and-error to figure out what each interactive element did.

In addition, there were two lessons learnt from this evaluation which did not relate to the heuristics used. Firstly I found that when choosing between a number of options, the older participants preferred buttons arranged top to bottom in a list form (see Figure 5.1(b)) than buttons arranged side-by-side (see Figure 5.1(a)). The readability of the labels on the buttons was clearer in a list form than side-by-side, and reading down a list may be more natural as the cognitive precursor to making a selection than reading the labels on an array of buttons.

Figure 5.1. From left. (a) The design of the buttons in the Home Screen, (b) The design of the buttons in the Main Screen

Secondly, one of the Interactivity categories of problems was “Concerns about how to proceed” where 14 participants encountered a total of 29 problems. Of these, 7 problems (encountered by 7 participants) were related to the use of the picker. Although the picker is a common input technique for touchscreen devices, the participants in the current study found the picker difficult to use. These participants commented that their physical abilities, such as poor vision and hand tremor, caused them to have difficulties in controlling the picker.

5.4.1 **Older adults design preferences and suggestions for MyDrinkApp**

For the add liquid task, 11 (55%) of the participants preferred the mugs option (see Figure 4.13(c) in Section 4.6.2) because it is easier to visualize the amount of liquid they have consumed as compared to view the water bottle or the measurement jug. One participant commented:

> *I prefer the mugs option because we can know how much you drinking based on the number of mugs or so and we have more idea of what we're drinking p2*

Participants suggested showing the exact number of mugs to tally with the daily liquid recommendation, as exemplified in the following comment:

> *I recommend the number of cups should tally then with the recommendation earlier on it's easier for us to think about it then p14*

Participants also suggested simplifying the process to add a drink. They preferred as few steps as possible to complete the task. One of the participants commented:

> *I would say the design should be very simple with a few steps the simplest way is that you open it ... it tells you the time have your images tap add and that's it and you can do that in a couple of seconds as little as possible steps the better p18*

Participants also suggested removing the features that allow users to update their liquid intake via inputting their own liquid volume rather than via the mugs, glasses, cups and tall glass options. They also suggested removing the feature to set own daily liquid recommendation, as exemplified in the following quotes:

> *can we simplify the add a drink features can you skip the part the user add own value here ... I think by having 2 options will make the system too complicated p20*

> *why not just stick to recommending the amount we suppose to drink water that's the purpose of this design isn't p19*

For reading tips, 16 participants (80%) preferred reading the tips screen by screen rather than reading the tips all in one screen. Participants commented that the amount of text to read in one screen can be tiring, boring and perhaps can lead to missing reading important tips. Some of the quotes by the participants include:

> *I prefer option 2 for the tips because scrolling can get bored with all those words p8*
>
> *I prefer option 2 you might miss some important thing if you keep on scrolling p12*

5.5 Conclusions

This study reports the 217 usability problems on the user-based evaluation with 20 older people of the prototype of the MyDrinkApp to support older adults in monitoring their liquid intake. Although the iPad version of the app revealed a disappointing number of usability problems, a number of interesting issues were highlighted by this evaluation. In particular, researchers should be wary of heuristics which make broad assumptions about the capabilities and preferences of older users. Older people are more heterogeneous than younger people in their capabilities and possibly in their preferences in relation to computing devices and apps. As the "baby boomer" generation ages, successive cohorts of older computer users will be more familiar with computing conventions and in exploring how to learn to use new devices and apps. This change can already be seen in this evaluation, with older participants only skimming instructions and being almost over-eager to get on with their task, behaviour usually associated with younger users. However, researchers and developers do need to be cautious about new developments which challenge the physical capabilities of older users. The resistance to the picker in this study is an interesting case in point.

Although there is a considerable amount of research on interaction techniques for computer, including tablets, that are appropriate for older people (see Chapter 6 for more supporting literature review in this area). However, little research has investigated the use of number picker as an interaction technique. Thus, before proceeding with an overall re-design and development of a hi-fidelity app, I was interested to investigate the suitability of the picker for number entry for older users on tablet computers.

Therefore, for the next study of the programme of research, I investigated older adults' performance with a number of interaction techniques for number entry tasks on both tablet computers and desktop computers. I was also interested to investigate their opinions and preferences for the different interaction techniques.

Nevertheless, all design preferences, comments and suggestions given by the participants in the current study were taken into consideration in the development of a hi-fidelity version of the MyDrnkApp to support older adults to monitor their fruit, vegetables and liquid intakes.

Chapter 6

Study 4: An investigation into older adults' interaction style on iPad and PC for number entry tasks

6.1 Introduction

In the previous study on the acceptability and usability of MyDrinkApp for older adults (see Chapter 5), the participants highlighted their concern about the use of the touchscreen for entering numeric information, and in particular the use of the number "picker" frequently used on tablets (see Figure 6.2, below). Thus, before proceeding with an overall re-design and development of a hi-fidelity app on healthy living, I investigated the suitability of the picker for number entry tasks for older users on tablet computers. As background to this study, a supplementary literature review on empirical studies about how older adults perform with interaction techniques on both personal computer (PC) and tablet computers is provided in Section 6.2 below.

Therefore, this chapter presents a study which investigated older adults' performance with a number of interaction techniques for number entry on both tablet and desktop computers. It also presents results on older adults' opinions and preferences for the different interaction techniques.

6.2 Research on interaction techniques with tablets for older users

This supplementary literature review focused on empirical studies about how older adults perform with different interaction techniques on both PC and tablet computers in order to identify which interaction techniques older adults find easier and more acceptable. The literature review also focused on the measures that are typically taken to measure text or number entry tasks on both PC and tablet computers.

There is a considerable amount of research on interaction techniques for computers, including tablets, that are appropriate for older people. One can divide a greater part of this body of research broadly into three topics: understanding how changes due to ageing such as visuospatial and motor skills affect interaction with a computer (Czaja & Sharit, 1993;

Czaja et al., 1998; Siek et al., 2005; Smith et al., 1999); innovations to make interaction with a computer easier for older users (e.g. PointAssist from Hourcade et al., 2010; Steadied-Bubbles from (Moffatt & McGrenere, 2010); and “swabbing”, in which user slides his finger towards a target on a screen edge to select (Wacharamanotham et al., 2011); and comparisons of different interaction techniques, in order to investigate which are the most appropriate for older users (Chung et al., 2010; Findlater et al., 2013; Jochems et al., 2013; Kobayashi et al., 2011; Patrick Rau & Hsu, 2005; Piper et al., 2010; Wood et al., 2005). It is this last topic that is most relevant to the present work. However, I could find no research which has investigated the use of the number picker as an interaction technique for older adults.

Patrick Rau and Hsu (2005) found that for older users, a touchscreen was better than mouse and keyboard or voice input for keyword search tasks. Wood et al. (2005) compared the use of a touchscreen, a standard mouse, an enlarged mouse (EZ Ball) and a touchpad as input devices for older adults. Unlike Patrick Rau and Hsu, they found that older users performed better with the mouse devices than with the touch devices. Participants raised the issue of the correct and consistent pressure required by the touch devices as the source of many of their problems (Wood et al., 2005).

Piper et al. (2010) investigated the use of a large surface touchscreen by older users, who found it less intimidating, frustrating and overwhelming than a PC (in this study actual performance was only with the touchscreen, and users’ perceptions of it in comparison with a PC were sought). Chung et al. (2010) investigated older users’ performance and preferences for physical and touchscreen keypads for number entry tasks, in the scenario of using a kiosk, so participants stood in front of an angled display for the tasks. They found that older users were significantly quicker to enter numbers using the touchscreen keypad than with the physical version, but they also made significantly more errors with the touchscreen keypad. Older users also found the touchscreen keypad easier to use than the physical one.

Kobayashi et al. (2011) investigated older users’ performance with small and large touchscreens (i.e. on a smartphone versus on a tablet computer), focusing particularly on different gestures such as tapping, dragging and pinching. Overall, older users performed more quickly on the larger touchscreen, in spite of it requiring twice the amount of finger movement on the screen. Jochems et al. (2013) compared performance and preferences of older users for different interaction devices for pointing tasks: the mouse, touchscreen and eye-gaze control. The touchscreen produced fastest performance, followed by eye-gaze control, with mouse pointing slowest. Users also rated the touchscreen as the easiest to use, and rated the eye-gaze as the most difficult. Findlater et al. (2013) compared older users' performance with a tablet touchscreen and keyboard/mouse on a PC, focusing on pointing, dragging, crossing and steering tasks. Older users were quicker with the touchscreen and made fewer errors than with the PC, and they also found the touchscreen generally easier to use than the PC. Zhou et al. (2014) compared older users' text-entry on touchscreens (both smartphone and tablet size) via keyboard and handwriting. Handwriting was faster and preferred on the smaller touchscreen, but there were no differences between the two on the larger tablet touchscreen.

Stößel and Blessing (2010) conducted a different kind of study of older users' preferences for different gestures to use with touchscreens. They investigated different gestures that could be used for 34 basic interactive tasks by asking younger and older users to try them out and rate their suitability. Older users' ratings were significantly different from younger users in 50% of the tasks and in 20 out of the 34 tasks (59%), older and younger users differed in the gesture that was rated most appropriate for the task.

Across these studies, which used different interaction techniques, devices and tasks, there is beginning to emerge a picture of touchscreens being faster and easier for older users. However, as mentioned, no studies could be found which investigated the suitability of the picker for number entry for older users on tablet computers, although this is currently a popular design option. More detailed research is needed into the suitability of different interaction techniques on the tablet for older users. Therefore, this study presents an investigation of older adults' performance with a number of interaction techniques for number entry on both tablet and desktop computers. It also presents results on their opinions and preferences for the different interaction techniques.

6.3 Method

6.3.1 Design

A within-participants design was used. The two independent variables were Device and Interaction Technique. Device had two conditions: desktop computer and tablet computer.

The desktop computer condition used a PC with a standard QWERTY keyboard and mouse; the tablet computer condition used an iPad with a touchscreen and a onscreen keyboard for interaction. The independent variable Interaction Technique had three conditions: the numeric Keypad (on the QWERTY keyboard for the PC, and on the touchscreen keyboard for the tablet); Number Selector (a pull down menu on the PC, see Figure 6.1; a number picker for the tablet, See Figure 6.2); and plus/minus buttons (henceforth I will refer to these as Buttons, see Figure 6.3).

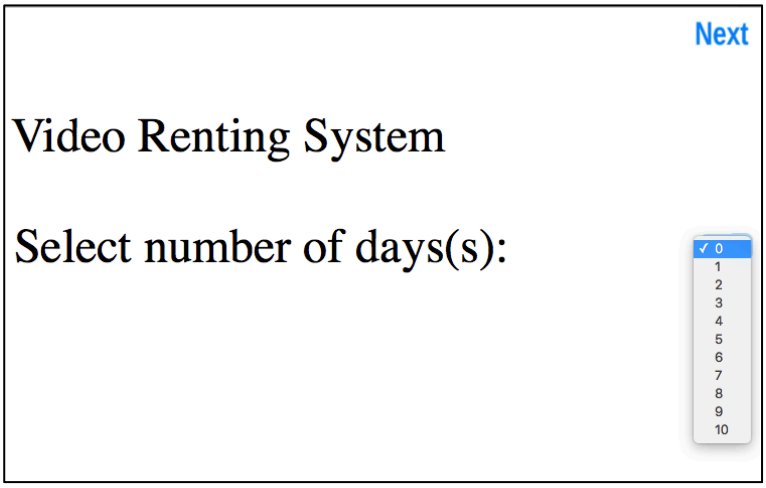

Figure 6.1. Video rental scenario with pull down menu (Number Selector for PC)

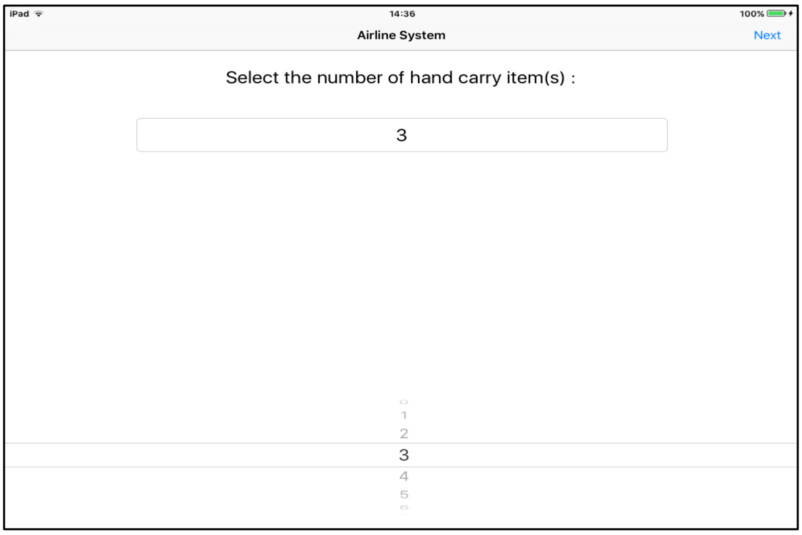

Figure 6.2. Airline ticket booking scenario with number picker (Number Selector for tablet)

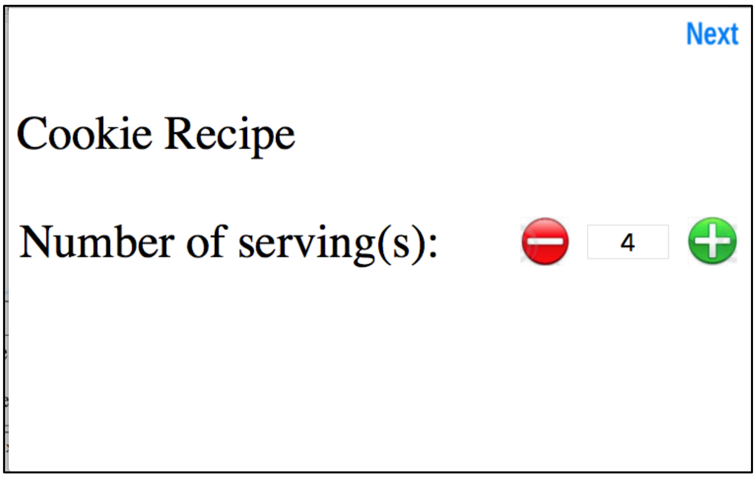

Figure 6.3. Baking cookies scenario with plus and minus buttons (Buttons for PC)

Each participant undertook three number entry tasks in each combination of the six combinations of Device and Interaction Technique, one each with an “easy”, “medium” and “difficult” number (see section 6.2.2, below) making 18 tasks in total. The order of tasks was counterbalanced to avoid practice and fatigue effects.

The dependent variables were time to enter each numeric element (digit or decimal point), errors made, participant workload and participant opinions and preferences.

Participant workload was measured using the NASA-TLX (Hart & Staveland, 1988). Participant opinions were measured on a series of 10-point rating items (10-point scales were used for consistency with the 10-point scales used in the NASA-TLX) which asked for ratings of how easy it was to enter numbers with the particular interaction technique, how fast participants thought they were with the technique, how accurate they thought they were with the technique, how confident they were in using the technique, and how satisfied they were with the technique. Preferences were measured by asking participants to choose which interaction technique they would prefer to use, on each device separately and then overall.

6.3.2 Equipment and Materials

The study used a PC with a 21.5 inch LED monitor, a standard QWERTY keyboard, and a 2-button non-scrollable mouse. The PC ran Windows 10 and Internet Explorer 11. For the tablet computer, the study used an iPad Mini 2 running iOS 9.3.1. Morae[24] software was used to record and analyse the sessions on the PC. ScreenFlow[25] software was used to record and analyse the sessions on the iPad.

A website for the PC and a mobile app for the iPad were created for the study. The first page was an orientation page, the next nine pages consisted of the number entry tasks with a ‘Next’ button on the top-right corner of each page (see Figures 6.1-6.3). The last page indicated that the tasks for that device had been completed. The font size for the text explaining the tasks was 18pt, black text on a white background. The button size was 50pt each. The screen size of the website on the PC was set to a similar size to the iPad screen, to make for comparable presentations.

The number entry tasks were situated in realistic scenarios of use such as online shopping, purchasing train tickets, borrowing library books, an airline check-in system, and a video renting services. For example, Figure 6.1 shows the pull-down menu interaction technique on a PC, for a video renting system. The task required the participant to enter the number of days they wanted to rent the video for.

The numbers chosen for the number entry tasks were categorized as “easy”, “medium” and “hard”. Most of the interaction techniques are designed for use with whole digits (for example the Buttons and the Number Selectors), only the Keypad is widely used for input which requires decimal points.

Therefore, in order to include the full range of numeric input, the numbers entered on the Keypad included decimals, while the numbers entered with the Buttons and the Number Selectors included only whole digits. Easy number entry tasks required entering only one digit; medium number entry tasks required entering three elements (which might include a decimal point for the Keypad entry); and hard number entry tasks required entering five to seven elements (which might include a decimal point).

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[24] https://www.techsmith.com/morae.html

[25] https://itunes.apple.com/gb/app/screenflow-6/id1107828211?mt=12

Each participant received an information sheet and an informed consent form. A copy of these materials can be found in Appendix 20 (information sheet) and Appendix 21 (informed consent form). For the NASA-TLX (Appendix 22), relatively large print paper versions (18pt) of the dimension pairwise comparison sheets and the task rating sheets were made.

A questionnaire was developed, and presented to participants in relatively large print (18pt) which asked them to rate each combination of Device and Interaction Technique on five 10 point scales:

- how easy it was to enter numbers with the particular technique
- how fast they thought they were with the technique
- how accurate they thought they were with the technique
- how confident they were in using the technique
- how satisfied they were with the technique

For consistency, 10 point rating scales were also used for the NASA-TLX.

The questionnaire also asked participants to rank their preferred interaction technique, within each device (i.e. on the PC and on the iPad) and then across both devices.

The questionnaire also collected demographic information about the participants, similar as used in Study 1 and Study 3.

The full set of the questionnaire can be found in Appendix 23.

Pilot Study

A pilot study was conducted with four participants, two women and two men. Their mean age was 29 years with a range from 18 years to 39 years. Participants were recruited from the Department of Computer Science. None of the participants had an idea of the aim of this study. No issues were found during the pilot study. Thus, no changes were made to the study design and procedure.

6.3.3 Participants

There were 12 participants. The inclusion criteria were to be 65 years or over, living independently and have some experience with computers. Participants comprised six women and six men. Their mean age was 71.5 years with a range from 65 years to 82 years (sd = 5.1). Four participants had completed secondary school, three had completed a bachelors degree, one had completed a post-graduate degree and four had completed a professional qualification. Nine participants were retirees and three were working part-time. All 12 participants were web users with experience of using the web from 2 to 30 years (mean = 20 years; sd = 9.9). Five men and five women were computer users with experiences of using computers from 7 to 30 years (mean = 16 years; sd = 9.97). Four men and five women were tablet computer users with experience of using tablets from two weeks to 6 years (mean = 3 years; sd = 1.76).

6.3.4 Procedure

The study took place in the Interaction Labs at the Department of Computer Science, a quiet, private location. Participants were first briefed about the study and completed an informed consent form. Participants were asked to familiarize themselves with the first device they would use in the study (PC or iPad) with one or more practice tasks, as requested by the participant.

For each task, a number printed on paper (font size 72, bold) was read aloud to the participant and then placed the number in clear sight for the participant to consult while entering the number, if they wished. After the practice task(s), participants completed the first part of the NASA-TLX, the pairwise comparison of dimensions. Participants then performed the 9 tasks with the first device (three tasks with each of the three interaction techniques) and then completed the second part of the NASA-TLX, their ratings of using the device to undertake those tasks, and a questionnaire on their opinions and preferences about the three interaction techniques they had just experienced.

The process was then repeated with the second device.

After completing the procedure with both devices, participants ranked their overall preference of all six interaction techniques for both devices and completed a short demographic questionnaire. Participants were then debriefed about the purpose of the study and invited to ask any questions about the study. Participants were offered a gift voucher worth £20 to thank them for their time and effort.

6.4 Data Analysis

A Shapiro-Wilks test showed that there was a significant skew in the distribution on majority of the Likert items in the post-study questionnaire. Therefore a log transformation (Howell, 2012) was applied to the data before proceeding to further data analysis.

Multilevel linear modeling (MLM) Snijders (2012) was used to statistically analyze the data. MLM was chosen because examples of interaction techniques used are different for iPad and PC. Thus, it is not a typical repeated measure. MLM analysis includes random coefficient regression analysis for data with several nested level Snijders (2012). Of specific interest was the relationship between the participants' time taken to complete the tasks, the NASA-TLX dimensions scores and the ratings of each input technique (on scales from 1 = poor to 10 = very good). The ratings included of how easy the technique was to use, how fast they thought they were with the technique, how confident they were in using the technique and how satisfied they were with the technique (level-1 outcome variables) and both the Interaction Technique (level-1 predictor variable) and the Device used (level-2 predictor variable), see Figure 6.4. Model testing included random intercept between the level-1 outcome variables and the Interaction Technique. This is also known as a random intercept model because the intercept between the level-1 outcome variables and the Interaction Technique is allowed to vary randomly between groups Snijders (2012). This means that the intercept is allowed to take on different values from a distribution. Model fit using chi-square tests on the log-likelihood va6lues to compare different models. All analyses were carried out in the IBM SPSS Statistic Version 25.

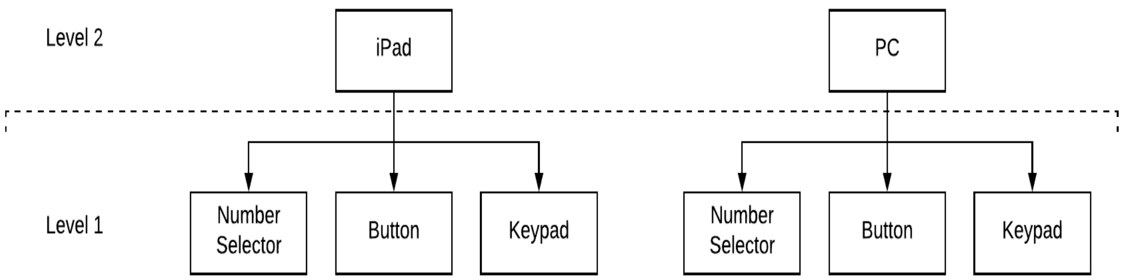

Figure 6.4. The model testing

6.5 Results

6.5.1 Time to enter numeric elements and errors

There were significant main effects of Device ($F(1, 60.0) = 9.44$, $p < 0.05$) and Interaction Technique ($F(2, 60.0) = 256.83$, $p < 0.05$) and the interaction between these two variables ($F(2, 60.0) = 6.54$, $p < 0.05$). The relationships between the Interaction Technique and the time taken to complete the tasks showed significant variance in intercepts across participants ($var(u_{0j}) = 0.11$, $x^2(1) = 24.69$, $p < 0.05$). Figure 6.4 shows that, for both devices, the Buttons interaction was fastest, Keypad intermediate and Number Selector was slowest.

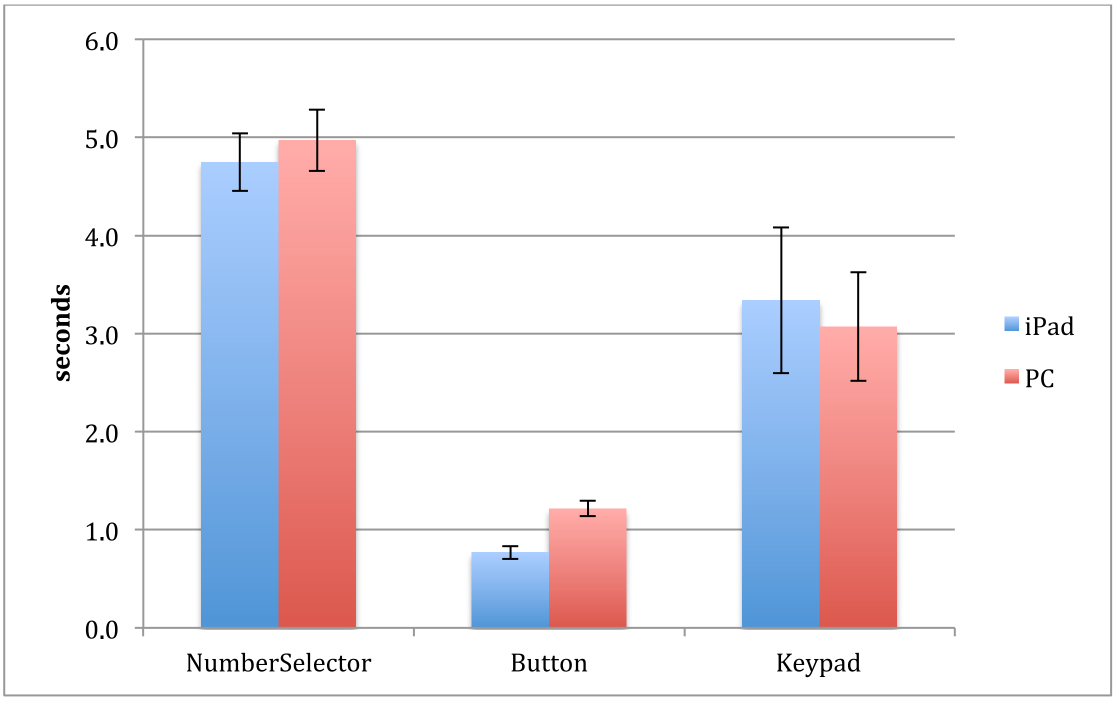

Figure 6.5. Mean time per element (seconds) for the three interaction techniques

Participants made no errors in entering numbers, although they did occasionally correct themselves during the process. So no further analysis on errors was conducted.

6.5.2 Workload: NASA-TLX dimensions

None of the NASA-TLX dimensions showed any significant main effects of Device or Interaction Technique or the interaction between these two variables.

Of the NASA-TLX dimensions, the relationships between the Interaction Technique and Mental Demand ($var(u_{0j})$ = 0.1, $x^2(1)$ = 61.86, $p < 0.05$) showed significant variance in intercepts across participants. Figure 6.5 shows that for Number Selector the picker was rated as more mental demanding to use than the pull down menu. Similar result was for the Keypad, where the iPad was rated more mentally demanding than using the PC. For Buttons, the iPad was rated less mentally demanding to use than the PC.

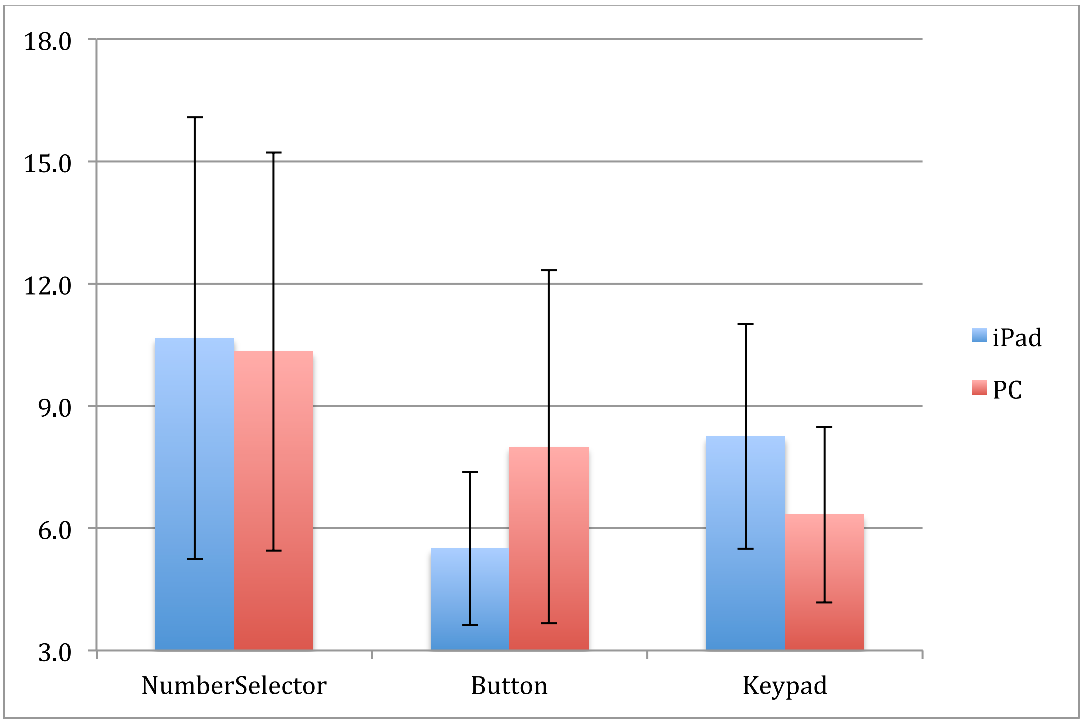

Figure 6.6. Mean rating of NASA-TLX (Mental Demand) for the three interaction techniques for the iPad and PC

The relationships between the Interaction Technique and Physical Demand ($var(u_{0j})$ = 0.2, $x^2(1)$ = 8.99, $p < 0.05$) also showed significant variance in intercepts across participants. Figure 6.6 shows that for the Number Selector the pull down was rated as more physical demanding to use than the picker. Similar result was for the Button, where the PC was rated more physically demanding than using the iPad. For Keypad, the PC was rated less physically demanding to use than the iPad.

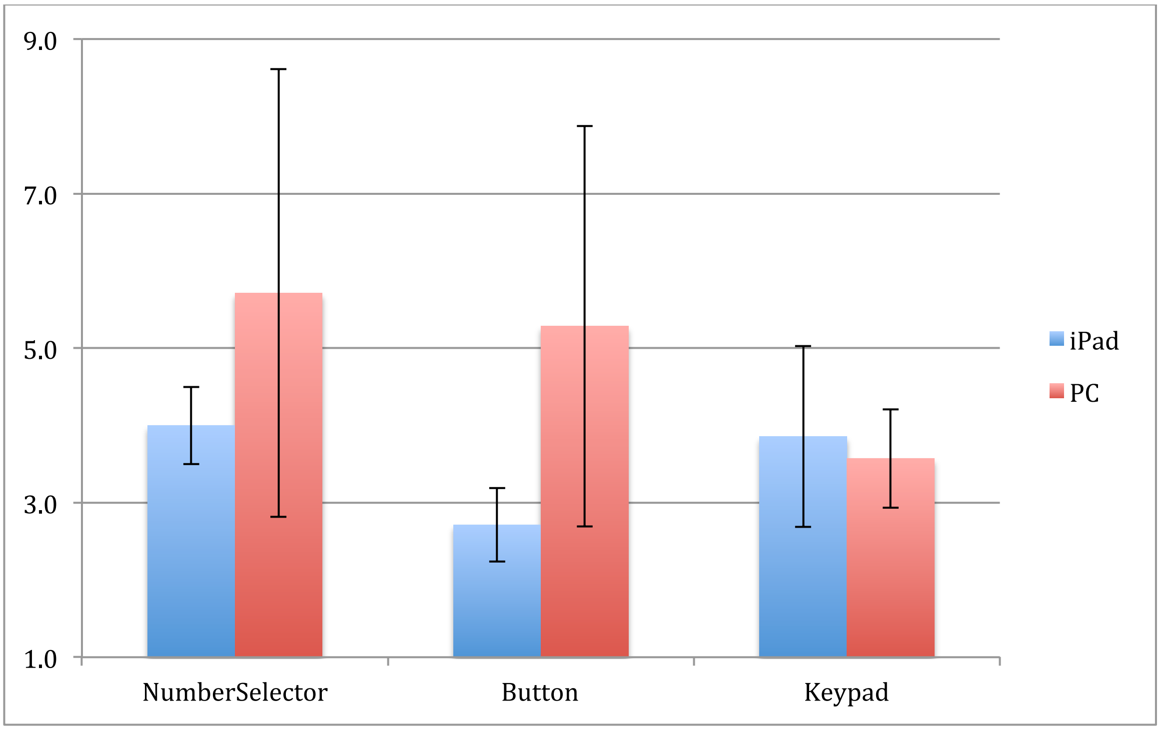

Figure 6.7. Mean rating of NASA-TLX (Physical Demand) for the three interaction techniques for the iPad and PC

The relationships between the Interaction Technique and Temporal Demand (*var*(u_{0j}) = 0.17, $x^2(1)$ = 83.64, p < 0.05) also showed significant variance in intercepts across participants. Figure 6.7 shows that for the Number Selector the picker was rated as more temporal demanding to use than the pull down menu. Similar result was for the Keypad, where the iPad was rated more temporally demanding than using the PC. However, for Button, the iPad was rated less temporally demanding to use than the PC.

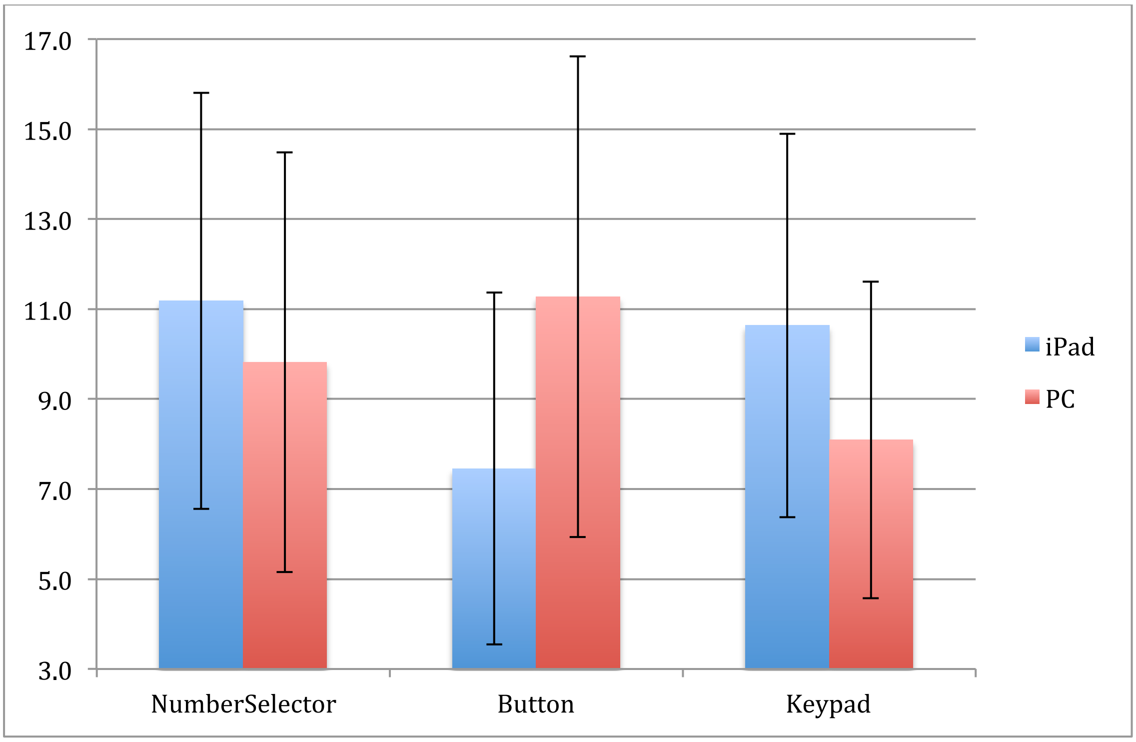

Figure 6.8. Mean rating of NASA-TLX (Temporal Demand) for the three interaction techniques for the iPad and PC

The relationships between the Interaction Technique and Performance ($var(u_{0j})$ = 0.05, $x^2(1)$ = 30.34, p < 0.05) also showed significant variance in intercepts across participants. Figure 6.8 shows that for the Number Selector participants performed better with the pull down menu than the picker, but for the Buttons and Keypad they performed better on the iPad than on the PC.

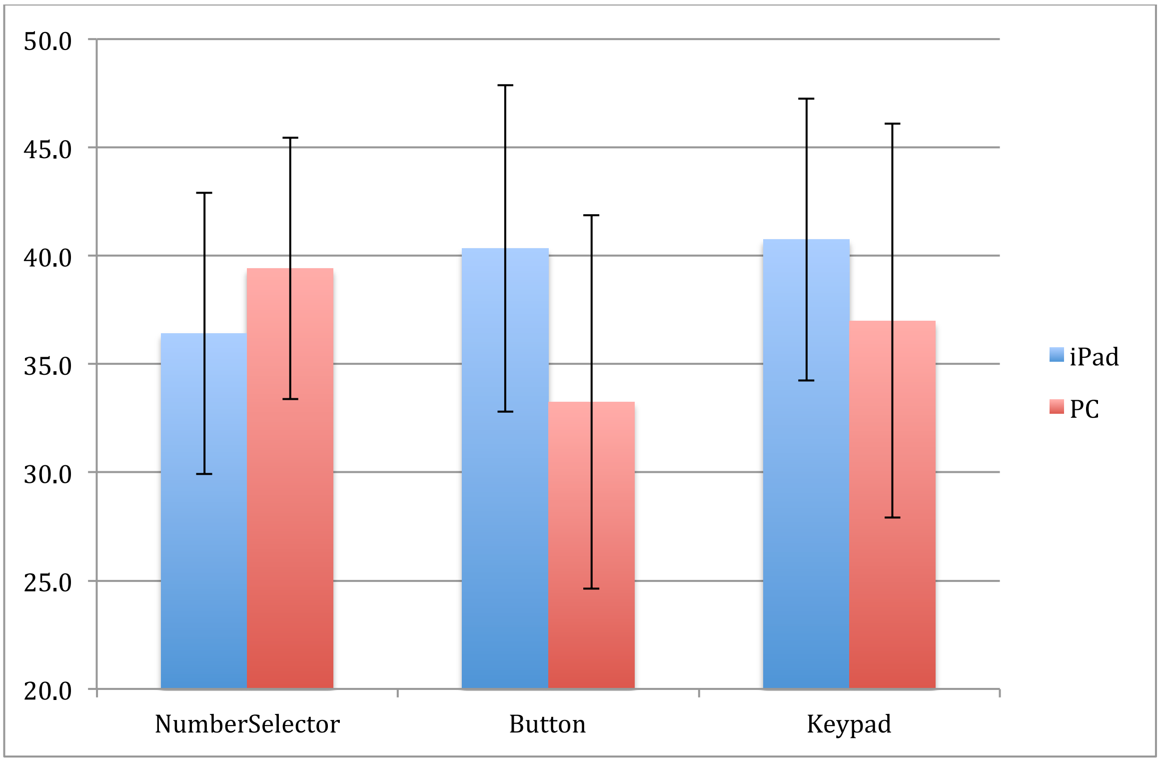

Figure 6.9. Mean rating of NASA-TLX (Performance) for the three interaction techniques for the iPad and PC

The relationships between the Interaction Technique and Effort ($var(u_{0j})$ = 0.19, $x^2(1)$ = 10.73, p < 0.05) also showed significant variance in intercepts across participants. Figure 6.9 shows that for the Number Selector participants required more effort to use the picker menu than the pull down, but for the Buttons and Keypad they required less effort to use the interaction techniques on the iPad than on the PC.

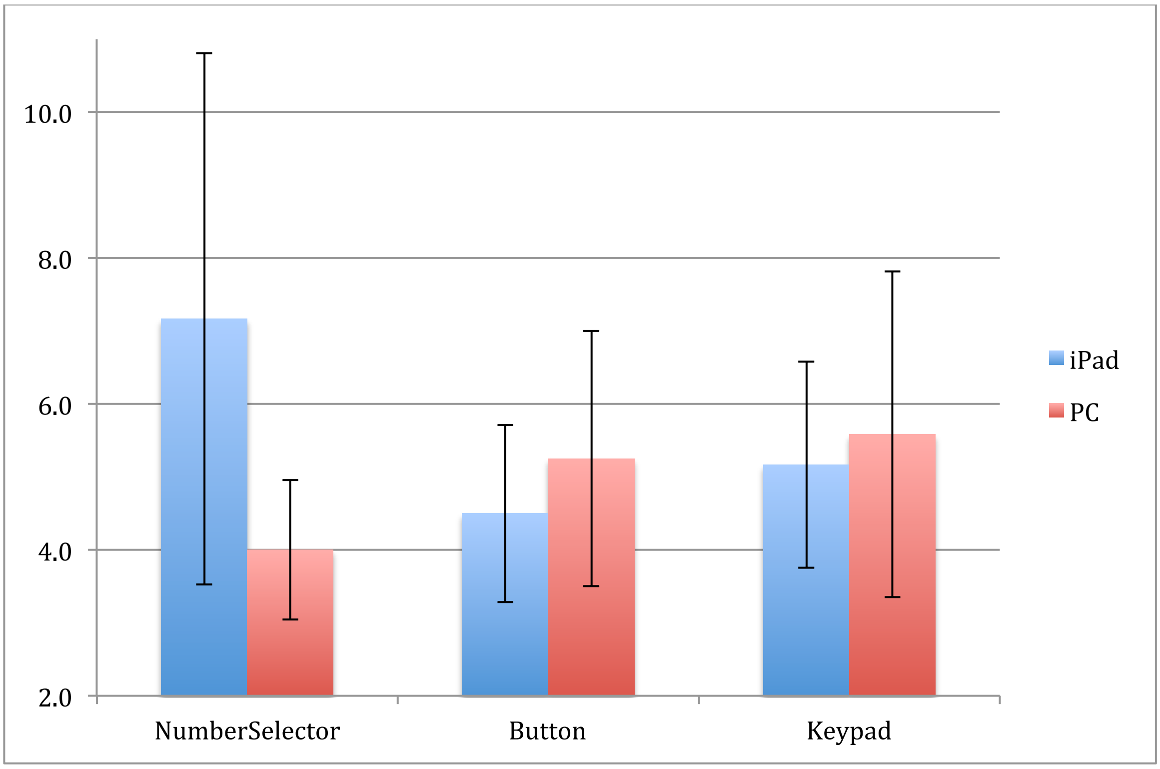

Figure 6.10. Mean rating of NASA-TLX (Effort) for the three interaction techniques for the iPad and PC

The relationships between the Interaction Technique and Frustration (*var*(u_{0j}) = 0.07, $x^2(1)$ = 25.46, $p < 0.05$) also showed significant variance in intercepts across participants. Figure 6.10 shows that for the Number Selector and Keypad, participants were frustrated more in using the iPad than the PC. However, for the Buttons, participants were frustrated more in PC than iPad.

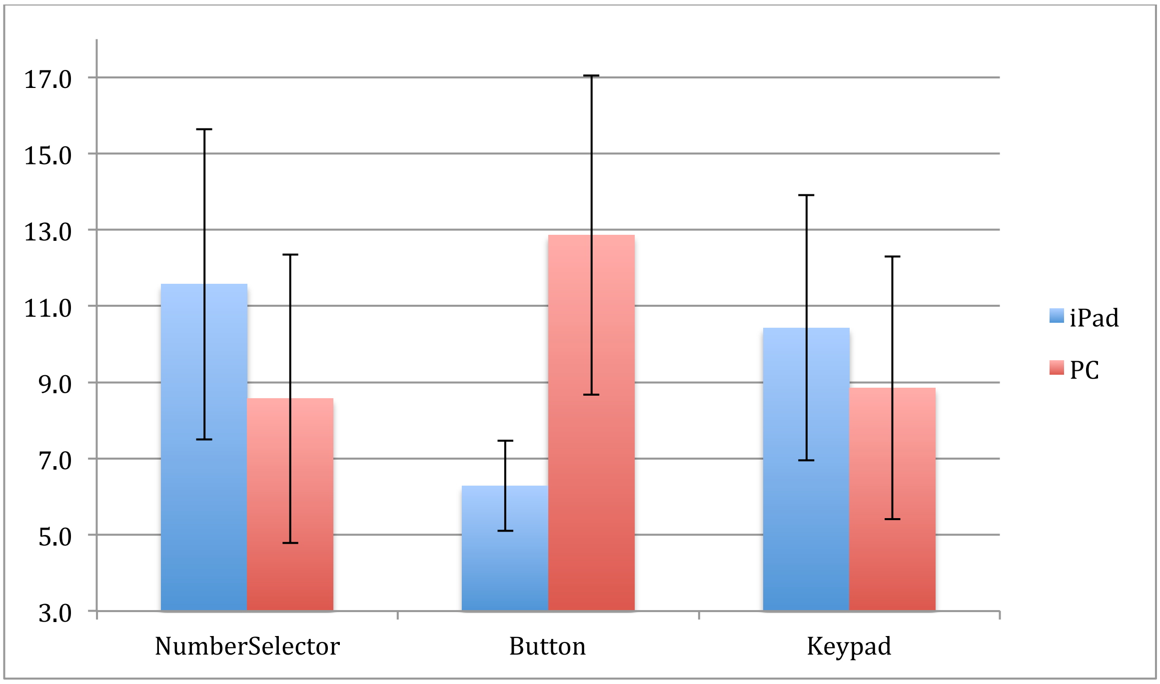

Figure 6.11. Mean rating of NASA-TLX (Frustration) for the three interaction techniques for the iPad and PC

6.5.3 Participants' opinions and preferences

For the ratings of how easy participants found it to enter the numbers, there were no significant main effects of Device or Interaction Technique or the interaction between these two variables. The relationship between the Interaction Technique and how easy participants found it to enter the numbers showed significant variance in intercepts across participants ($var(u_{0j}) = 0.006$, $x^2(1) = 9.32$, $p < 0.05$). Figure 6.11 shows that for Number Selector the pull down menu was rated as easier to use than the picker, for Buttons the iPad was rated easier to use than the PC and for Keypad, there was very little difference in ratings of how easy they were to use on each device.

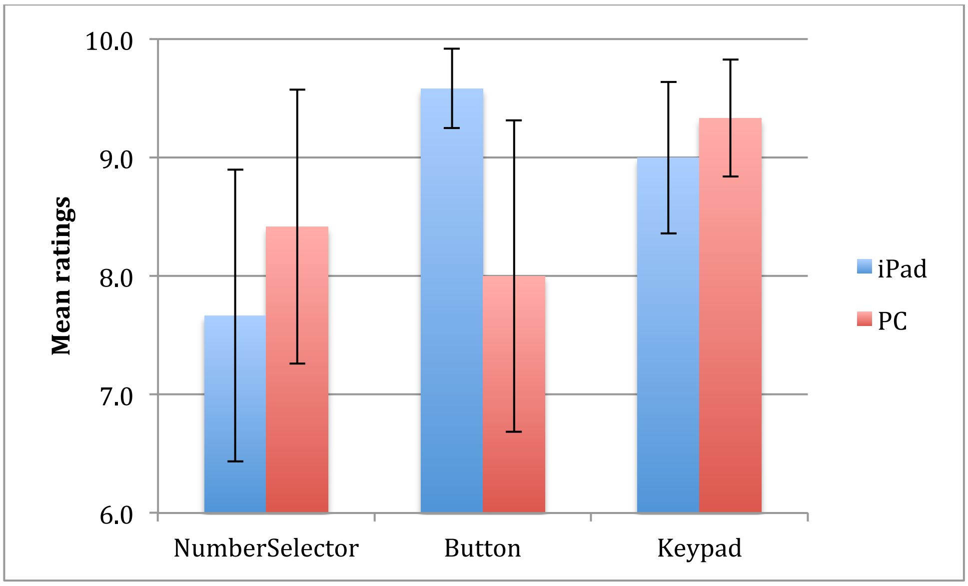

Figure 6.12. Mean rating of ease of number entry for the three interaction techniques for the iPad and PC

For the ratings of how fast participants thought they were, there were no significant main effects of Device or Interaction Technique or the interaction between these two variables. The relationship between the Interaction Technique and how fast participants thought they were showed significant variance in intercepts across participants ($var(u_{0j}) = 0.006$, $x^2(1) = 12.22$, $p < 0.05$). Figure 6.12 shows that for Number Selector the pull down menu was rated faster than the picker, for Buttons the iPad was rated faster than the PC and for Keypad, there was no difference in ratings of how fast participants felt they were.

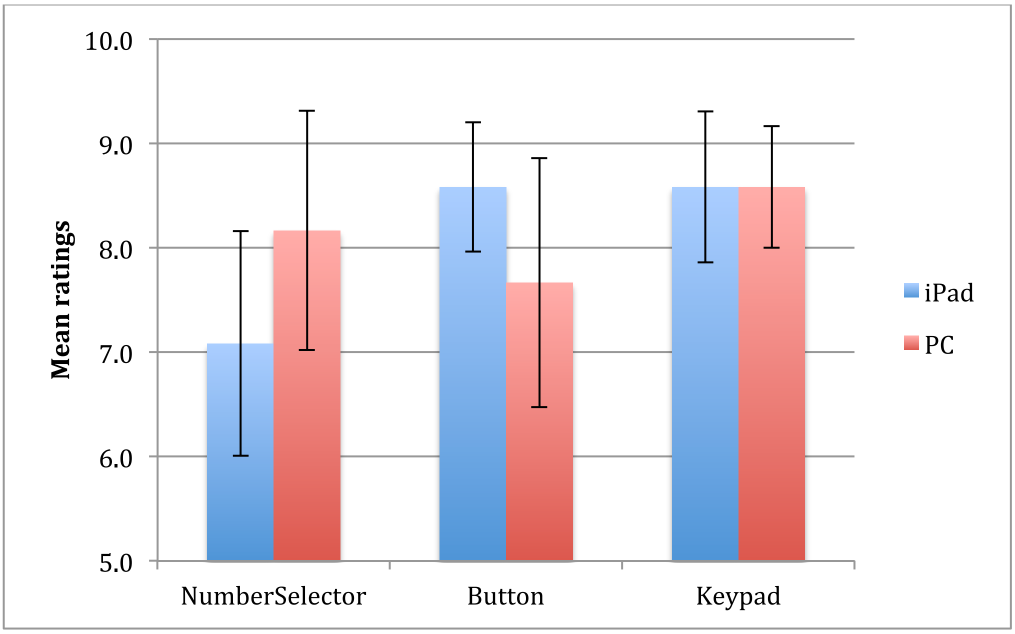

Figure 6.13. Mean rating of perception of how fast number entry was for the three interaction techniques for the iPad and PC

For the ratings of how confident participants felt in using the interaction techniques, there were no significant main effects of Device or Interaction Technique or the interaction between these two variables. The relationship between the Interaction Technique and how confident participants felt in using the interaction techniques showed significant variance in intercepts across participants ($var(u_{0j}) = .003$, $x^2(1) = 5.74$, $p < 0.05$). Figure 6.13 shows that for Number Selector participants were more confident with the pull down menu than the picker, but for Buttons they were more confident on the iPad than on the PC and for Keypad, they were more confident on the PC than on the iPad.

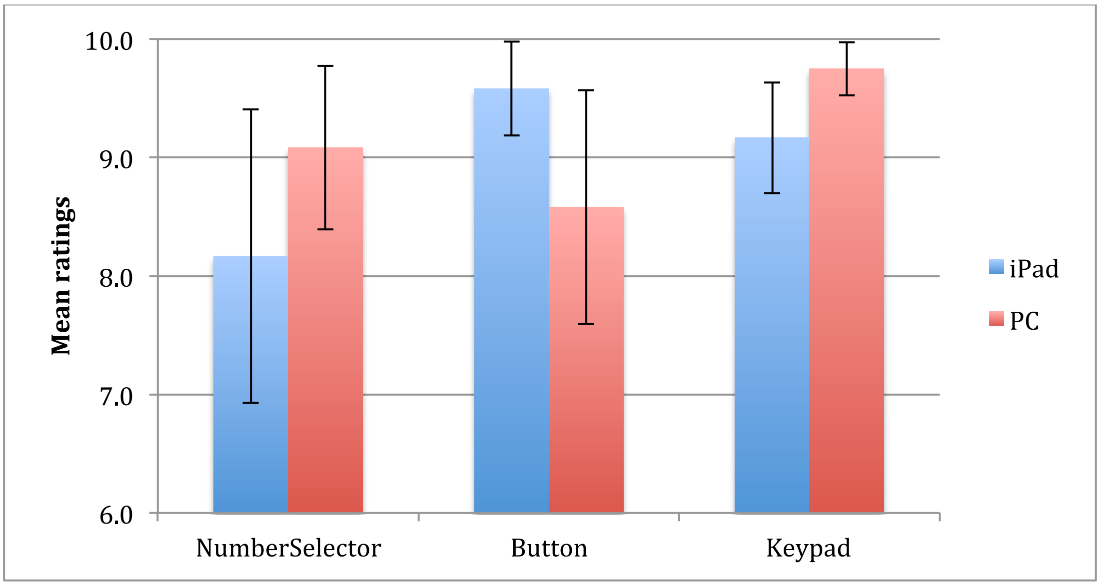

Figure 6.14. Mean rating of confidence in number entry for the three interaction techniques for the iPad and PC

For the ratings of how accurate participants felt to enter the numbers in using the interaction techniques, there were no significant main effects of Device or Interaction Technique or the interaction between these two variables. The relationship between the Interaction Technique and how accurate participants felt to enter the numbers in using the interaction techniques showed no significant variance in intercepts across participants ($var(u_{0j})$ = .0002, $x^2(1)$ = 0.19, p = n.s). Figure 6.14 shows that for the Number Selector participants felt more accurate with the pull down menu than the picker, but for the Buttons they felt more accurate on the iPad than on the PC and for Keypad, they felt more accurate on the PC than on the iPad.

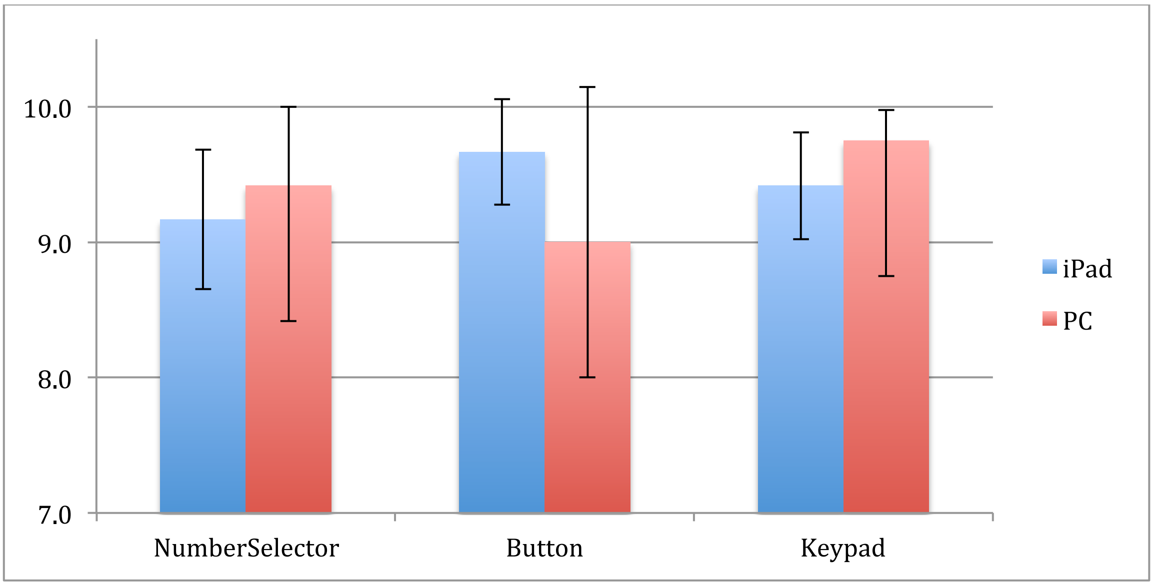

Figure 6.15. Mean rating of accuracy with number entry for the three interaction techniques for the iPad and PC

For the ratings of how satisfied participants felt in using the interaction techniques, there was no significant main effect of Device. However, there was a significant main effect of Interaction Technique ($F(1, 60.0) = 4.45$, $p < 0.05$). There was no significant effect between the interactions of these two variables. The relationship between the Interaction Technique and how satisfied participants felt in using the interaction techniques showed significant variance in intercepts across participants ($var(u_{0j}) = 0.004$, $x^2(1) = 9.29$, $p < 0.05$). Figure 6.15 shows that for the Number Selector participants were more satisfied with the pull down menu than the picker, but for the Buttons they were more satisfied on the iPad than on the PC and for the Keypad, there was little difference in the satisfaction ratings for the PC and the iPad.

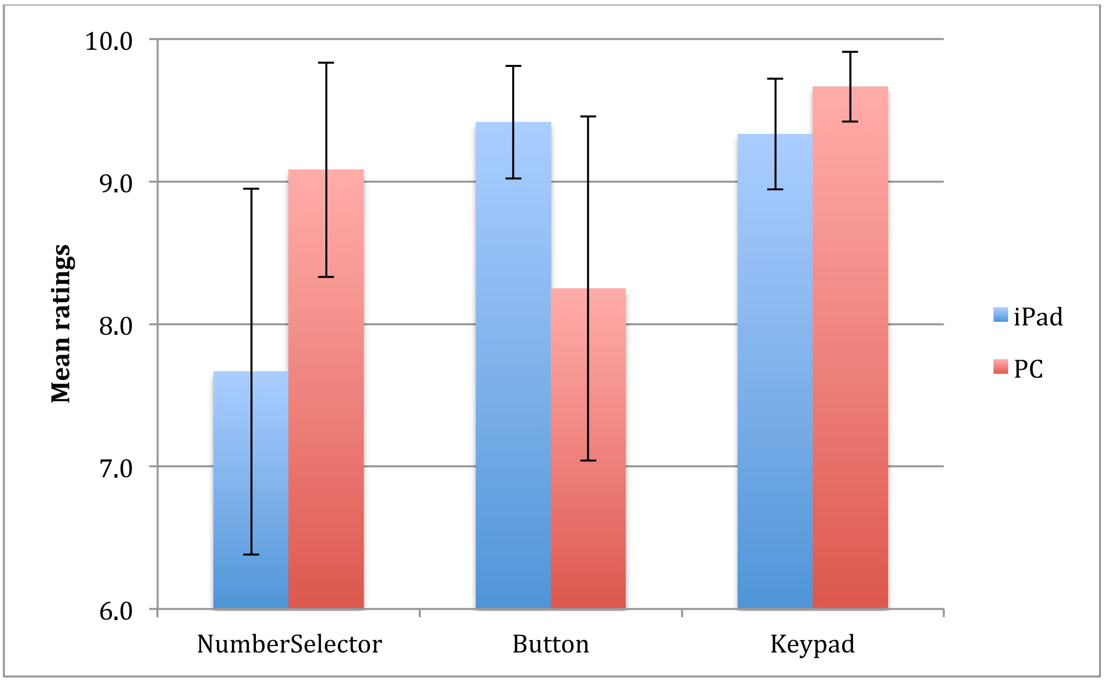

Figure 6.16. Mean rating of satisfaction with number entry for the three interaction techniques for the iPad and PC

Finally, participants were asked which interaction technique they would prefer for entering numbers if using an iPad, if using a PC and which was their overall preferred interaction technique. A chi-square test was used to investigate the differences in preferences for the interaction techniques, and between the devices, there was no significance difference ($x^2 = 1.67$, $df = 1$, n.s). For the iPad, there was a narrow majority preference for using the Keypad to enter numbers (preferred by 7 out of the 12 participants, 58.3%), with a quarter of participants preferring Buttons (3 participants, 25%) and only two participants preferring the Number Selector (16.7%). For the PC, there was also a narrow majority preference for using the Keypad to enter numbers (preferred by 7 out of the 12 participants, 58.3%), with a third of participants preferring Number Selector (4 participants, 33.33%) and only one participant preferring the Buttons (8.3%).

When asked for their overall preference, 5 participants (41.7%) chose the Keypad on the PC, 4 participants chose the Keypad on the iPad (33.3%) and one participant each chose the Buttons on the PC, the Number Selector on the PC and the Number Selector on the iPad.

6.5 Discussion

This study investigated older users' performance, opinions and preferences for undertaking number entry tasks on two devices, the desktop computer and the tablet computer, using a number of different interaction techniques.

In terms of performance, that was no difference between the devices, in spite of being a keyboard and mouse on one device and the other a touchscreen. This applied to both time taken to enter numbers and perceived workload. However, there were interesting differences between the three interaction techniques. In terms of time taken to enter numbers Buttons were the fastest method, followed by Keypad, with Number Selector slowest.

In terms of older users' opinions and preferences, the pattern across the five opinion rating questions was quite consistent. There were few overall differences between the two devices, although on overall satisfaction, there was a difference, with participants giving highest ratings to the Keypad, intermediate ratings to the Buttons and lowest ratings to the Number Selector. There were no interactions between Device and Interaction Technique on all five questions and the NASA-TLX. However, there were significant variance in intercepts across participants between the Interaction Technique and on all five questions, apart for accuracy, and the NASA-TLX; with participants giving higher ratings to the pull down menus (PC) in comparison to the picker (iPad) for the Number Selector, higher ratings to the Buttons on the iPad in comparison to the Buttons on the PC, and little difference in ratings for the two Keypad versions.

In terms of overall preferences, there was only a narrow overall preference for the Keypad on both devices, with the Number Selector on iPad being the least preferred option.

The current results provide some contrasts with previous research. Patrick Rau and Hsu (2005), Chung et al. (2010), Piper et al. (2010), Jochems et al. (2013) and Findlater et al. (2013) all found that a touchscreen produced faster results than a more physical device (e.g. keyboard and mouse, physical keypad) for older users, whether the current study found no overall difference between the tablet with the touchscreen and the PC. However, only the study by Chung et al. (2010) used number entry tasks as used in the current research, the other studies used text entry tasks or more basic tasks such as pointing and dragging. Differences may also be due to improvements in touchscreen technologies, which mean that the latest devices only require a short, light taps to select items.

Overall the results show that the current generation of tablet touchscreens do not provide any particular difficulties for older users for number entry if a Keypad or Buttons are used. However, the Number Selector interaction technique was problematic for older users. They were significantly slower with this interaction technique and liked it least.

6.6 Conclusion

This study investigated 12 older users' performance, opinions and preferences for undertaking number entry tasks on two devices, the desktop computer and the tablet computer, using a number of different interaction techniques. As this programme of research is interested in mobile technology, participants in this study do not have any difficulties in using Keypad or Buttons for number entry tasks in using tablet computers. However, Number Selector was found problematic for these participants.

One limitation of this study is that a 10 point rating scales were used for the NASA-TLX. This perhaps may influence the psychometric properties of the NASA-TLX. However comparisons were not being made with other studies, but only for internal comparisons, so the results remain valid.

On the basis of the results in this study and the results of the previous studies which evaluated the usability of MyDrinkApp (see Chapter 2 and Chapter 3), the next chapter will report the new design and development of the MyHealthyLivingApp, an app to support monitoring fruit, vegetables and liquid intake for older adults. The next study will also evaluate the MyHealthyLivingApp with a group of experts.

Chapter 7

Study 5: Expert Evaluation of a Web-App of MyHealthyLivingApp to Support Monitoring Fruit, Vegetables and Liquid Intake

7.1 Introduction

This study is similar to Study 2 (see Chapter 4). Whereas Study 2 conducted an expert evaluation of a paper prototype of MyDrinkApp to support liquid monitoring, this study used the same expert evaluation method with a web-app prototype of MyHealthyLivingApp to support monitoring of fruit and vegetables (FV) intake in addition to liquid intake. In addition, Study 2 used the heuristics developed by Silva et al. (2015) which were developed to evaluate smartphone apps for older adults, whereas this study used the heuristics developed by Petrie and Power (2012) which were developed to evaluate interactive websites. This was because so many problems had been encountered in using the Silva et al. (2015) heuristics in the evaluation in Study 2. Both studies aimed to identify potential usability problems of the prototypes using the CHE evaluation method developed by Petrie and Buykx (2010).

7.2 Method

7.2.1 Design

A tablet computer web-app, called MyHealthyLivingApp, to support older adults to monitor their FV and liquid was evaluated by three experts using the CHE method. The reason to have three experts is as explained in Chapter 4 (Section 4.3.1). A content analysis (Krippendorff, 2012) was conducted to categorize the usability problems. Problems were then analyzed to guide the redesign of the app.

7.2.2 The MyHealthyLivingApp

MyHealthyLivingApp was developed after carefully considering all the usability problems encountered by users in Study 3 (see Chapter 4) in the evaluation of MyDrinkApp, as well as their comments and suggestions for the re-design of the app and users' opinions and preferences for the interaction techniques for number entry tasks in Study 4 (see Chapter 6).

MyHealthyLivingApp was developed using Web-based technologies including Hypertext Preprocessor (PHP), Cascading Style Sheet (CSS), and JavaScript, as well as MySQL as the database system. The app uses a responsive Web design approach that supports dynamic adaptation of the app interface to a device's characteristics (for example the screen size and device orientation).

The font size for the text was at least 18px. The target size for the buttons was at least 1.5cm (height) x 1.5cm (width) each (Kobayashi et al., 2011). The gap in between targets was at least 5mm (Jin et al., 2007). All text was black on a white background.

The features of the MyHealthyLivingApp consist of the ability to create a profile, update FV and liquid intake, view congratulation messages upon reaching a daily target, view progress on FV and liquid intakes, and read tips on healthy living particularly the importance of FV and proper hydration. To maintain consistency, avoid confusion and reduce mental demand, the design to update intakes, view congratulation messages, view intakes progress, and read tips were similar for both FV and liquid.

Main Screen

The users in Study 3 did not favour the dark blue background colour for the Main Screen. The background colour in MyHealthyLivingApp was therefore changed to white. The image was also changed to suit the context of use of both eating FV and drinking liquid. Figure 7.1 shows the Main Screen for MyDrinkApp and Figure 7.2 shows the Main Screen for MyHealthyLivingApp.

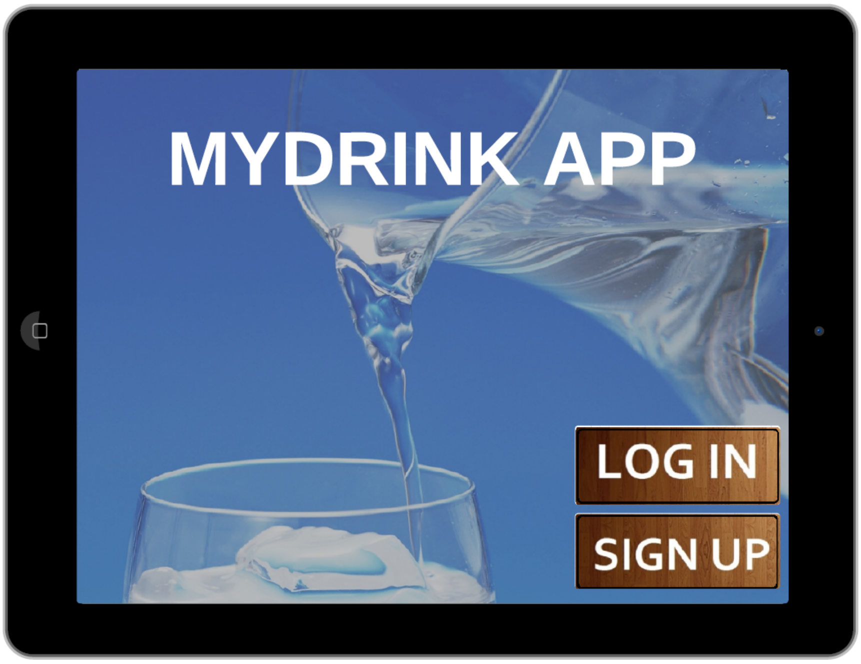

Figure 7.1. The Main Screen for MyDrinkApp

Figure 7.2. The Main screen for MyHealthyLivingApp

Set Profile

The users in Study 3 were concerned about providing information such as their email address, password and username to create a user profile. Thus, in the MyHealthyLivingApp, users were given a unique username to log into the app. To complete their profile, users needed only to provide their name, gender and liquid measurement preference. To set their name, an input box was designed. To set their gender, a pull-down menu with the option of “Male” and “Female” was designed. To set their liquid measurement preference, a pull-down menu with three preferences was designed. The preferences included cup, glass, and pint glass, as suggested by the users in Study 3. Users could update their profile, if needed, on the “My Profile” screen.

Home Screen

The users in Study 3 did not like the use of the blocks of buttons in the Home Screen in MyDrinkApp (see Figure 7.3) and suggested using a list style to present the features. The users were also confused with the naming of the buttons. Therefore, for MyHealthyLivingApp (see Figure 7.4), a list style was used to present the features in the app. To ease the understanding of each feature, a brief explanation was given underneath each feature.

In both the previous apps, users could add their intake, view their progress and read tips. Figure 7.5 shows the list of features for “My Liquid Intake App”.

Figure 7.3. The Home screen in MyDrinkApp

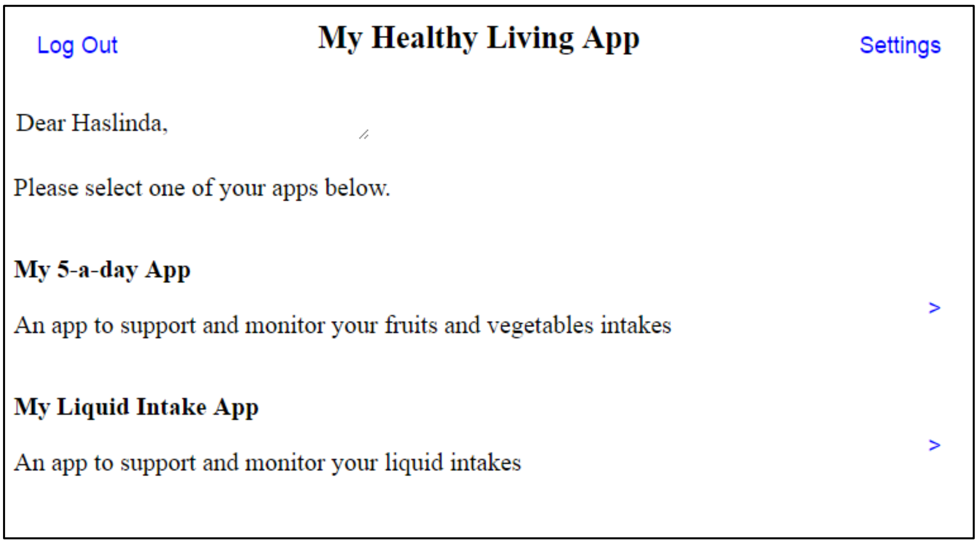

Figure 7.4. The Home screen in MyHealthyLivingApp

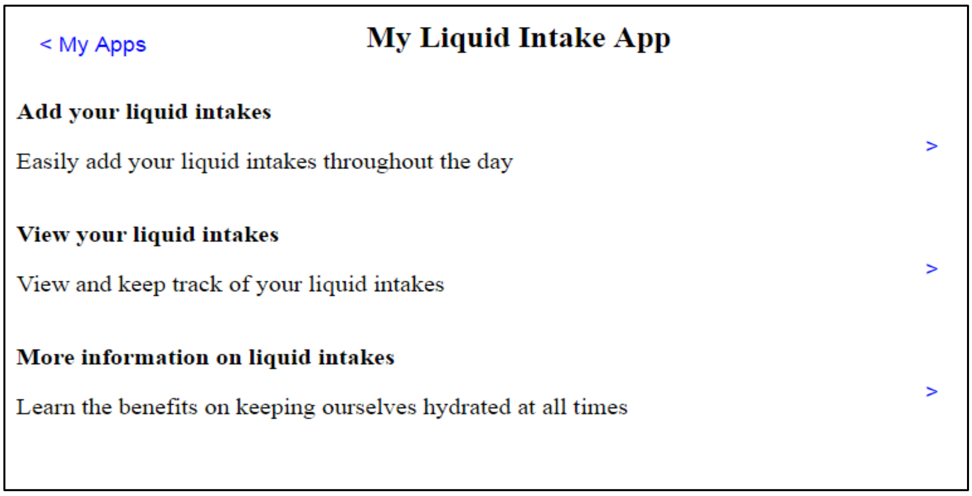

Figure 7.5. List of features for the My Liquid Intake App in MyHealthyLivingApp

Updating intakes

A number of users in Study 3 raised concerns about setting their own daily liquid intake recommendation. To address this, I referred to the British Nutrition Foundation (BNF)[26]. BNF recommends drinking 1.6L of fluid per day for women and 2L of fluid per day for men. For the FV, I referred to the National Health Service (NHS)[27] 5-A-DAY campaign, which recommends five servings of FV per day.

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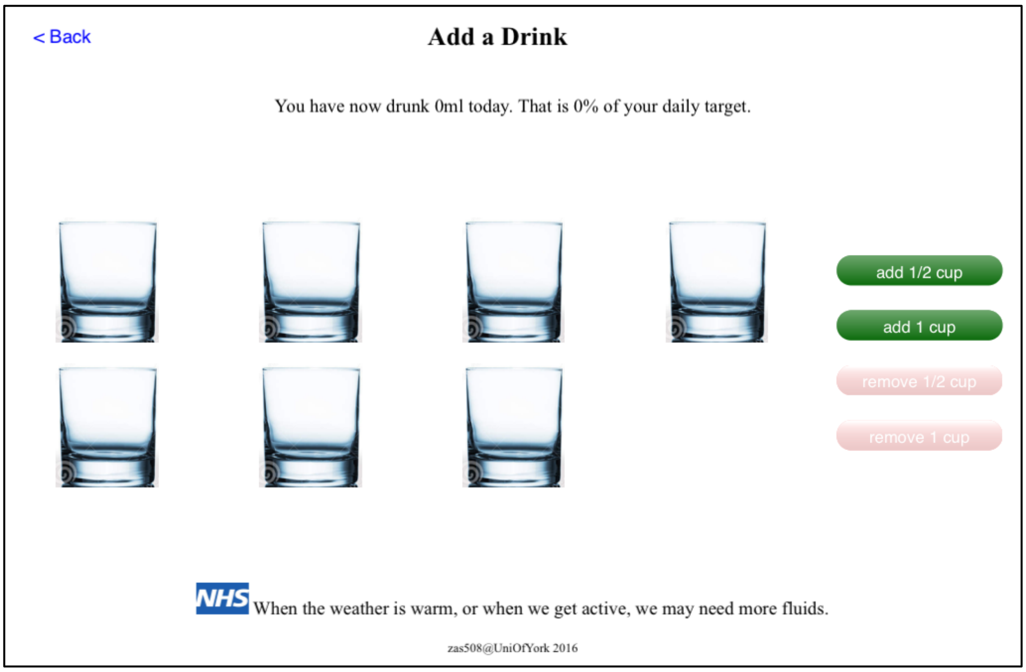
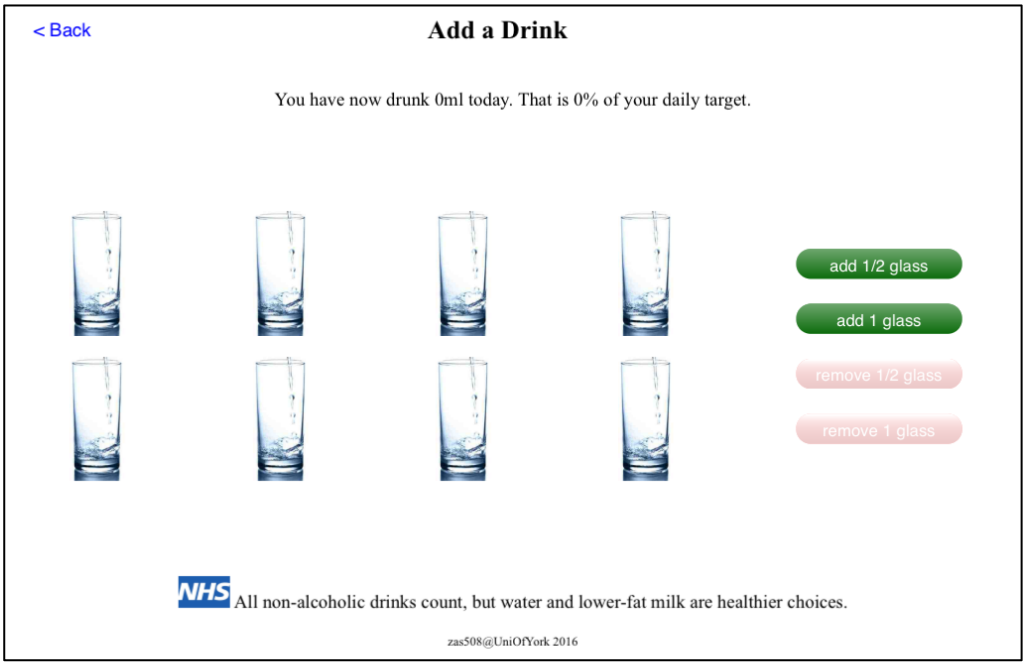
26 https://www.nutrition.org.uk/healthyliving/hydration/healthy-hydration-guide.html

27 http://www.nhs.uk/Livewell/5ADAY/Pages/5ADAYhome.aspx

Users in Study 3 suggested having different measurement options for updating liquid intake. Three options were designed to meet this requirement. Figure 7.6 shows the designs using cups, pint glass and glass as the measurement option. The number of these items tallies with the recommended liquid intake given by BNF.





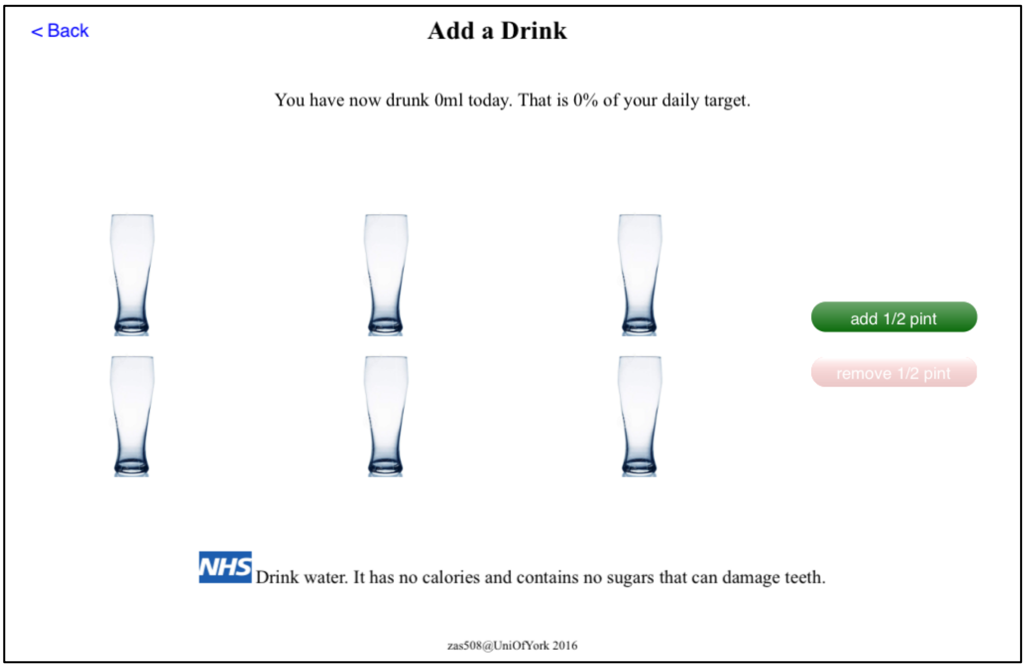


Figure 7.6 (from top to bottom): Updating liquid via(a) cups, (b) glass, and (c) pint glass in MyHealthyLivingApp

To update intakes in MyHealthyLivingApp, I referred to the users' opinions and preferences in Study 4. The use of buttons for number entry tasks was found the fastest for the iPad. The users were also more satisfied, confident, and thought they were faster to complete tasks when using buttons compared to other interaction techniques, especially the picker. The use of buttons was also found to be easier than the keypad and picker.

Thus, to update intakes, four buttons were designed. To update liquid via cup (see Figure 7.6a), the "add ½ cup", "add 1 cup", "remove ½ cup", and "remove 1 cup" buttons were designed. Similar buttons were designed for the glass option (see Figure 7.6b). For the pint option (see Figure 7.6c), the "add 1 pint" and "remove 1 pint" buttons were removed as 1 pint is 560ml, and this could be a large volume to be drinking in one sitting, especially for older adults. All "add" buttons were green, and all "remove" buttons were red. To update the intakes, user would just simply tap on any of the buttons.

The users in Study 3 were concerned about the amount of instructions and feedback messages available throughout the MyDrinkApp. Therefore, in MyHealthyLivingApp an instruction to do a task is only provided at the beginning of a task and immediate feedback is given after completing a task.

Figures 7.7 to 7.9 show the process to update a FV intake. Figure 7.7 shows the add FV screen in MyHealthyLivingApp. The instruction to update an intake, at the top of the screen, appears only once each day. Upon updating an intake, the daily progress is shown in two options: 1) a text message showing the number of servings and the total percentage of the overall daily target (located at the top of the screen, replacing the previous instruction on how to update an intake) and 2) the colour change in the images of the hearts (see Figure 7.8).

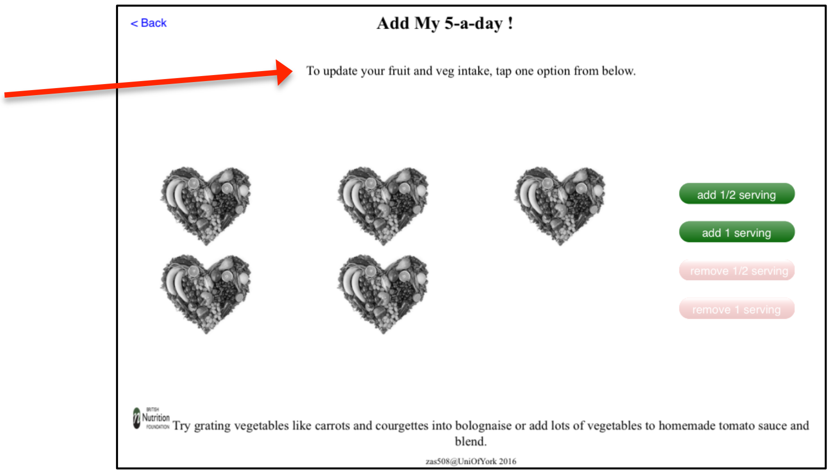


Figure 7.7. The instruction how to add an intake appears only one time each day in MyHealthyLivingApp

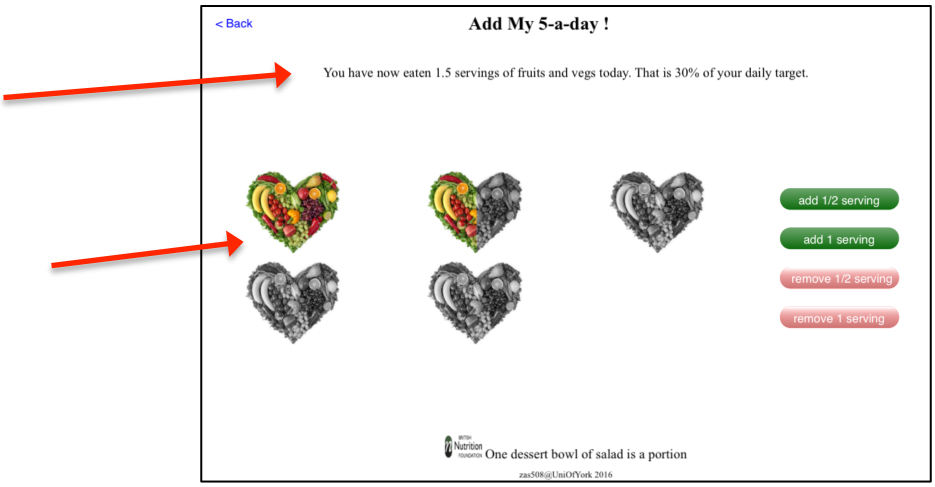


Figure 7.8. Immediate feedback of daily progress is displayed in both text and images upon updating an intake in MyHealthyLivingApp

Upon reaching the daily target, a congratulation message is shown (see Figure 7.9).

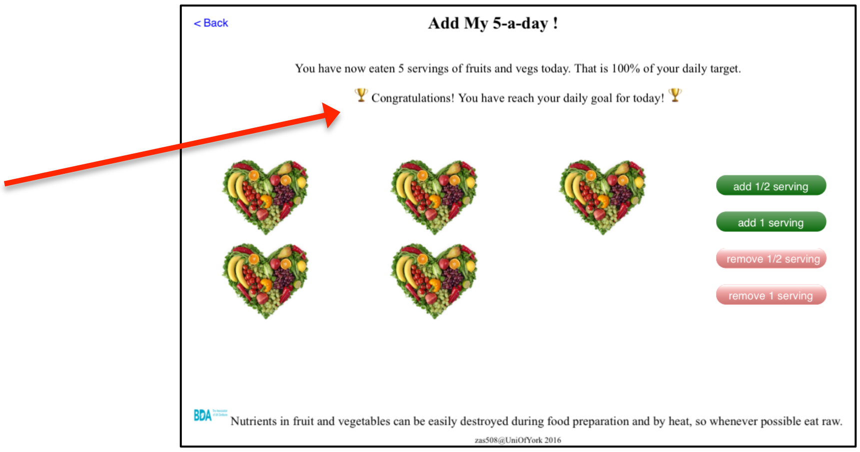


Figure 7.9 The congratulation message is shown upon reaching the daily target in MyHealthyLivingApp

There are two options to view one's progress in MyHealthyLivingApp. The first option is a coloured list of all consumptions (see Figure 7.10a). The second is a coloured chart of the last seven consumptions (see Figure 7.10b). The use of the traffic light metaphor to represent progress is similar to that used in MyDrinkApp.

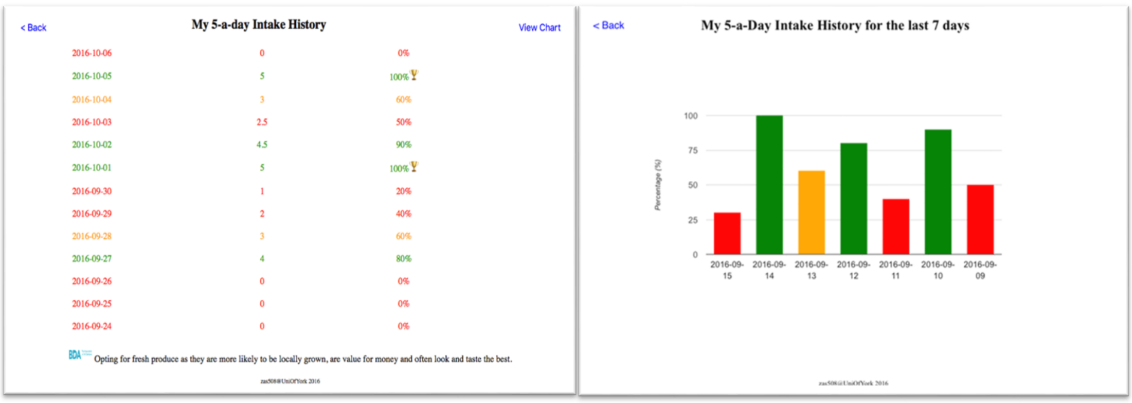


Figure 7.10 (from left): The two options to view one's progress (a) coloured list of overall FV consumptions, and (b) coloured chart of the last 7 FV consumptions in MyHealthyLivingApp

There were two options to read tips about healthy eating and drinking. For example for tips on healthy drinking, the first option is by tapping the "More Information on liquid intakes!" button (see Figure 7.4), which brings the user to a screen that consists of a series of buttons that link to external websites (e.g. NHS, BNF) about liquid consumption. The second option is when each time users update a liquid consumption, the tips at the bottom of the screen change randomly (see Figure 7.6). The second option also features on the progress intake screen (see Figure 7.10a). However, since there is no interaction apart from scrolling the progress list on this screen, only one tip is randomly provided each time the users view this screen. The tips were all taken from reliable sources in the UK such as from the NHS and BNF.

7.2.3 Experts

Three experts participated in the CHE. They were members of the HCI Research Group in the Department of Computer Science, University of York. One expert was a professional and two experts were postgraduate students in the group. All the experts had experience with CHE and with interactive systems for older adults. Two experts were Apple users and one was an Android user.

7.2.4 Evaluation Tasks

Five tasks were designed for the experts to use in the evaluation. Each task was situated within a realistic scenario of use. The tasks and scenario can be found in Appendix 24.

Each time an expert proposed a potential usability problem, all experts would then match the problems with the heuristics developed by Petrie and Power (2012). All experts would then privately rate its severity problem using a five-point scale, where 0 = no a problem in that expert's opinion, 1 = very minor, 2 = minor, 3 = moderate, 4 = major and 5 = very major.

7.2.5 Materials and Equipment

Each expert was given the list of scenarios with the tasks (see Appendix 24), and the heuristics developed by Petrie and Power (2012), see Appendix 25. To use the app, the study used an iPad Mini 2 running iOS 9.3.5.

7.2.6 Procedure

One CHE session was conducted. The CHE session was audio-recorded for later detailed analysis. During the CHE session, the experts worked as a group. I guided the experts through MyHealthyLivingApp. One expert recorded the potential usability problems raised by the experts. The heuristics relevant to each problem were also recorded. The experts privately rated the severity of problems using the five-point scale. The CHE session lasted approximately 75 minutes.

7.2.7 Data Analysis

A list of usability problems identified by the experts was created. The content analysis conducted is as described in Section 4.3.7.

7.3 Results

The experts identified 24 usability problems in MyHealthyLivingApp. Table 7.1 shows the categorization of usability problems, their frequency and their mean severity ratings. Only three of the four major categories from the Petrie and Power (2012) categorization were found in this set of problems. These were Physical Presentation, Content and Interactivity. The major category that was not identified was Information Architecture. The majority of the problems were found equally in the Interactivity (37.5%) and Physical Presentation (37.5%) categories. The remaining 25% of problems were found in the Content category.

Four of the sub-categories of the usability problems had a mean severity rating as major, which were "changes to content / interactive elements not noticed", "too much content", "concerns about how to proceed" and "labels / instructions / icons on interactive elements not clear". The remaining problems had a mean severity rating as moderate and minor. See Appendix 26 for the full list of problems identified in MyHealthyLivingApp and their individual mean severity ratings.

Table 7.1. Categorization of usability problems identified in MyHealthyLivingApp and the frequency of problem categories and sub-categories and the mean severity ratings of sub-categories

Category	Example problem	Mean Severity Rating	% (frequency)
Physical Presentation			**37.5 (9)**
Text / interactive elements not large / clear / distinct enough	the button is too small	3.11	12.5 (3)

Changes to content / interactive elements not noticed	liquid not visible for the pints and cups option	3.83	8.3 (2)
"Look and feel" not consistent	the font is not consistent between the pages	2.25	16.7 (4)
Content			**25 (6)**
Too much content	a lot of text here	4.00	4.2 (1)
Content not clear enough	"settings" is too technical	3.00	12.5 (3)
Content not suitable for the users	the about [description of the app] is not welcoming enough	2.50	8.3 (2)
Interactivity			**37.5 (9)**
Concerns about how to proceed	need to be told what is happening next	3.67	8.3 (2)
Labels / instructions / icons on interactive elements not clear	why am I being asked about glasses here	4.33	4.2 (1)
Excessive effort required by user to complete a task	why have a second page?	3.27	20.8 (5)
Interaction not as expected	the tips changes too often	3.00	4.2 (1)

7.4 Discussion

A web-app for tablets, MyHealthyLivingApp, was evaluated by a group of experts using the CHE method. The experts identified 24 potential usability problems in three categories adopted from the Petrie and Power (2012) categorization of usability problems. The experts' main concerns were found in the Interactivity and Physical Presentation categories, in particular the sub-category of Interactivity "Excessive effort required by user to complete a task", which contributed to 20.8% of the overall number of problems.

7.5 Re-design of MyHealthyLivingApp

MyHealthyLivingApp was re-designed before progressing to the next study. All 24 problems raised during the CHE were taken into consideration during the re-design stage. All design suggestions given by the experts were also taken into consideration. The explanations of the suggestions are discussed below.

To ease the readability of this chapter, the MyHealthyLivingApp used in the current study will be called "MyHealthyLivingApp_v1". The redesigned of MyHealthyLivingApp will be called "MyHealthyLivingApp_v2".

Features of MyHealthyLivingApp_v2

The basic features of MyHealthyLivingApp_v2 remain the same. That is, MyHealthyLivingApp_v2 provides the ability to set liquid measurement preferences, to add or remove FV and liquid intakes, view congratulatory messages upon reaching a daily target, view intake progress, and read tips on FV and liquid intake.

Physical presentation and content

The font size of 18px in MyHealthyLivingApp_v1 was rated as a problem with the highest severity mean at 4.33. Referring to Silva et al.'s heuristic *"Allow sufficient white space to ensure a balanced user interface design"*, the experts suggested making the font size bigger especially on screens that have too much blank space. To improve the readability of text, the font size is now at least 24px in MyHealthyLivingApp_v2.

The experts commented on a number of inconsistencies in the design at different places in MyHealthyLivingApp_v1. The first inconsistency was the type of font used. To improve the readability for the older adults, the experts suggested using sans serif fonts throughout the MyHealthyLivingApp_v2, replacing serif fonts.

To login into MyHealthyLivingApp_v1, the users need to visit (1) the Main Screen (see Figure 7.11a) then (2) the Login Screen (see Figure 7.11b). The experts highlighted the inconsistencies of the buttons in the Main Screen and Login Screen with one being "ENTER" and one is "Enter". The experts also commented that the words "Enter" and "Logout" (see Figure 7.13) did not match. To simplify the login process, the experts suggested having only one Login Screen and suggested using the words "Login" and "Logout", as this is more common combination. Figure 7.12 shows the Login Screen of MyHealthyLivingApp_v2.

Figure 7.11. Inconsistency in labeling the buttons in the (a) Main Screen and (b) Login Screen in MyHealthyLivingApp_v1

Figure 7.12. the Login Screen in MyHealthyLivingApp_v2

In the Home Screen of MyHealthyLivingApp_v1, users tap on the ">" element to navigate to the next screen (see Figure 7.13). Only the ">" element is clickable and not the labels associated to it. The experts were concerned with the small size of the element and the labels associated with the element being non-clickable add a further layer of difficulty to navigate within the MyHealthyLivingApp_v1.

Figure 7.13. using the “>” element in the Home Screen to navigate to the next screen in MyHealthyLivingApp_v1

Figure 7.14 shows the Home Screen of MyHealthyLivingApp_v2. The new design includes buttons labeled with verbs. The buttons are arranged as a list as this was preferred by the users in Study 3 in the evaluation of the MyDrinkApp prototype (see Chapter 5). To avoid the “fat-finger” effect (Siek et al., 2005), which is that the size of the users’ fingers may cause difficulty in interacting with mobile devices, the width of the button is as long as the description labeled on the button. The height of the button is 50px. The experts were also concerned with the used of the word “Settings” (see top-right in Figure 7.13), they felt it was too technical for older adults. Thus, it is now called “Additional Features” (see top-right in Figure 7.14).

Figure 7.14. The re-design of the Home Screen in MyHealthyLivingApp_v2

To update a liquid intake in MyHealthyLivingApp_v1, users access five screens: (1) the Main Screen (see Figure 7.11a, then (2) the Login Screen (Figure 7.11b, then (3) the Home Screen (Figure 7.13), then (4) the My Liquid Intake App Screen (Figure 7.15a), and finally (5) the Add a Drink Screen (Figure 7.15b). The experts thought that such a sequence would be too long and this process of visiting numerous screens to perform tasks everyday might be too tedious for older users.

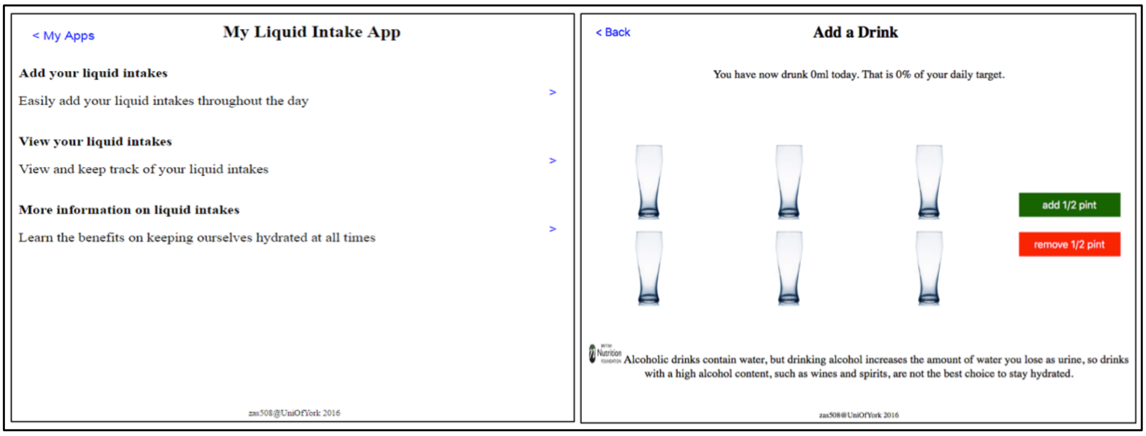


Figure 7.15. (a) The My Liquid Intake App screen, and (b) the Add a drink screen in MyHealthyLivingApp_v1

To reduce the number of screens, rather than separating the FV and liquid features in the Home Screen as shown in Figure 7.13, the experts suggested having one button each for updating FV, updating liquid, viewing progress, and reading tips, as shown in Figure 7.14.

In MyHealthyLivingApp_v2, to update a liquid intake, users visit only three screens: (1) the Login Screen (Figure 7.12), then (2) the Home Screen (Figure 7.14), and then (3) the Add a Drink Screen (Figure 7.16).

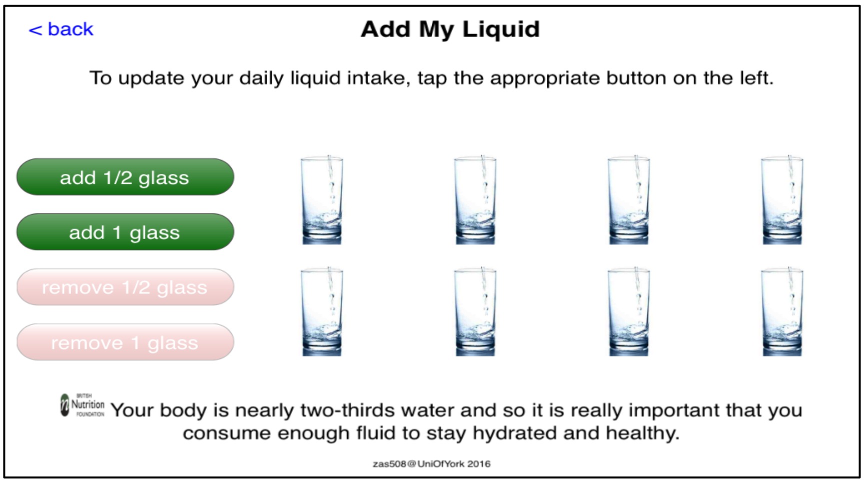


Figure 7.16 the Add My Liquid Screen in MyHealthyLivingApp_v2

As with MyHealthyLivingApp_v1, the interaction to update an intake remains the same apart from the "add" and "remove" buttons which have been moved on the left of the screen as people who read European languages typically work down a screen from top left to bottom right. So upon tapping on the left of the screen, users can see the update on the right of the screen.

To view the 7-day progress chart for the FV consumption in MyHealthyLivingApp_v1, users have to view their overall progress first and then tap the "View Chart" button at the top-right corner of the My-5-a-day Intake History Screen (see Figure 7.17). The experts were concerned that users may not want to see their overall intake, and suggested to not limit the users' interaction within the MyHealthyLivingApp_v1. The experts suggested a new screen, called Your Healthy Living Progress (see Figure 7.18), which consists of four buttons, separating the progress option for FV and liquid using both list of the overall intake and the 7-day progress chart.

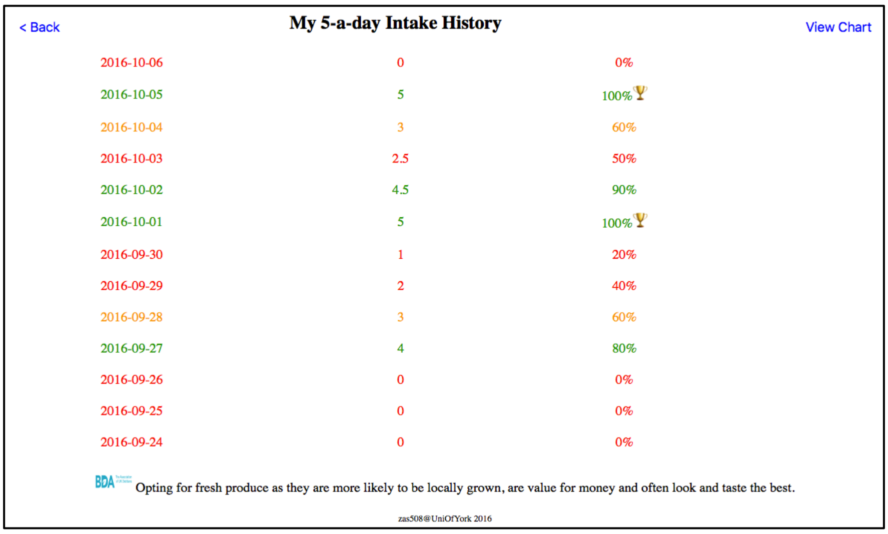


Figure 7.17. The My-5-a-day Intake History Screen in MyHealthyLivingApp_v1

Figure 7.18. The Your Healthy Living Progress Screen in MyHealthyLivingApp_v2

The two options to view one's progress remain the same as in MyHealthLivingApp_v1. A minor change to this feature was the colour used in the traffic light metaphor. In MyHealthyLivingApp_v2, a darker green colour is used to represent intake that is greater than 100% as suggested by the users in Study 3 (see Figure 7.19).

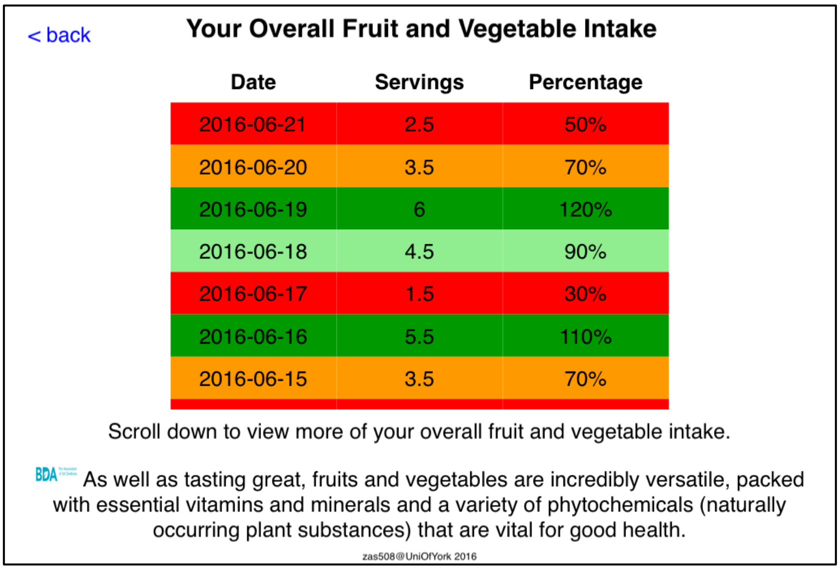


Figure 7.19. The Your Overall FV Intake Screen in MyHealthyLivingApp_v2

Read tips

The two options to read tips about healthy eating remain the same in MyHealthLivingApp_v2.

7.5 Conclusions

This study reported on the CHE evaluation of the MyHealthyLivingApp. Three usability experts found a total of 24 usability problems. The app was re-designed on the basis of these problems and design suggestions made by the experts.

The experts highlighted the importance of designing an app that is consistent in presentation of information and interaction for users. This includes the fonts, the navigation style, the layout, the sizes of the buttons and images, and the words used in the app. The experts also suggested designing an app that requires minimum effort to do tasks, especially when the app is for older users. They suggested reducing the number of screens that need to be navigated to complete tasks. Other suggestions included minimizing the amount of text and using bigger fonts to increase readability for older users. They also felt the app needed to be simpler, more action-oriented, friendlier, and use simple English words.

After reviewing the problems encountered and analyzing the suggestions given by the experts, a re-design of the app was proposed to solve the usability problems and implement the design suggestions before proceeding with the final study in this programme of research, the field study of the app.

Chapter 8

Study 6: A 2-week Field Study of the MyHealthyLivingApp to Support Monitoring Fruit, Vegetables and Liquid Intake by Older People

8.1 Introduction

This study is the final user study in this programme of research. The redesigned version of a web-based app of MyHealthyLivingApp to support healthy living, which allows the user to monitor whether they are eating sufficient fruit and vegetables (FV) and drinking sufficient liquid, was used in this study.

The gold standard for the evaluation of new technologies is testing with potential users of systems, to see how they use a system and what problems they have with it. A field study is often conducted at the end of the development stage to investigate the overall acceptance, usefulness and usability of a system (Doyle et al., 2014; Fan et al., 2012; Grimes et al., 2010; Hakobyan et al., 2016).

Therefore, for this study, to evaluate the acceptability, usefulness and usability of the app, a two week field study was conducted. In addition, this field study also aimed to investigate whether each feature of the app raises awareness and motivates participants to eat more FV and drink more liquid.

8.2 Method

8.2.1 Design

A tablet computer app, called MyHealthyLivingApp (hereafter the "app"), to support older adults to monitor their FV and liquid intake was evaluated by 15 older adults during a two-week period in their daily lives. The reason to recruit 15 participants is as explained in Chapter 5 (Section 5.2.1). To introduce the app, a one-to-one briefing session was conducted with each participant. To encourage participants to self-monitor their diet and to evaluate the acceptability, usefulness and usability of the app, no contact was made with them during the field study. Participants owned their own tablet computer, which allowed them to be familiar with the technology. However, participants were welcomed to contact me if they needed help in using the app during the field study.

The main features of the app include of the ability to set liquid measurement preference, add or remove FV and liquid consumed, view congratulation messages upon reaching daily target, view intake progress, and read tips on healthy living. At the end of the two week period, participants were asked to complete a short questionnaire and were interviewed. The questionnaire covered overall acceptance of the app, the ease of use of the app, the usefulness of each feature of the app, and whether each feature raises awareness and motivates the participants to eat more FV and drink more liquid and whether their eating and drinking habits changed during the study. Further comments on each feature of the app were gathered via open-ended questions.

The questionnaire also included questions in what were the most motivating features of the app that encourage the participants to eat more FV and drink more liquid. Participants were welcomed to select all features that apply to them.

The questionnaire also included the System Usability Scale (SUS), a 10-item questionnaire assessing the perceptions of a technology usability (Brooke, 1996). SUS is chosen as found to be the most reliable usability questionnaire for usability studies when compared with four other questionnaire (Tullis & Stetson, 2004) and to be useful over a wide range of products (Bangor et al., 2008). SUS consists of ten questions rated on a scale of 0 (strongly disagree) to 4 (strongly agree). Final scores range between 0 and 100, where higher score indicate better usability. Bangor et al. (2008) reviewed 2, 324 SUS surveys from 206 usability test and proposed a mean score of 70 and above as an indicator of a system with better usability. In this programme of research, the term "system" in all 10 questions was replaced with "My Healthy Living App".

The questionnaire also included the Mobile Devices Proficiency Questionnaire (MDPQ-16), a 16-item questionnaire measuring older adults' proficiency in using mobile devices (Roque & Boot, 2016). MDPQ-16 is chosen as to my best knowledge upon conducting this study, was the only reliable and valid questionnaire that measures older adults' proficiency specifically in using mobile devices. Each item is rated on a scale of 1 (never tried) to 5 (very easily). Final scores range between 8 and 40, where higher score indicate better mobile devices proficiency.

The questionnaire also included demographic information, similar as used in Study 1.

The interview explored further what the participants liked and disliked about the app, what was easy and difficult to use, what changes they would like and any other comments about the app.

8.2.2 The MyHealthyLivingApp

The design of app is explained in Section 7.5.

8.2.3 Materials and Equipment

During the briefing session, participants were shown the app on an iPad Mini (running iOS 9.3.5). However, during the field study, participants used their own tablet computer. Participants were also given an information sheet (Appendix 27) and completed an informed consent form (Appendix 28).

A user manual and a post-study questionnaire were developed and presented in large print (16pt). The user manual includes detailed explanations of how to use the app (Appendix 29).

The post-study questionnaire (Appendix 30) includes the following rating items (all 1 – 7 Likert items with 1 – most negative, 7 – most positive):

- ease of use to update consumption
- usefulness of different options to update consumptions (e.g. add ½ serving or remove 1 serving) and to change liquid measurement option feature)
- each app feature (e.g. view progress, read tips) for usefulness, helpfulness in raising awareness and motivation to eat more FV and to drink more liquids
- if the overall usage of the app helped raise awareness or motivation to eat more FV and to drink more liquid
- if eating and drinking habits changed during the study

The questionnaire also includes open-ended questions to gather further comments on the features of the MyHealthyLivingApp and demographic information (similar as used in Study 1, Study 3 and Study 4). Participants also completed the SUS (Brooke, 1996) and the MDPQ-16 (Roque & Boot, 2016).

In addition, a six-question post-study interview (Appendix 31) schedule was developed. The questions included what participants like and dislike about the app, what was easy and difficult to use, what changes they would like and what other comments they have about the app.

8.2.4 Participants

Fifteen participants took part in the study. Of these, six participants were participants who had evaluated in the MyDrinkApp (in Study 3, see Chapter 5). Five other participants were participants in the investigation of interaction techniques for number entry in Study 4 (see Chapter 6). These participants were interested in the current study to see the results of their input to the design process. Four participants were totally new to the programme of research. Working with the same group of participants who see how the technology or system develops is an integral part of the iterative user-centred design lifecycle. This also allows them to become co-designers and responsible for the outcomes of their evaluations (Rosson & Carroll, 2002). In addition, using similar participants in designing technology is common in HCI research (Abdul Razak et al., 2013; Hakobyan et al., 2016).

The inclusion criteria for the current study were to be 65 years or over, live independently, either alone or with a partner, have experiences and own tablet computer, and to have access to the Internet. Nine participants were women, six were men, their mean age was 70 years with a range from 66 to 78 years (sd: 4.1; age range 66 – 78 years). All participants lived with a partner. Four participants had secondary school education, four had a bachelor degree, four had a post-graduate degree and three had professional qualifications. Thirteen participants were retirees, two were working part-time. In addition, all participants were Internet users with experience ranging from 3 to 30 years (mean: 19 years; sd: 8.9). Eleven participants were computer users with experience ranging from 2 to 30 years (mean: 16 years; sd: 9.6). All participants were tablet computer users with experience from 1 month to 6 years (mean: 3 years; sd: 1.6).

See Appendix 32 for the list of participants by their gender and age.

8.2.5 Procedure

A one-to-one briefing session was held with each participant in the Interaction Lab, Department of Computer Science or at the participant's own home. The session included reading the information sheet, explaining any questions about the information sheet, completing an informed consent form and a demonstration of how to use the app. Participants then explored the app themselves and asked questions. Each session lasted approximately 45 minutes.

Participants were then given a unique username, the link of the app, and the user manual.

Participants used the app for two weeks on their own, using it as much or as little as they chose. I made no further contact with participants during the two week period. However, participants were welcome to contact me if they needed help in using the app.

After the two week period, a debriefing meeting was arranged, again either in the Interaction Lab or at the participant's own home. Participants completed a questionnaire about the app and were interviewed. They were then invited to ask any questions about the purpose of the study. Participants were offered a gift voucher worth £50 to thank them for their time and efforts. Each debriefing session lasted approximately 60 minutes.

8.2.6 Data Analysis

A Shapiro-Wilk test showed that there was a significant skew in the distribution on majority of the Likert items in the post-study questionnaire. Therefore analysis of the quantitative data was done using non-parametric tests. A content analysis (Krippendorff, 2012) was conducted on the qualitative data from the interviews and open ended questions to identify the patterns of the participants' experiences of using the app, with a priori set of well known usability categories, those developed by Shackel and Richardson (1991) and Nielsen (2003). However those categories were developed in the early 90s and 2000s, so I was very open to the need for new or different categories. To ensure the reliability of the categorization, a second coder went through all the scripts and any discrepancies were resolved by discussion.

A list of usability problems identified by the users was created. The data analysis conducted for the usability problems is as described in Section 4.3.7, apart that there were no calculation for the mean severity ratings for each usability problems, as it was not asked in this study.

8.3 Results

Figure 8.1 shows the total number of participants using the app for at least one time per day to monitor their FV and liquid intake during the 14 days of the study. Eight participants used the app for 14 days, 12 participants for 13 days, and 14 participants used for 10 days. Four participants continued using the app after the study completed.

Reasons for not entering FV or liquid intake varied, with participants reporting reasons such as being away from home (i.e. having no Internet connection), feeling unwell, attending events during the weekends (e.g. attending weddings, funerals), or forgetting altogether.

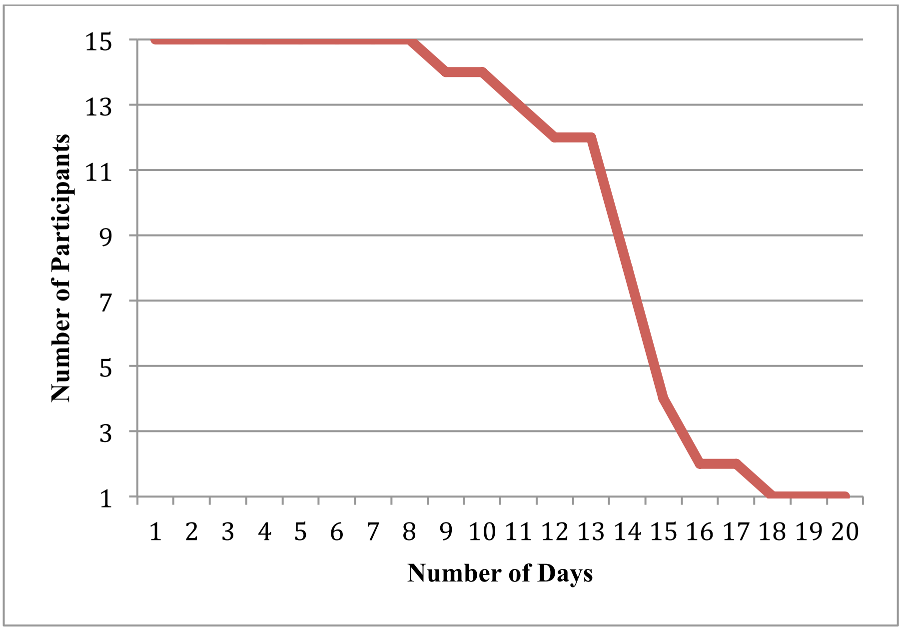


Figure 8.1 Participants' adherence to using the app

A Spearman's rank-order correlation was conducted to investigate the relationship between the number of days which participants used the app for FV and mean FV consumptions. There was no significant relationship found between the two measures, $r_s = .362$, n.s. Nor was there a significant relationship between numbers of days using the app for liquid intake and mean liquid consumptions, r_s = .344, n.s. Thus overall the length of time using the app does not relate to FV and liquid intakes.

Figure 8.2 shows the median ratings of the easiness of updating FV / liquid and the option to change liquid measurements. A one-sample Wilcoxon signed-rank test indicated that the median of the ease of use of the updating intake features against the neutral mid-point rating of 4 were significant for update FV (mdn = 7, IQR = 7, z = 3.58, p < 0.00, r = 0.92) and update Liquid (mdn = 7, IQR = 7, z = 3.64, p < 0.00, r = 0.94) only.

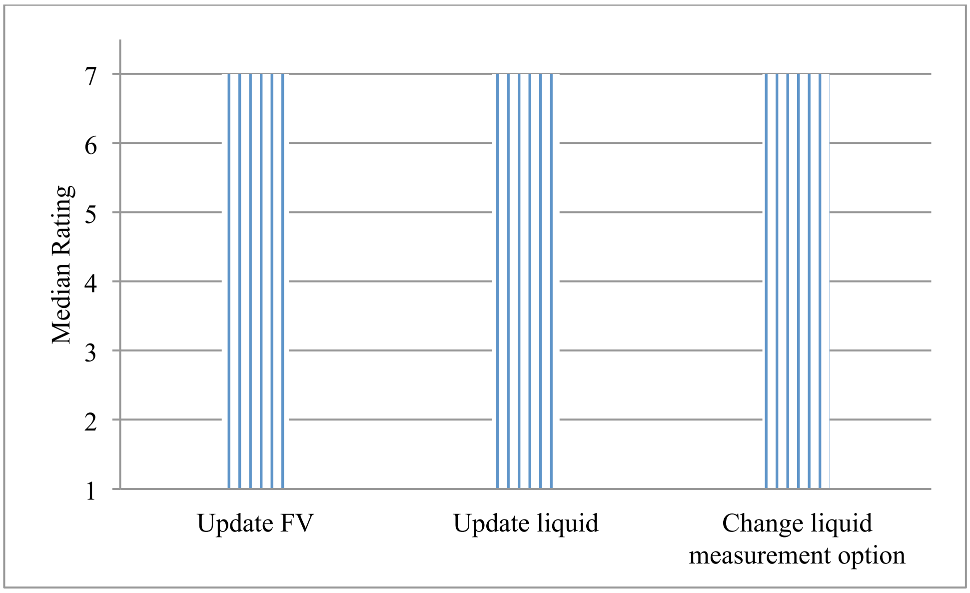


Figure 8.2 Median ratings of easiness for the options to update FV/liquid, and to change the liquid measurement option

Figure 8.3 shows the median ratings of the usefulness of having different options to add or remove a consumption (for example "add ½ serving" or "remove 1 glass"). A one-sample Wilcoxon signed-rank test of the usefulness of having different options to update an intake against the neutral midpoint rating of 4 showed that the median for "add 1" feature for both FV and liquid scores were significant, mdn = 7, IQR = 7, z = 3.77, p < 0.00, r = 0.97 (FV) and mdn = 7, IQR = 7, z = 3.41, p < 0.01, r = 0.88 (liquid). There were no other significant effects. All the Add features scored above the midpoint. All other features scored below the midpoint.

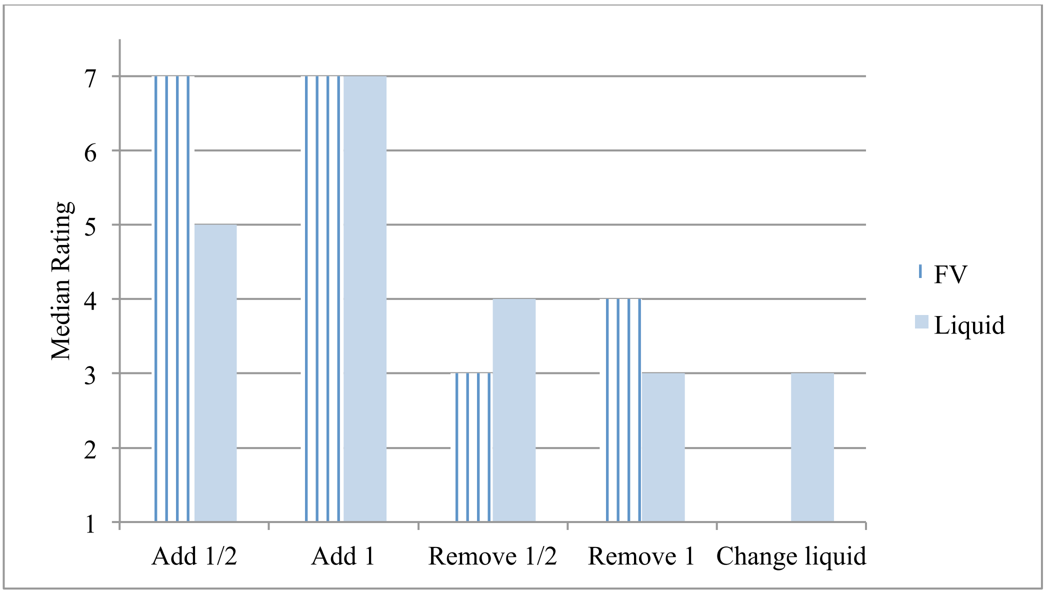


Figure 8.3 Median ratings of usefulness for the options to add/remove FV/liquid, and to change the liquid measurement option

Figure 8.4 shows for the median ratings for the different options for viewing progress. Wilcoxon signed-rank tests of the ratings of usefulness, ability to raise awareness about healthy eating and drinking (hereafter "awareness") and motivation to eat more FV and drink more liquid (hereafter "motivation") of having different options to view progress features against the neutral mid-point rating of 4 showed that the usefulness of viewing the overall list for both FV and liquid score was significantly higher than neutral, *mdn* = 7, *IQR* = (4.50 - 7), $z = 2.88$, $p < 0.004$, $r = 0.74$ (FV) and *mdn* = 7, *IQR* = (5.50 - 7), $z = 3.09$, $p < 0.002$, $r = 0.79$ (liquid). The ratings of awareness of viewing the overall list for both FV and liquid scores were also significant higher than neutral, *mdn* = 6, *IQR* = (4.50 - 7), $z = 2.39$, $p < 0.17$, $r = 0.62$ (FV) and *mdn* = 6, *IQR* = (5 - 7), $z = 3.10$, $p < 0.002$, $r = 0.8$ (liquid). There were no other significant effects were found. All the usefulness and awareness ratings were above the midpoint. In term of motivation to eat more FV / drink more liquid, viewing a chart of the last seven consumptions were rated less well than the overall intake view for both FV and liquid.

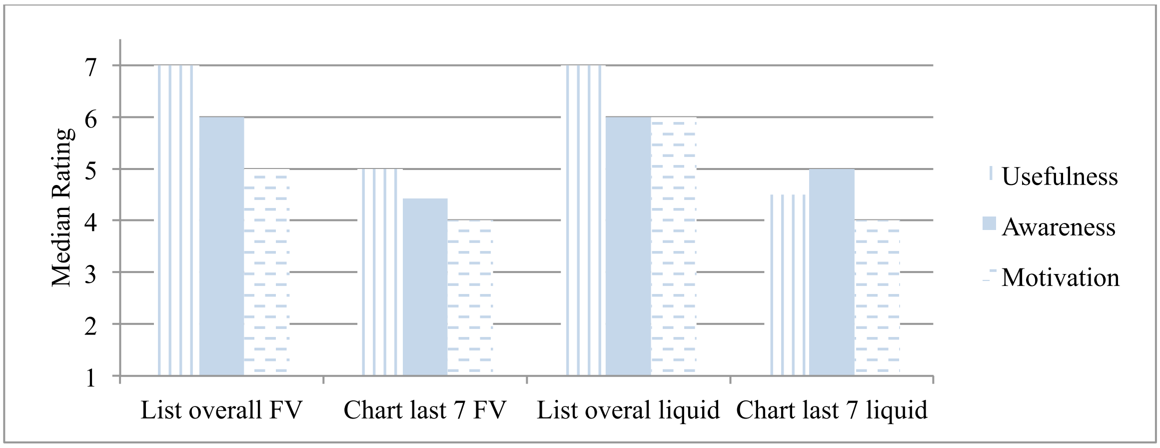


Figure 8.4 Median ratings of usefulness, awareness, and motivation of having different options to view the progress

Figure 8.5 shows the median rating for the tips options. Wilcoxon signed-rank tests of the ratings of usefulness, awareness and motivation of having different options to read tips against the neutral mid-point rating of 4 showed that only the ratings of the usefulness of reading FV and liquid tips were significantly higher than neutral, mdn = 6, IQR = (4.5 - 7), z = 2.69, p < 0.007, r = 0.69 (FV) and mdn = 5, IQR = (4 - 7), z = 1.99, p < 0.046, r = 0.5 (liquid). Reading FV and liquid tips were found useful and raise more motivation to eat more FV / drink more liquid at the tips screen. However, reading FV and liquid tips were found to raise more awareness to eat more FV / drink more liquid while updating consumptions.

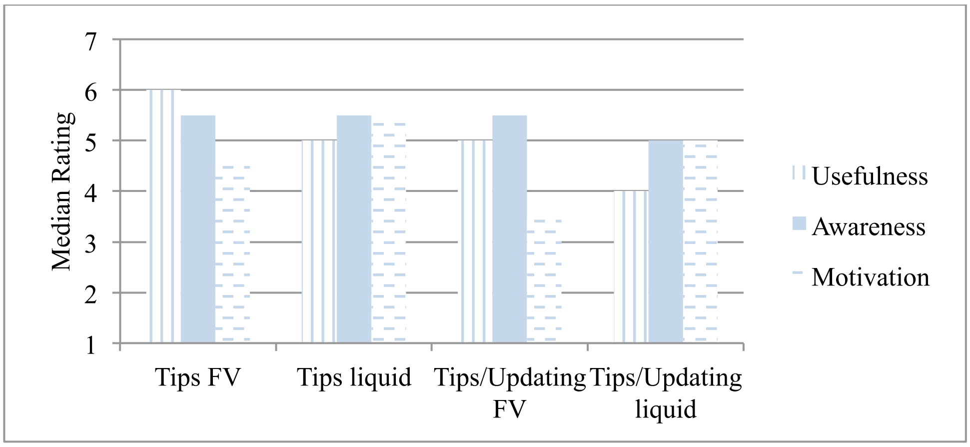


Figure 8.5 Median ratings of usefulness, awareness, and motivation of having different options to read tips

Figure 8.6 shows median ratings of seeing the congratulations messages. A Wilcoxon signed-rank test of the usefulness, awareness and motivation of seeing congratulation messages against the neutral mid-point rating of 4 showed that none of the features were significantly different from neutral. There were very little difference in terms of usefulness and raising awareness in seeing the congratulations message upon reaching the daily target for both FV and liquid. However, seeing the message motivated to drink more liquid than eating more FV.

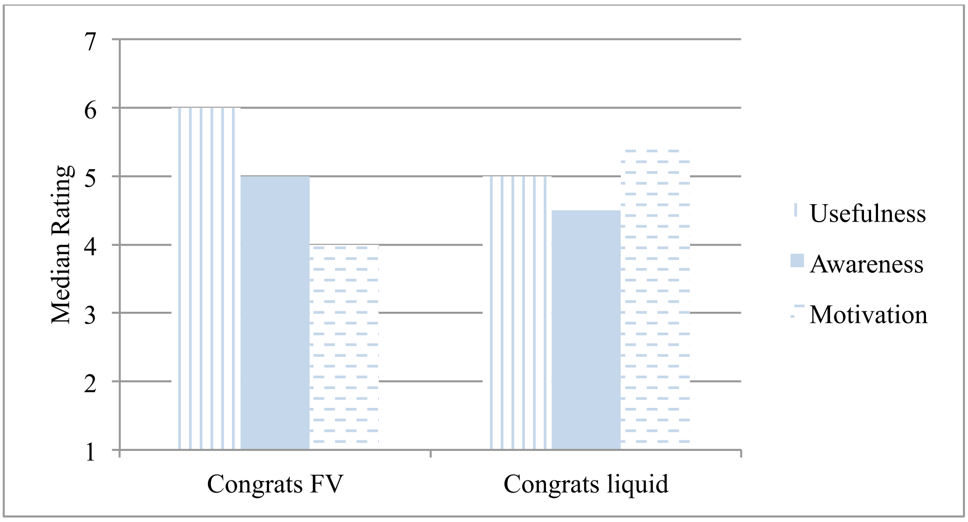


Figure 8.6 Median ratings of usefulness, awareness, and motivation of congratulation messages

Figure 8.7 shows the median ratings overall awareness, motivation and eating/drinking habits of using the app for two weeks. A Wilcoxon signed-rank test of these ratings against the neutral mid-point rating of 4 showed that only the mean of awareness scores were significantly higher than neutral, $mdn = 7$, $IQR = (6.5 - 7)$, $z = 3.36$, $p < 0.001$, $r = 0.87$ (FV) and $mdn = 7$, $IQR = (6.5 - 7)$, $z = 3.36$, $p < 0.001$, $r = 0.87$ (liquid). In overall, using the app made the participants more aware and more motivated to eat more FV and to drink more liquid. Participants moderately agreed with the idea that they ate more FV and drank more liquid during the study than before.

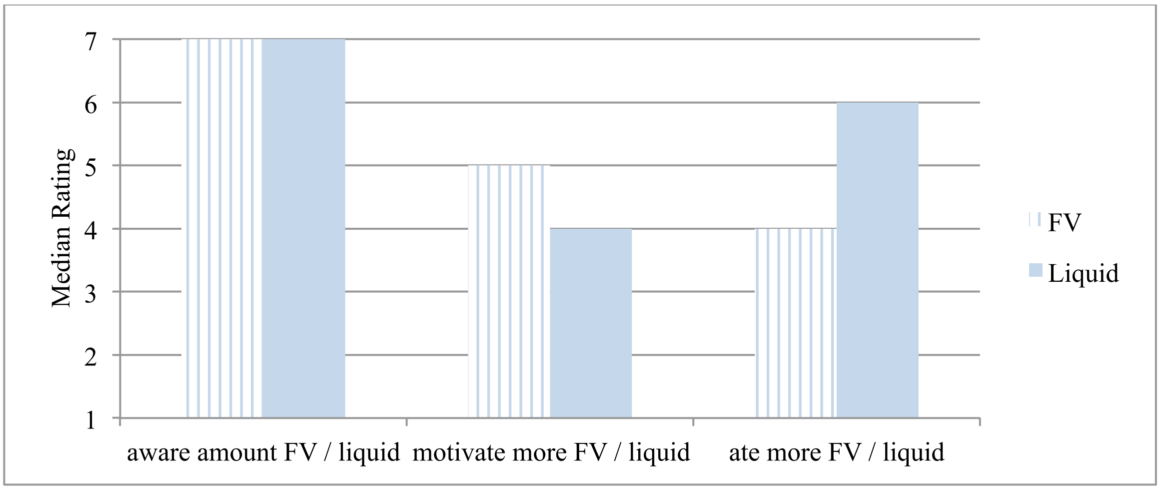


Figure 8.7 Median ratings of overall awareness, motivation and eating/drinking habits of using the app

A chi-square test was conducted to investigate the differences in preferences for the most motivating features between the FV and liquid, there was no significance difference ($x^2 = 1.43$, $df = 1$, n.s). For FV, the ability to view the list of overall consumption was the most motivating feature by seven participants (17.9%). The ability to both servings, add 1 and add ½, were the second most motivating features by six participants (15.4%). The third most motivating feature was the ability to see the congratulation message upon reaching the daily target by five participants (12.8%). Whereas for liquid, eight participants selected the ability to add 1 serving as the most motivating features (19.4%), followed by the ability to view the list of overall consumption by seven participants (16.7%). The third most motivating feature was the same as FV, being ability to see the congratulation message upon reaching the daily target by five participants (12.8%). The other features were least preferred (approximately 10% and lesser) to motivate participants to eat more FV or to drink more liquid. See Table 8.1 for these results.

Table 8.1: Features of MyHealthyLivingApp with percentage / number of users who preferred these features as the most motivating to eat more FV and drink more liquid (f% (N))

Feature	FV	Liquid
add ½ serving	15.4 (6)	11.9 (5)
add 1 serving	15.4 (6)	19.4 (8)
remove ½ serving	0 (0)	0 (0)

remove 1 serving	2.6 (1)	0 (0)
read tips while updating intake	10.3 (4)	4.8 (2)
read tips at healthy living tips screen	10.3 (4)	9.5 (4)
see congratulation message upon reaching the daily target	12.8 (5)	14.3 (6)
view coloured list of the intakes	17.9 (7)	16.7 (7)
view coloured chart of the last seven intakes	7.7 (3)	11.9 (5)
change the liquid measurement options	-	2.4 (1)
see updated intakes while updating intakes	5.1 (2)	7.1 (3)
the recommendation of daily servings for FV and liquid intakes	2.6 (1)	2.4 (1)
	100 (39)	100 (42)

Spearman's rank-order correlation was run to investigate the relationship between the number of years of experience using tablet computers and the individual SUS score. There was no significant relationship found between the two measures, *rs* = 0.13, *p* = n.s. Similarly, there was no significant relationship found between age and the individual SUS score, *rs* = 0.11, *p* = n.s. In related to gender factor, the mean SUS score for male participants was 94.17 (sd = 6.45) and 85.83 (sd = 10.6) for female participants. An independent-samples t-test was conducted to determine if the variance between genders were different was not significant at $t(13) = 1.712$, *p* = n.s.

Thus, the experiences in using tablet computers, age or gender were not correlated to the individual SUS score. The overall mean score was 89.17 (SD = 9.8, range = 70 to 100), indicating that the participants found the app highly usable (Bangor et al., 2008). See Appendix 33 for each participant's SUS score.

Spearman's rank-order correlation was also run to investigate the relationship between the number of years of experience using tablet computers and the individual MDPQ-16 score. There was no significant correlation between the two variables, *rs* = 0.68, *p* = n.s. However, there was a significant negative correlation between the participants' age and the individual MDPQ-16 score, *rs* = -0.51, *p* = 0.05. In related to gender factor, the mean MDPQ-16 score for male participants was 32.9 (sd = 6.2) and 33.94 (sd = 3.5) for female participants. An independent-samples t-test was conducted to determine if the variance between genders were different was not significant at $t(13) = -.41$, p = n.s.

The outcome of these results shows that the experiences in using mobile devices and the gender factor were not correlated with the MDPQ-16 score. However, there was a significant correlation with age factor. The older the participant, the lower the MDPQ-16 scores. In overall, the mean MDPQ-16 score was 33.53 (SD = 4.6, range = 23 to 40), indicating that the participants were proficient in using mobile devices. See Appendix 34 for the participant's MDPQ-16 score.

8.3.1 Analysis of the interview and open ended questions

Six questions were asked during the short interview to gather more information about participants' views regarding their experiences with the app. Open-ended questions were asked to gather further comments about each feature of the app.

The analysis of the interview and open-ended questions produced seven themes: (a) efficiency, (b) effectiveness, (c) learnability, (d) raising awareness to eat and drink healthily and to facilitate self-monitor diet, (e) raising motivation to eat and drink healthily and to facilitate self-monitor diet, (f) potential to support social interaction and (g) potential to support memory. The findings of each theme are elaborated below.

Efficiency

Participants' main comments in terms of the app's efficiency were that the app was straightforward and designed as what it is supposed to do. Seven participants acknowledged this:

> *it [the app] was obviously what it was for very straightforward p10*

> *it [the app] was very straightforward [to use] with both the liquid and fruit and vegetable p13*

> *it [the app] was straightforward [to use] once you get the idea what was 1 portion p8*

Four participants highlighted that using the app was quick and it did not take a lot of time, as explained below:

it is easy and quick on its own now p12

if it got into taking more of my time I'd get impatient with it I like that I can do it quickly and forget about it and the fact that you can do it anytime p15

it's quick it's easy to put in information and it gives a picture on how you're getting on p12

Effectiveness

Participants' main comments in terms of the app's effectiveness was the ease of use of the app, as exemplified in the following comments:

that it was easy to use well it was obviously what it was for very straightforward and it was a nice way to record information and I can just press a button and see all my history and that's what I like p10

I think it's sufficiently straightforward and easy enough for most people p15

When asked about what was difficult to use about the app in its overall form, 14 participants reported that there was no difficulty at all. Only one participant commented that the image of the ½ and 1 cup graphical representations were confusing, as exemplified in the following comment:

it was the half and full cup because I could not really understand that I could not really see p9

Other participants commented positively about what was difficult to use about the app:

everything was fine for me it was easy if this was to be difficult I wouldn't have done it p15

I don't think anything was difficult at all p7

Two participants noted that although they were not technology savvy, yet they found the app easy to use. As commented by one of them:

I found it all easy I am not a technical person p14

Further comments from two participants highlighted that the ease to use and the way the app was designed encouraged them to want to use the app. The simplicity of the app was crucial to gain the participants' enthusiasm to use the app:

easy to use which encourage you to use it p3

it [the app] is easy to use and importantly they way it is designed makes you want to use it p2

Nine participants commented that the app, as a whole, was easy to understand:

everything was easy to understand p2

everything seems very simple and easy to understand p7

Learnability

Participants were not fearful of using new technologies, despite having different technology backgrounds, particularly in using a touchscreen.

I prefer to play with the system to lose my fear of the system it took me three days to get the understanding of how the app works p5

I am not a technical person but once it was explained to me the practice session helped because if I was given to it just like that I don't think I would be confident enough to use it p14 *it only take a minute or two to understand and use the app p15*

The app was designed based on Apple iOS platform. Although three participants were not Apple users, they managed to quickly understand how to use the app, especially when navigating between the screens. As one of the participants commented:

there was one time when I was doing it I realised that the back and logout was all on the left whereas most system on the computers they have the X on the right don't they I don't know I'm using Microsoft all the time but the good thing about your design is that everything is on your left so back back back then your off p12

Seven participants found the practice session prior to the study was helpful to gain understanding of using the app.

the practice session we had help a lot to understand using the app p11

you explained how to use the app very clearly to me at the beginning p10

In addition, six participants mentioned referring to the user manual prior the study to gain understanding of using the app:

I did read the instruction to begin with that was straightforward so yes it was very straightforward with both liquid and fruit and vegetables p13

I read it through to get an idea of the app couldn't do the app without it p4

These findings are in line with recent study, for example by (Grindrod et al., 2014; Hakobyan et al., 2016) which shows that older adults in their studies are also interested in investing time and effort in using new technologies to monitor their health as long as the technologies bring benefits for them.

Raising awareness to eat and drink healthily and to facilitate self-monitor diet

The results revealed that one of the main advantages of using the app for participants was its capability to raise awareness to eat more FV and drink more liquid. This is important for the participants to improve health, longevity, and independence as studies have shown that older adults prefer to be independent for as long as they can (Chaudhuri et al., 2015; Demiris et al., 2004), rather than relying on others (e.g. family members or carers) to perform daily activities. The participants indicated that the fact that the app showed them their current eating and drinking habits, which triggered their awareness to eat and drink more healthily:

> *I like the fact that it made you very aware of what you're eating and drinking I find it very helpful because I know you know that we have to eat FV and all but keeping a record of it you know you can see what how much you eat actually it is very helpful p13*

The design, colours and images used in the app also raised awareness to eat and drink more healthily. Participants emphasized the simplicity of the interaction design to update an intake was satisfying and the design reminded them to eat and drink healthily:

> *you know you can see how much you eat actually it is very helpful the changes in colour of the heart is also good p13*

> *this is a useful tool and it's just a very good reminder for healthy living p6*

> *the hearts the shape the colours it reminds you that this is good for your heart and eating healthy p9*

> *to see the hearts it's more satisfying that's what I like about it actually I enter an intake and this little heart changes colour I like that actually I really really like that p10*

Each feature of the app was found to positively encourage the participants to self-monitor their diet. In particular, the use of text message to show the percentage of their intake as a form of feedback raised awareness for six participants to change their diet. Comments from the participants included:

> *the percentage is ok [we] can know where we stand to should drink more or less in later of the day p1*

> *the colours didn't really matter to me I looked more that the percentage that made me more aware of my eating habits p15*

Four participants found the use of graphical representation, in particular the changes of the colours of the graphical representation upon updating an intake, as a form of feedback raised awareness to self-monitor their diet. Participants commented:

> *the changes in the colour of the heart is also good it is very helpful p13*

> *it gives you a picture on how you getting on p12*

Nevertheless, three participants reported the combination of using graphical representation and text message (showing the percentage of intake) as the form of feedbacks upon updating their intakes is more satisfying and raised awareness to change their diet. Participants utilize this feature to monitor their daily intake and ability to meet the daily goal. Comments from the participants included:

> *I can see the percentage but to see the heart is more satisfying p10*

> *the pictures was good too if you just had the numbers it would not be the same it was very important to see those feedbacks p6*

The recommendation of daily servings for FV and liquid intakes was also found to raise awareness to eat more FV and drink more liquid:

> *this study tells me more about myself I did not know that I don't drink enough or eat enough but now be able to see it p15*

I can see that I am eating and drinking enough according to the recommendation it's good to know the target though I know at some times I'm above it and sometimes I am below makes me realise that I have to eat and drink more some of these things p11

I think it's useful as a reminder I didn't realize that I was so far under the limit this made me a bit more aware p6

Raising motivation to eat and drink healthily and to facilitate self-monitor diet

Participants also found the app useful for keeping track of their eating and drinking habits. Participants highlighted the app acted as a motivational tool to support them to self-monitor their diet.

it motivates me to drink more and keep hydrated because prior to before I had no idea I was lacking the amount of liquid I was taking p14

it's a motivation tool for one to see what they have done what they need to do for both aspect the fruit vegetables and liquid p1

Participants also reported that the app motivated them to make positive changes to their diet.

I looked more at the percentage that made me more aware about my eating habits I now finished all the foods on my plate same as drinks I finished all the liquids in the cup because before this I tend to leave some food or coffee now I do finished them all seeing the percentage did changed the way I eat and drink p15

I think it came on the right time for me there's been quite a lot about drinking water and I have a strong feeling about that I have also decided to cut down a lot on alcohol because it interferes with my sleep I now drink coffee in the morning and then tea later I drink more juices now p5

I think it's very useful as a reminder for my intakes especially for the liquids I didn't realise that I was so far under the limit this made me a bit more aware so it made me drink a bit more than I normally do p6

Participants were also surprised to learn how much FV and liquid they consumed on a daily basis and throughout the study:

I was surprised at how much I did drink p7

over the period of the trial I increased my daily consumption of fresh fruit and enjoyed eating it p2

Each feature of the app was found to positively encourage the participants to self-monitor their diet. The recommendation of daily servings for FV and liquid intakes was found to motivate participants to eat more FV and drink more liquid. This supports findings from previous studies that older adults are more likely to agree using self-monitoring technologies and to adhere to the recommendations when the use of technologies can improve their health (Fowles et al., 2004). As commented by one of the participants:

seeing a percentage of the total recommendation spurred me on to drink and eat more vegetable that day p13

Ten participants reported that the congratulations message was helpful in motivating them to eat healthily. Participants were also keen to maintain healthy eating to be able to receive the messages:

the message is motivating for me to try to get 100 percent but I always fail I am always at 70 percent p15

to get this [the congratulation message] I tried eating more fruit and vegetables p14

this [the congratulation message] is very encouraging and therefore motivates me to maintain or do better p2

The use of the traffic light metaphor as a form of feedback was also found to motivate six participants to change their diet and to keep using the app. This finding contradicts with the findings by previous studies, for example by Doyle et al. (2014) and Grimes et al. (2010), where some older adults in their studies did not understand the concept of the traffic light metaphor as a form of feedback while using apps. Participants commented:

> *I like the traffic colour code it made me wanting to use the app more so that I can avoid seeing red p5*

> *it's a motivation to see the 100 percent and the greens all the time p8*

Participants emphasized that the progress options showed clearly how much FV and liquid they consumed, thus motivating them to change their diet. Participants also find it interesting to be able to monitor and analyse their intake. The willingness to change is important for their health as this age group are often linked to various health problem, such as dehydration, that can cause various negative consequences including increased risk of infections of many kinds, increased falls due to dizziness, and difficulties metabolizing medications (Abdallah et al., 2009). Comments from the participants on this topic included:

> *looking at the reds in the graphs does affect me it did made me wanting to drink more and eat more it brings the good effect to change p13*

> *by looking at the list motivate me and raise my awareness to drink that extra cup to get 100 percent p8*

> *I thought it was a simple way to look back at what I have been eating and drinking in a day quite nice to see quite precisely p11*

> *each morning I analyse my intakes with my wife p5*

In particular, five participants emphasized that the bar chart to show their weekly progress was useful to monitor their progress and motivate them to change their diet:

I like the bar chart it's good to see it affects my behaviour to get better readings p5

it's [bar chart] the best way to see my progress it's easier to see p11

Nevertheless, five other participants reported the list to show the overall progress interesting to self-monitor their diet. Some of the comments were:

I found it [list chart] interesting to follow my whole progress p3

it was interesting to see how much we had eaten p7

The tips section was also found to motivate eight participants to eat and drink healthy. The findings show that the tips, both at the tips screen and the add intake screen, motivated the participants to improve their diet. Comments from the participants included:

this [tips at tips screen] is ok because I was conscious of not drinking enough it did motivate me to drink more p14

interesting to see the tips [tips at add intake screen] changes all the time keeps me motivated p15

Participants also reported the tips educate them with new knowledge and encourage learning. Participants commented that the tips provided a better understanding of FV and liquid intake making them want to learn more about healthy living:

tips help me with my understanding of fruit and vegetables helps me to understand eat less but eat better p5

it educated me a bit more than I thought I thought I was doing alright but then you know that 5 fruit and vegetable what's the history about it p11

I always read the tips to get an idea what is a serving and then update my intake p8

The tips also motivated participants to eat and drink healthily, especially to incorporate more variety of FV and drinks to their diet. Comments from participants included:

> *I read the tips I now include peppers to my diet p5*

> *I like the random messages it helps to think about what to eat drink change or buy to fulfill the target p1*

Potential to support social interaction

One finding less frequently mentioned by participants but important, is that the app can potentially support social interaction among family members while they improve their dietary habits. I did not explicitly assess the impact of using the app on participants' social interaction, however, the comments indicate that some participants felt the app contributed to their social interaction. Two couples, who participated in the study, compared their progress intakes between each other, seeing who reached their daily target first. One of the participants, who was part of a couple, further suggested making the app accessible to the various members of a family, so they could use it together. Another participant shared and analysed his progress with his wife every day, even though she was not part of the study. Comments from participants included:

> *I like comparing my hearts and cups with [p11, their spouse] I usually get more perhaps can add social groups among family not with everyone P10*

> *I would have liked the icons to reflect the total amounts drunk I was amazed at how much I drink and how little [p6, their spouse] drinks p7*

> *the fact that we used it daily I like that it's an everyday thing each morning I'll enter what I had the previous day and analyse my intakes with my wife p5*

These comments shows that communicating and social interaction is important (Grimes et al., 2010), be it to analyse daily intake or to compare each other's intake progress, as loneliness, social isolation, and poor diet can cause health problems and often appear as an issue for this age group (Ong et al., 2015).

Potential to support memory

Another finding less frequently mentioned by the participants is that the app could potentially support their memory. I did not assess the impact of using the app on participants' memory, however, two participants repeatedly commented on how the app supported their memory. Participants were required to remember what they had consumed and update their intake and this could possibly improve their cognitive abilities. The comments included:

> *the app made us think first what we had before we put it in it made us think so it was good p13*

> *the app is good at one point because we have to calculate first what we drunk say for example a bottle is 500ml so it's 1 2 and half p14*

This finding shows, although very little number of participants reporting it, by having productive engagement of using the app, it can potentially older adults memory ability, an area that many older adults require assistance (Maciuszek et al., 2005).

8.3.2 Analysis of usability problems found in MyHealthyLivingApp

99 usability problems were identified in MyHealthyLivingApp. Table 8.2 shows the distribution of problems in the app into major categories and specific categories within those major categories, the number of participants who encountered them and the total frequency of each problem. All four major categories from the Petrie and Power (2012) categorization were found, being Physical Presentation, Content, Information Architecture and Interactivity. Over half the usability problems (51.5%) were found in the Interactivity category. Nearly one third (27.3%) were found in the Physical Presentation category and nearly 20% of problems were found in the Content category. Less than 10% was found in Information Architecture.

Table 8.2 Categories of usability problems identified in the MyHealthyLivingApp with percentage/number of users who encountered them and frequency of the problem category (f)

Category	**Examples**	**Users % (N)**	**f % (N)**
Physical Presentation (27.3%)			
Inappropriate colour / pattern / image combination	I can't see the difference between the half cup and full cup p9	20 (3)	5.1 (5)
Text / interactive elements not large / clear / distinct enough	it was quite difficult [to tap] the buttons to add p5	20 (3)	9.1 (9)
Changes to content / interactive elements not noticed	I didn't realise this feature [random tips at update intake screen] p8	33.3 (5)	13.1 (13)
Content (19.2%)			
Too much content	it was a bit cumbersome to find the information I needed almost too much information p10	13.3 (2)	3 (3)
Content not clear enough	when you look at it [bar chart] at the glance it's confusing p12	26.7 (4)	8.1 (8)
Content not detailed enough	if only it was more specific rather than just general tips then it would be more helpful p5	26.7 (4)	4 (4)
Content not suitable for the users	I did find some of the health advice amusing I thought it was weak you cannot live my age and know so little p5	20 (3)	4 (4)
Information Architecture (2%)			
Content not in appropriate sequence / unfamiliar format	the dates are in American format so confusing p12	13.3 (2)	2 (2)
Interactivity (51.5%)			

Labels / instructions / icons on interactive elements not clear	I didn't know what the difference colours meant p9	20 (3)	4 (4)
Excessive effort required by user to complete a task	one [problem] is that I have to keep on logging in and out that was a bit of fiddle p10	13.3 (2)	2 (2)
Input format unclear	I just don’t understand ml at all and don’t have the intention to learn it p7	53.3 (8)	12.1 (12)
Concerns related to the feedback	it was hard for me to just see the percentage p7	26.7 (4)	4 (4)
Options not logical / complete	all is ok the ability to add half and full option is ok but sometime wonders what is a portion p6	0.6 (1)	1 (1)
Interaction not as expected	the only thing that was quite annoying was the fact that it kept logging you off p8	26.7 (4)	4 (4)
Interactive functionality expected is missing	the way to enter your food was difficult to measure p4	40 (6)	10.1 (10)
Interactive elements not grouped clearly / logically	I realised that the back [and] logout was all on the left where as most system on the computers they have the X on the right don’t they p12	0.6 (1)	1 (1)
Too many tasks / interactive elements presented in a single screen	I concentrate more on updating the intakes and seeing the percentage and servings I don't bother the others p11	53.3 (8)	13.1 (13)

8.3.3 Older adults design suggestions for MyHealthyLivingApp

The analysis of the interview and open-ended questions also revealed five concerns about the functionality and usability of MyHealthyLivingApp in its current form. The concerns were with the: (a) updating intakes, (b) login process, (c) tips section, (d) progress intakes and (e) overall presentation of the app. Participants further suggested possible design to improve the functionality of the app thus possibly improving the usability of the app. The findings of each concern are elaborated below.

Concerns with updating intakes

Three participants reported having difficulty to add an intake due to the size of the buttons. Thus, they were confused to knowing whether an intake has been updated or not. Comments from the participants included:

> *sometimes I cant press the button properly maybe its just my fingers so I don't know whether the intake is in or not p11*

> *sometimes the button didn’t work p9*

> *it was quite difficult the buttons to add intakes p5*

Two participants reported difficulty in differentiating the two graphical representations (the ½ and 1 serving) used to update a liquid intake via cup. Another participant reported the colour of the graphical representations for the glass and the background colour was slightly the same. The comments included:

> *I didn't see the difference for the ½ and full cup in the picture very helpful p15*

> *what was difficult was the colour of the glass and the background was slightly the same p4*

Two participants had difficulty in updating their FV intakes mainly because they lacked knowledge about the serving size of a portion. Two other participants were confused to update their liquid intake because the measurement used in the app is not the same as the one they usually used. The comments from these participants:

> *the ability to add half and full option is ok but sometime wonders what is a portion p6*

I think the way to enter your food because that was difficult to measure p4

the other thing was that the fact my cup was 300ml but the one you had in the system was 200 ml p8

the things like the measurement like the glasses for example it varies in size p14

Two participants had difficulty in updating their intakes due to forgetting whether they have updated the previous intakes or not when they logged into the app. The comments included:

it made me think that cup of tea I had a 2 o clock did I put it in p10

I'm a bit absent minded a bit on 3 or 4 occasions I've come to it and I was thinking have I done it p12

Two participants, who often eat/drink more the recommended daily target, had difficulty knowing whether their intakes were updated or not due to the inconsistency of the images and the percentage as the form of feedback once they reached their target. One of the comments included:

I often go off limit but the icons remain the same only the percentage changes so I often think like hang on did I add one or too many there p7

Eleven participants thought their intakes were updated but only realized that they were not once they looked at their intake progress, but then found that they could not edit their intake. This contributed to another concern about the app, that it did not allow editing of previous intakes, especially for days when participants missed updating their intake. The comments included:

if you were out until midnight and you have been eating and drinking but now you cannot change the thing and when you put it in [the app] you got it in on the wrong day it's confusing p12 *can't add previous days so [the app] didn't really show exact intake p14*

All 15 participants gave suggestions to improve the functionality of updating an intake thus improving the usability of the app. The suggestions are as below:

Although was not a concern to any of the participants, two participants suggested removing the remove intake features. No further comments were given about this.

In related to the design of the buttons, the two participants who had this problem suggested the buttons to be longer and having bigger gaps in between them. The comments included:

buttons should be larger not longer p9

need bigger space in between the buttons p5

In related to the graphical representations to update the intakes, all three participants suggested changing the graphical representations.

In related to lack knowledge of the FV serving size, one of the participants who had this difficulty suggested having a list of buttons labeled with the serving sizes of different FV, and then he / she could tap on those buttons to add servings. Another participant who did not find having lack knowledge of the FV but rather wanting to improve the functionality of the app, also suggested this idea. Comments included:

rather than having 1 or ½ serving I think it would be better to add tomatoes salad lettuce I think that would be better p4

I think it'll be good to have a list of banana apple and all so then we can just click to what we had eaten p13

Similarly, although was not found as a problem but wanting to improve the functionality and thus possibly improving the usability of the app, three participants suggested separating the FV altogether but remain the ½ and 1 serving buttons to ease the update. They were interested to know exactly what they were consuming. Comments included:

> *You can actually separate the buttons ½ fruit 1 fruit ½ vegetable 1 vegetable you still got room on the screen here p10*

> *why not differentiate the fruit and vegetable intakes I think that would be interesting because I know I eat more fruit than vegetable but I think you should eat more vegetable actually this will be good then p13*

In addition, one participant suggested having options to add whether the FV is either raw or cooked, so that one can see exactly what they have eaten. The comment was:

> *it's interesting to know how much that we eat is raw and how much is cooked and fruits because now it can be five servings but all fruits which is not good p10*

Another suggestion was to have more colours representing the FV consumption rather than only having green and red on the graphical representation as a form of feedback upon updating FV intakes (see Figure 7.7 in Section 7.5). One participant suggested having a panel of colours to appear after tapping the ½ or 1 serving buttons, and then one could tap on any colour that matches the FV to add intakes.

For liquid, eight participants suggested better defined measurement / volume to update a liquid intake. Of these, five participants suggested allowing them to enter their own liquid volume each time they want to do an update. Four participants (including one who suggested to allow to enter own volume) suggested using other measurement options rather than cups, glass or pint-glass. Comments from the participants included:

> *perhaps if I can enter the volume by myself rather than having a fix volume per button p8*

> *it can be us to type in the volume or even have buttons that represent the volume p14*

> *I prefer a mug option p4*

[I prefer] bottles because that is 500ml p14

Two participants suggested refining the liquid (e.g. tea, coffee, juices etc) so that they can monitor their liquid intake precisely. The comments included:

why not include an option to add what type of drink is it tea coffee or water rather than general p5

make it more refine you can say water juice tea alcohol you know rather than making it general so I could record and keep an eye of number of drinks each week p10

In related to having difficulty to remember whether they have updated the intake or not, both participants who encountered this problem suggested including a time-stamp feature on the update intake screen. This time-stamp will allow them to remember exactly which intakes have been updated. Comments included:

I would add the date and time the reason I would add time is because when I go in it made me think that cup of tea I had a 2 o clock did I put it in did I remember to put it in or not so if you had that time feature we can know that cup was for which drink or time I had it p10

In related to the confusion of the form of feedback once reaching the daily target, both participants who encountered this problem suggested that the pictorial representation and the percentage should tally each time an interaction was made. This would allow them to easily see the amount of intakes they have consumed is updated or not. In addition, one of the participants noted that it is more satisfying seeing the pictorial representation than just seeing the percentage increasing. Comments included:

it will be useful to have the app to show exactly the amounts consumed once over the goal it was tricky to quickly see what has had added or not p7

> *there were times when I ran out of hearts because I hit more than 100 percent so I think I would like to see more hearts And a few more cups too I can see the percentage but to see the hearts it's more satisfying that's what I like about it actually I enter an intake and this little heart changes colour I like that actually I really really like that but then I ran out of hearts same with the cups I always drink more than the recommend so I ran out of them p10*

In related to the non-editing previous intake feature, all 11 participants who encountered this problem suggested allowing editing previous intakes. However, of the 11, three participants raised concerns about allowing editing. Of the three, two noted that people would perhaps tend to not update their intakes on a daily basis (knowing that they could make updates on later days), which would lead to not using the app regularly and accurately. One participant further commented that allowing people to edit previous intakes opens up the possibility of cheating on reporting. Two participants suggested allowing editing for just a few days back, because people will tend to forget what they had consume if it is far back anyway. Comments included:

> *allow you to go back and edit your previous days it shouldn't be that long back you know only a few days like 1 to 2 days p10*

> *having a feature to be able to edit your previous day can perhaps be useful I think but you don't want people to keep on relying on it you don't want people to keep on delaying their input because you can then make a mistake and the chart will be inaccurate then however then maybe perhaps just be able to edit 1 to 2 days only not the whole time p15*

There were also some suggestions to improve the functionality and thus possibly improving the usability of the updating intakes. Two participants suggested minimizing the number of screens they needed to visit to update a FV and liquid intake, by having buttons to link between the two updating intakes screens. The comments included:

> *can links work across the intakes pages rather than going back and forth to the main page p12*

Three participants suggested including motivational messages or tips to participants who did not reach the daily target. The comments included:

> *maybe when you do not drink enough have a message to remind them you are not drinking enough too not just for people who drinks enough p12*

> *perhaps you can give tips to one who has not reach 100 percent for that day p8*

Concerns with the login process

Four participants also found the login process[28] cumbersome since they were using their own tablet computers, especially given the fact that the app auto logged them off if there was no interaction after a few minutes. Any interaction done after the auto logged out would not be updated in the app. As one of the participants commented:

> *one is that I have to keep on logging in and out but I'm assuming that once it's on my phone that I don't have to do that but that was a bit of a fiddle and sometimes when you are in and updating your liquid in and you want to update your vegetables in it won't let you so you have to log out and come back in and check so I found that very fiddly p10*

Two participants suggested to remove the login process altogether. Another participant suggested providing notification before auto-logging them out from the app.

Concerns with the progress intakes

Two participants reported having some confusion on the date format used in the app, as it followed the United States convention of month-day-year rather than the UK of day-month-year. Two participants (one of which reporting the date format is confusing) reported that the chart of the seven latest intakes in confusing due to showing the latest intake on the left of the chart. Comment from the participants included:

> *so confusing the graph has the latest entry on the left contrast to the normal graph design second thing it's the date it's following the American style p12*

[28] A log in was necessary as the participants' data needed to be stored securely on a server.

Both participants reported confusion on the on the date style preferred the date to be in UK format. In addition, both of these participants and another participant who did not report to be confuse with the American date style suggested removing the year of the date, as the date is repeating and it looks crowded on the chart. Comment from the participants included:

> *dates should just show us without the year it's too crowded p5*

> *maybe you can take out the year now it's the same year repeating p13*

In related to the confusion to the order of the dates on the graph to show the last seven intakes, both participants who encountered this problem suggested reversing the order of the dates. Comment from the participants included:

> *now it's showing the latest date on your left I prefer the other way around it was a bit strange for me p13*

Although viewing the chart of the weekly progress intakes was not found as a problem, two participants suggested improving it. One participant suggested having a line across the seven days representing their average of intakes for that week. Another participant suggested providing the ability to compare intakes between months, so that one can see their progress after using the app for a long time. He / she also suggested to prolong the chart to show the whole month intakes rather than showing the last seven intakes only. Comments from the participants included:

> *perhaps you can include a line crossing all days showing the average of that week p5*

> *your history was just for a week or so the chart why not make it per month or so so we can see our progress in a long time you can also say that in July in average you reach 90% of your target in August you got this you know then in a year you can see are you getting better at this then p10*

Two participants commented the dark green colour used to represent the intakes for more than 100% is not suitable. One participant commented the two greens (i.e. for intakes 70%

to 100% and for intakes more than 100%) were too similar. He / she suggested to remain using only one colour of any green once one reached 70% of their intake. The other participant suggested changing the green for intakes more than 100% to another lighter colour green. Comments from the participants included:

> *the colour were just too similar perhaps just as long as more than 70 percent make it just one green don't have to change colour p13*

> *I think the colours need have some thinking about because the green represents good but the green that you chose was dark for the above 100 percent so it does not represent a good thing it's a sad looking colour it's more like a dull feeling so if you choose a more like a grass green it would be more better now it doesn't look successful it does give you that feeling of success it's dull now and like it's when you see a page of darkness or blackness you don't feel good I suggest using different colour but it should be happier make the red one dark and sad but the goods one brighters p12*

Concerns with the tips

Eight participants reported not interested in reading the tips on healthy living. Reasons to not reading the tips varied, with participants reporting reasons such as they do not find the tips useful because they always eat or drink more than the recommended daily intake, they already know what to eat or drink, busy with family, or was simply not interested in reading them. Comments from the participants included:

> *I usually drink more than the suggested daily intake of water I didn't see the need to use this feature p2*

> *no wasn't interested in it p4*

Two of these participants suggested to remove the tips altogether. Two participants suggested remaining the tips in the app, as it can be useful for other people, as they commented:

for me it [tips] was not particularly useful but for others I'm sure it would be very useful indeed p7

I know already about what to eat and all maybe this [tips] just can be a reminder for us just leave it there as it is p15

Three participants reported that the tips at the very bottom of the add intake screen are hardly noticeable, where they can simply miss them. Comments from the participants included:

the tips at the bottom of the page was so low at the bottom of the page where people can easily miss it not even notice p7

I did not realize this feature it's at the bottom p9

Five participants reported the tips were too general for people of their age, and wanted more specific tips on healthy living. Comments from the participants included:

these are just general tips p15

I did find some of the health advice amusing I thought it was weak you cannot live my age and know so little but seriously it was true I know it was from NHS and all I think if only it was more specific rather than just general tips then it would be more helpful p5

Five participants (two of whom had commented the tips were too general) reported they did not read tips at the update intake screens. These participants are more interested to update their intake and see their progress rather than reading the tips. Comments from the participants included:

I concentrate more on updating the intakes and seeing the percentage and servings I don't bother the others p11 *all I wanted was to update my intake and see the percentage and I prefer reading the tips at the tips page p8*

In regarding to improve tips, nine participants gave comments. Six participants suggested to provide simple, precise and specific tips on healthy living, especially on the matter of what is a serving. Comments from the participants included:

specific measurement for dried fruit fresh fruit fresh vegetables would be helpful p8

the tips section should be more precise and make it clear p15

Two participants suggested making the tips more noticeable by having pop-up message boxes or placing the tips in a higher location of the screen. One participant suggested rewarding the participants with prizes or trophies when they read more tips. The comments included:

maybe you can have a pop up message to make it stand out and we can read it p11

maybe can include prize or trophies when [we] read more tips p1

Concerns with the presentation of the app

Two participants reported that the font size used in the app was too small, that they did not notice the congratulation messages and the random tips at the add intakes screen. Both participants suggested bigger fonts. Comments included:

I honestly didn't realize this feature [congratulation messages] I looked at the history [screen] to see my progress ... the fonts are too small I didn't really notice this p11

make it [font] bigger so that it stands out p11

message should be bigger p9

One participant commented the app was too professional; that it lacked animations and fun features that could motivate one to using the app. The participant suggested including positive reminders messages to remind people to drink and add the intakes to the app, animations and sounds-effect to motivate people to using the app. The comment was:

> *the app itself is all good all accurate you felt confident that it was all adding your intake and all it's all professional and you obviously have done your research that this is all proficient [but] for tips have new tips make it obvious same for congratulation messages add more visual remind people to add intake at certain time give positive messages not annoying one make it friendlier chatty like Siri add flashing image buzz sounds or a ping as rewards add animation this perhaps can motivate people p9*

8.4 Discussion and Conclusions

This study reports the results of a two week field study to investigate the use of MyHealthyLivingApp to support healthy living among older adults, in terms of eating sufficient FV and drinking sufficient liquid.

Participation in the field study was good, with most participants providing a lot of data. Just over half the participants used the app for the whole 14 days, and nearly half used the app for 10 out of the 14 days, and there were no drop-outs. There were a number of legitimate reasons for missing days, but in general participants were eager to use the app.

A number of features were included in the app to raise awareness about healthy eating and drinking and to motivate people to eat more FV and to drink more liquid. These were the ability to add and remove FV and liquid intake via ½ or full serving buttons, view congratulation messages upon reaching daily target, view overall intake progress via a list or view the weekly intake progress via a bar chart, and read tips on healthy living particularly the importance of FV and proper hydration. All these features scored significantly above the midpoint of the rating scale for usefulness except for the removing intake options and the change liquid measurement options. All features also scored significantly above the midpoint of the rating scale for ability to raise awareness and motivation to eat and drink more except for the bar chart for viewing weekly progress, which participants did not find motivating.

The top two most motivating features that encourage participants to eat more FV and drink more liquid were the ability to view the list of the overall progress and add intakes. The list option was also found to be more useful, to raise more awareness, and motivated participants to eat more FV and drink more liquid when compared with viewing the chart of the last seven intakes. The ability to add intake, for both FV and liquid, was also found to be more useful when compared with other updating intakes (i.e. removing intakes and change measurement options).

Related to the qualitative findings of the current study, seven major themes in related to the participants' experiences of the app were identified. The themes were (a) efficiency, (b) effectiveness, (c) learnability, (d) raising awareness to eat and drink healthily and to facilitate self-monitor diet, (e) raising motivation to eat and drink healthily and to facilitate self-monitor diet, (f) potential to support social interaction and (g) potential to support memory.

These themes were also found in studies of apps with older adults to improve health by, for example, Grindrod et al. (2014); Hakobyan et al. (2016); King et al. (2013) and Årsand et al. (2010). The current results also support previous findings that older adults find using apps useful as a effective tool to support maintaining and self monitoring their lifestyle despite having different technology backgrounds, particularly in using touchscreens (Grindrod et al., 2014).

Each feature of the app in the current study was found useful, raised awareness and motivated participants to eat more FV and to drink more liquid. This is important for the participants to improve their health, longevity, and independence as studies have shown that older adults prefer to be independent for as long as they can (Chaudhuri et al., 2015; Demiris et al., 2004). Furthermore, although not formally tested, the unexpected but encouraging findings from the qualitative findings showed that the app also supported memory ability and potentially improved social interaction, areas that are often problematic for older adults (Maciuszek et al., 2005; Ong et al., 2015).

There were some concerns on the app's functionality and usability. Participants then suggested design suggestions to overcome their concerns of the app in its current form, and thus can improve their motivation to using the app. Suggestions that were given by the participants but not investigated in this study includes collecting rewards upon reading tips, ability to share progress with family / friends, or providing reminders messages to remind them to eat / drink and update the intakes to the app. Nevertheless, overall, the participants reported that the app in its current form was successful in promoting positive dietary changes through the use of the various features in the app. Participants also reported that the app did successfully motivate them to eat and drink healthily, encourage them to self-monitor their diet and it also improved their healthcare knowledge.

One limitation of this study is that participants only used the app for two weeks. This is not a particularly long period of time to establish whether the app would be used if participants had it available for a long period and whether it would continue to motivate them in eating and drinking healthily, as health behaviour change is only beneficial when observed over a long period of time (Conner & Norman, 2005; Prochaska, 2013). However, the purpose of this study was to establish the usability of an app in the nutrition and hydration area by older adults, and the results suggest this is very much the case.

Another limitation is that I acknowledge that the self-report might be susceptible to user bias.

8.5 Conclusions

This study is the final user study in this programme of research. To develop an evidence based heuristics to assists the development and evaluation of tablet computer apps specifically for older adults, I compile and investigate the usability problems reported in Study 2 (Chapter 4), Study 3 (Chapter 5), Study 5 (Chapter 7) and Study 6 (Chapter 8). The next chapter will report the findings.

Chapter 9

Heuristics to assist the Development and Evaluation of Tablet Computer Apps for Older Adults

9.1 Introduction

This chapter presents the last stage in this programme of research. It presents an analysis of usability problems identified in the user evaluations of the prototypes of MyHealthyLivingApp (see Chapter 5: Study 3 and Chapter 8: Study 6). The analysis allowed me to develop a new evidence-based heuristics to assist the development and evaluation of tablet computer apps for older adults.

Chapter 4 (Section 4.1) of this thesis discussed the various sets of guidelines and heuristics relevant to the design and evaluation of apps for older adults. To recap, only the touchscreen guidelines from Kobayashi et al. (2011) were developed from direct empirical evidence, an evaluation with 20 participants in their 60s and 70s. The other sets of heuristics were developed by reviewing research on usability issues for older adults (Al-Razgan et al., 2014; Calak, 2013; Silva et al., 2015; Watkins et al., 2014). Given that some of these authors reviewed research dating back to the 1990s (e.g. Nielsen (1994) and early 2000s (e.g. Chisnell and Redish (2005), when interaction styles were very different, it is important to validate these guidelines and heuristics against the current actual experience of older users.

Section 4.4.2 of this thesis discussed the experts' experiences of using the Silva et al. (2015) heuristics to evaluate MyDrinkApp. The experts had difficulty in using these heuristics because they are very long and have no high level structure. The experts also noted that many of the heuristics include general usability principles and it would be helpful to have a set of heuristics which concentrate on the additional aspects important for older users, and not mix them up with heuristics for all users, which usability experts are likely to already be familiar with.

Thus, this study developed a set of evidence-based heuristics using data from the user evaluations of the MyHealthyLivingApp conducted in this programme of research. The app is in the domain of health and well-being, which may limit the generalizability of the heuristics to other kinds of apps, but does make them directly comparable to the heuristics developed by Watkins et al. (2014) and Silva et al. (2015).

9.2 Method

9.2.1 Design

The usability problems found in the two rounds of user evaluations of the MyHealthyLiving (see Chapters 5 and 7) were used to develop the heuristics. The usability problems from users were compared with the problems found by experts in the CHE evaluations (see Chapters 4 and 6), to assess to what extent the experts were identifying the problems users actually encountered. The overall frequency of problems identified by the users and the number of users (at least 50%) identifying the problems were also compared with the severity ratings given by the experts, to investigate whether the users and the experts were identifying problems similarly. However, this comparison needs to be treated with some caution, as the designs evaluated by the users and the experts were not exactly the same, due to the iterative nature of user-centred design and the fact that after each evaluation there was some refinement.

The new set of heuristics was then compared to the heuristics developed by Watkins et al. (2014) and Silva et al. (2015), which were both developed for the evaluation of mobile apps for older adults to support their health and well-being.

9.2.4 Data Analysis

The data analysis conducted is similar as described in Section 4.3.7.

9.3 Results

Users identified a total of 313 instances of usability problems across two evaluations and experts identified a total of 43 instances of problems across two evaluations. Of the 356 problem instances, 233 problems were identified in the MyDrinkApp and 123 were identified in the MyHealthyLivingApp.

Table 9.1 shows the categorization of the users' usability problems and provides examples of each category. The major category of Physical Presentation includes heuristics that relate to the visual representation of the app. Content includes heuristics that relate to the information in the app. Information Architecture includes heuristic that relate to representation of the app as a whole. Finally, Interactivity includes heuristics that relate to the interactions that the user can interact within the app.

Information Architecture is the smallest major category with just one sub-category. Physical Presentation has three sub-categories, Content has five sub-categories and Interactivity has 13 sub-categories. Two sub-categories found related to Interactivity were not addressed by the categorization of usability problems by Petrie and Power (2012). These sub-categories, "too many tasks/interactive elements presented on a single page" found in the MyHealthyLivingApp and "inconsistent interaction" found in the MyDrinkApp, are presented as the last two sub-categories in Interactivity.

Table 9.1: Categorization of usability problems with examples

Category	Examples
Physical Presentation	
Inappropriate colour / pattern / image combination	the colours for the history page is a bit worrying because my husband is colour blind (P5, MyDrinkApp) the colour of the glass and the background was slightly the same so perhaps that need a change (P13, MyHealthyLivingApp)
Text / interactive elements not large / clear / distinct enough	it's not clear that there are five buttons (P7, MyDrinkApp) the fonts are too small I didn't really notice this (P11, MyHealthyLivingApp)
Changes to content / interactive elements not noticed	I didn't realize where was the next button (P7, MyDrinkApp) for the liquid measurement I didn't see the difference for the half and full cup in the picture very helpful (P15,

	MyHealthyLivingApp)
Content	
Too much content	when I read it I don't know the answer (P15, MyDrinkApp) it was a bit cumbersome to find the information I needed almost too much information all I needed was a simple chart with what counts and how is 1 serving (P10, MyHealthyLivingApp)
Content not clear enough	by looking at the name are you looking into all aspects of fluid intake … the name is not clear (P10, MyDrinkApp) the tips section should be more precise and make it clear (P9, MyHealthyLivingApp)
Content not detailed enough	asking for weight was a bit confusing as this app is for monitoring liquid intake … why asking for weight (P1, MyDrinkApp) I think if only it was more specific rather than just general tips then it would be more helpful (P5, MyHealthyLivingApp)
Content not suitable for the users	the image of ice … [we] shouldn't be drinking ice water (P17, MyDrinkApp) I did find some of the health advice amusing I thought it was weak you cannot live my age and know so little (P5, MyHealthyLivingApp)

Category	Examples
Contradictory content in the same page	I don't understand the two options because above you talk about the cups glasses and mugs while at the bottom you gave fluid ounces and this is confusing (p12, MyDrinkApp) I don't understand the two options because in above you talk about the cups glasses and mugs why at the bottom you gave fluid ounces and liter this is confusing (P12, MyDrinkApp)
Information Architecture	
Content not in appropriate sequence / unfamiliar format	I actually don't know where is this going … I honestly don't know the measurement of this mug (P18, MyDrinkApp) maybe have it the other way around so that the latest date on the right (P13, MyHealthyLivingApp)
Interactivity	
Concerns related to the information on how to proceed	I cannot do set the measurement task because the instruction is not clear the instruction says select one but it didn't tell me how to select (P6,MyDrinkApp) adding a drink is confusing for the first time … looking at it I thought that we can only use it once (P6, MyDrinkApp)
Labels / instructions / icons on interactive elements not clear	what is removing a drink … [is it] removing the daily target (P2,MyDrinkApp) I didn't know what the different colours meant perhaps you can have a little reminder of what it is at the side (P9, MyHealthyLivingApp)
Excessive effort required by user to complete a task	why do I have to press the plus button 10 times to add 10 cups of tea in a day (P11, MyDrinkApp)

	one problem is that I have to keep on logging in and out but I'm assuming that once it's on my phone that I don't have to do that but that was a bit of a fiddle (P10, MyHealthyLivingApp)
Input format unclear	how many letters are for the password … do we need alphanumeric (P1, MyDrinkApp) maybe if I can enter the volume by ourselves rather than having a fix volume per button this would suit me better I guess (P14, MyHealthyLivingApp)
Concerns related to the feedback	it will be useful to have the app to show exactly the amounts consumed once over the goal images … it was tricky to quickly see what has had added or not (P7, MyHealthyLivingApp)
Design and sequence of interaction elements illogical	next button should be at the bottom because you read down it's more logical when you read it (P18, MyDrinkApp) now it takes me to login and not sign up … (P13, MyDrinkApp)
Options not logical / complete	I can't figure out how many litres are they in a fluid ounces or so … if it's like this this will totally confuse me (P16, MyDrinkApp) the ability to add half and full option is ok but I wonder what is a portion (P6, MyHealthyLivingApp)
Interaction not as expected	I thought that by clicking the red remove button would then delete 1 of the mugs (P11,MyDrinkApp) the fact that it logged me out at the beginning I think when we put our name in we aspect that we are in the system and not been logged out (P8, MyHealthyLivingApp)

Category	Examples
Interactive functionality expected is missing	the app cannot edit the previous days that I forget the enter (P11, MyHealthyLivingApp)
Interactive elements not grouped clearly / logically	there was one time when I was doing it I realised that the back and logout was all on the left whereas most system on the computers they have the X on the right don't they (P12, MyHealthyLivingApp)
Too many tasks / interactive elements presented in a single page	the colours didn't really matter to me I looked more at the percentage that made me more aware about my eating habits (P15, MyHealthyLivingApp)
Inconsistency interaction	the number of glass should be the same as what was recommended earlier (p15, MyDrinkApp) the bottle and jugs just probe me … I didn't know where would I go with the bottles and jugs … that completely threw me (P8, MyDrinkApp)

Table 9.2 shows the distribution of usability problems into the sub-categories identified by the users in the MyDrinkApp and MyHealthyLivingApp.

In the MyDrinkApp, the most identified problems by overall frequency or by at least 50% of the users identifying the problems were related to the Content and Interactivity categories. In related to Content, the most identified problems were related to "content not clear enough" identified 20 times and by 10 users and "content not detailed enough" identified 28 times and by 13 users. In Interactivity, they were "concerns related to the information on how to proceed" identified 29 times and by 14 users, "labels / instructions / icons on interactive elements not clear" identified 27 times and by 16 users, "excessive effort required by user to complete a task" identified 28 times and by 11 users, and "options not logical / complete" identified 24 times and by 15 users.

In the MyHealthyLivingApp, the most identified problems by overall frequency were related to the Physical Presentation and Interactivity categories. In related to Physical Presentation, the most identified problems were related to “changes to content / interactive elements not noticed” identified 13 times and by 5 users. In Interactivity, they were “input format unclear” identified 12 times and by 8 users, “interactive functionality expected is missing” identified 10 times and by 6 users and “too many tasks / interactive elements presented in a single page” identified 13 times and by 8 users. However, the problems identified by at least 50% of the users were only related to the Interactivity category in particular, the sub-categories of “input format unclear” 8 users identifying 12 problems and “too many tasks / interactive elements presented in a single page” also 8 users identifying 13 problems.

Table 9.2: Categories of usability problems identified in the MyDrinkApp and MyHealthyLivingApp prototypes with percentage / number of users who encountered them and frequency of the problem category (f)

Category	**MyDrinkApp**		**MyHealthyLivingApp**	
	Users %(N) (N=20)	**f % (N)**	**Users %(N) (N=15)**	**f % (N)**
Physical Presentation				
Inappropriate colour / pattern / image combination	15 (3)	1.4 (3)	20 (3)	5.1 (5)
Text / interactive elements not large / clear / distinct enough	15 (3)	1.4 (3)	20 (3)	9.1 (9)
Changes to content / interactive elements not noticed	25 (5)	2.3 (5)	33.3 (5)	13.1 (13)

Category	MyDrinkApp		MyHealthyLivingApp	
	Users %(N) (N=20)	f % (N)		Users %(N) (N=20)
Content				
Too much content	40 (8)	6.5 (14)	13.3 (2)	3 (3)
Content not clear enough	50 (10)	9.3 (20)	26.7 (4)	8.1 (8)
Content not detailed enough	65 (13)	13.0 (28)	26.7 (4)	4 (4)
Content not suitable for the users	30 (6)	4.7 (10)	20 (3)	4 (4)
Contradictory content in the same page	20 (4)	2.3 (5)	0 (0)	0 (0)
Information Architecture				
Content not in appropriate sequence / unfamiliar format	20 (4)	1.8 (4)	13.3 (2)	2 (2)
Interactivity				
Concerns related to the information on how to proceed	70 (14)	13.5 (29)	0 (0)	0 (0)
Labels / instructions / icons on interactive elements not clear	80 (16)	12.6 (27)	20 (3)	4 (4)
Excessive effort required by user to complete a task	55 (11)	13.0 (28)	13.3 (2)	2 (2)
Input format unclear	35 (7)	3.7 (8)	53.3 (8)	12.1 (12)
Concerns related to the feedback	0 (0)	0 (0)	26.7 (4)	4 (4)
Design and sequence	5 (1)	0.4 (1)	0 (0)	0 (0)

of interaction elements illogical				
Options not logical / complete	75 (15)	11.2 (24)	0.6 (1)	1 (1)
Interaction not as expected	15 (3)	1.9 (4)	26.7 (4)	4 (4)
Interactive functionality expected is missing	0 (0)	0 (0)	40 (6)	10.1 (10)
Interactive elements not grouped clearly / logically	0 (0)	0 (0)	0.6 (1)	1 (1)
Too many tasks / interactive elements presented in a single page	0 (0)	0 (0)	53.3 (8)	13.1 (13)
Inconsistency interaction	5 (1)	0.4 (1)	0 (0)	0 (0)
Total	**214**		**99**	

The distribution of usability problems encountered by users was compared with the problems identified by the experts. As the prototypes were not exactly the same, this was done at the level of major category, rather than specific sub-categories and across both prototypes (see Table 9.3). The greatest number of problems identified for both users and experts were found in the Interactivity category. However, the difference of the percentage of the usability problems between the users and experts was not that much, approximately 2.8% (i.e. 58.1% for experts vs. 55.3% for users). The experts were also highly concerned on the Physical Presentation category (23.2%), but this was not really an issue for the users (12.1%). The users were highly concerned on the Content category (30.7%). The difference between the users and experts for this category was approximately 12% (18.6% for experts vs. 30.7% for users), which is far greater than the difference between the experts and users in the Interactivity category. In both prototypes, the experts failed to identify any problems with the Information Architecture, but users encountered problems in this category, although the number was not large (1.9%).

Table 9.3: Comparison of frequency (% and number) of usability problems encountered by users and identified by experts for the MyDrinkApp and MyHealthyLivingApp prototypes

Category	**MyDrinkApp**		**MyHealthyLivingApp**		**Total Expert**	**Total User**
	Expert	**User**	**Expert**	**User**		
Physical Presentation	5.3 (1)	5.1 (11)	37.5 (9)	27.3 (27)	23.2 (10)	12.1 (38)
Content	10.5 (2)	36 (77)	25 (6)	19.2 (19)	18.6 (8)	30.7 (96)
Information Architecture	0 (0)	1.9 (4)	0 (0)	2 (2)	0 (0)	1.9 (6)
Interactivity	84.2 (16)	57 (122)	27.5 (9)	51.5 (51)	58.1 (25)	55.3 (173)
Total	100 (19)	100 (214)	100 (24)	100 (99)	100 (43)	100 (313)

To investigate the type of usability problems that were encountered by the users but missed by the experts, the optimal would have been to compare the severity ratings given by the experts with the severity ratings given by the users. However, for both prototypes, the users did not rate the severity of the usability problems. Therefore, the overall frequency of problems identified and the number of users (at least 50%) identifying the problems were used as the measure for the users. Table 9.4 shows the data for this. As can be seen in Table 9.4, for MyDrinkApp, two sub-categories, "Content not detailed enough" (in Content) and "Options not logical / complete" (in Interactivity) were not found as a problem by the experts. For MyHealthyLivingApp, the two most identified sub-categories of problem for users were also not found as a problem by the experts. The sub-categories, both in Interactivity, are "too many tasks / interactive elements presented in a single page" and "Input format is unclear".

Spearman correlations conducted for both prototypes separately showed no significant relationships between the experts' severity ratings and the user measures.

Table 9.4: Severity ratings by experts and number of users/frequency of user encountering categories of usability problems (expressed in % only)

Category	Mean Expert Severity Rating		Users			
	MyDrink App	MyHealthy LivingApp	MyDrinkApp		MyHealthy LivingApp	
			No. (N=20)	Frequency	No. (N=15)	Frequency
Physical Presentation						
Inappropriate colour / pattern / image combination	not found as problem	not found as problem	15	1.4	20	5.1
Text / interactive elements not large / clear / distinct enough	not found as problem	3.11	15	1.4	20	9.1
Changes to content / interactive elements not noticed	not found as problem	3.83	25	2.3	33.3	13.1
Content						
Too much content	not found as problem	4.00	40	6.5	13.3	3
Content not clear enough	2.50	3.00	50	9.3	26.7	8.1
Content not detailed enough	not found as problem	not found as problem	65	13.0	26.7	4
Content not suitable for the users	1.75	2.50	30	4.7	20	4

	Mean Expert Severity Rating		Users			
	MyDrink App	MyHealthy LivingApp	MyDrinkApp		MyHealthy LivingApp	
			No. (N=20)	Frequency	No. (N=15)	Frequency
Contradictory content in the same page	not found as problem	not found as problem	20	2.3	0	0
Information Architecture						
Content not in appropriate sequence / unfamiliar format	not found as problem	not found as problem	20	1.8	13.3	2
Interactivity						
Concerns related to the information on how to proceed	2.81	3.67	70	13.5	0	0
Labels / instructions / icons on interactive elements not clear	2.50	4.33	80	12.6	20	4
Excessive effort required by user to complete a task	2.75	3.27	55	13.0	13.3	2
Input format is unclear	not found as problem	not found as problem	35	3.7	53.3	12.1
Concerns related to the feedback	2.88	not found as problem	0	0	26.7	4
Design and sequence of interaction elements illogical	not found as problem	not found as problem	5	0.4	0	0

Options not logical / complete	not found as problem	not found as problem	75	11.2	0.6	1
Too many options	not found as problem	not found as problem	15	1.9	26.7	4
Interaction not as expected	not found as problem	3.00	0	0	40	10.1
Interactive functionality expected is missing	2.67	not found as problem	0	0	0.6	1
Too many tasks / interactive elements presented in a single page	2.25	not found as problem	0	0	53.3	13.1
Inconsistency interaction	not found as problem	3.00	5	0.4	0	0

There were a number of reasons that prompted me to develop a new set of heuristics. Firstly, given the differences in the distribution of problems between users and experts and the lack of relationship between the severity ratings of experts and the user measures; secondly, to overcome the experts' concerns in using Silva et al. (2015) in Study 2 to evaluate MyDrinkApp; and finally, to develop a set of evidence-based heuristics to guide developers and expert evaluators of mobile apps specifically for older adults. On the basis of these reasons, I proposed a new set of 16 evidence-based heuristics for developing and evaluating mobile apps specifically for older adults. This set of heuristics is based on the problems encountered by users, either the frequency of problems or the number of users identifying problems across both prototypes. Therefore, the sub-categories in Table 9.4, now turned into positive heuristics for developers and evaluators.

Examples of the process for developing the heuristics is as below:

In Physical Presentation, #3 "Make changes to content and interactive elements noticeable" was developed based on usability problems of the sub-category "Changes to content / interactive elements not noticed" which were identified by at least 25% of the users in both app prototypes (25% of users in MyDrinkApp and 33.3% of users in MyHealthyLivingApp).

In Interactivity, #11 "Ease of input entry" was developed based on usability problems of the sub-category "Input format is unclear" which were identified by more than 50% of the users (53.3%) and by more than 10% of the overall frequency of problems (12.1%) in MyHealthyLivingApp.

In Interactivity, Heuristic #14 "Provide a logical and complete set of option" was developed based on two sub-categories "options not logical / complete" and "too many options" which were identified by 75% of the users in MyDrinkApp and nearly 27% of the users in MyHealthyLivingApp.

In Interactivity, #15 "provide appropriate functionality", was developed based on usability problems of the sub-category "interaction not as expected" and "interactive functionality expected is missing" which were least identified in MyDrinkApp but were identified more than 40% of the users in MyHealthyLivingApp.

Table 9.5 presents the resulting set of 16 heuristics.

Table 9.5: Heuristics for designing and evaluating tablet computer apps for older adults

Category		**Rationale for inclusion**
Physical Presentation		
1	**Use high contrast colour combinations of text, images, and interactive elements** Make sure the colour combinations are appropriate for all text, images and interactive elements	MyDrinkApp Frequency (f) (%): 1.4 Participants (p) (%): 15.0 MyHealthyLivingApp f: 5.1 p: 20.0

2	**Make text and interactive elements clear and large** Make sure the text is large and easy to read and interactive elements are clear and distinct	MyDrinkApp f: 1.4 p: 15.0 MyHealthyLivingApp f: 9.1 p: 20.0
3	**Make changes to content and interactive elements noticeable** Ensure the changes to the content and interactive elements are noticeable and distinguishable	MyDrinkApp f: 2.3 p: 25.0 MyHealthyLivingApp f: 13.1 p: 33.3
Content		
4	**Provide appropriate and relevant content** Make sure the content is appropriate and relevant to the users and enables them to complete their tasks	MyDrinkApp (appropriate) f: 6.5 p: 40.0 MyHealthyLivingApp f: 3.0 p: 13.3 MyDrinkApp (relevant) f: 4.7 p: 30.0 MyHealthyLivingApp f: 4.0 p: 20.0

Category		Rationale for inclusion
5	**Provide sufficient but not excessive content** Provide specific content that is not too much or too little for the users	MyDrinkApp (sufficient) f: 9.3 p: 50.0 MyHealthyLivingApp f: 8.1 p: 26.7 MyDrinkApp (excessive) f: 13.0 p: 65.0 MyHealthyLivingApp f: 4.0 p: 26.7
6	**Provide clear content** Use words that are easy, straightforward and not jargon	MyDrinkApp f: 2.3 p: 20.0
Information Architecture		
7	**Make the sequence of content logical** Design the sequence of content to be logical for the users	MyDrinkApp f: 1.8 p: 20.0 MyHealthyLivingApp f: 2.0 p: 13.3
Interactivity		
8	**Provide sufficient but not excessive instructions** Provide specific instructions that are not too	MyDrinkApp f: 13.5 p: 70

	much or too little for the users to complete their tasks	
9	**Provide clear labels and instructions** Provide clear labels and instructions on all interactive elements	MyDrinkApp f: 12.6 p: 80.0 MyHealthyLivingApp f: 4.0 p: 20.0
10	**Avoid excessive effort by users** Avoid having tasks or interactions that require excessive effort by the users	MyDrinkApp f: 13.0 p: 55.0 MyHealthyLivingApp f: 2.0 p: 13.3
11	**Ease of input entry** Use easy, straightforward, consistent and appropriate input and interaction techniques for users to enable them to complete their tasks	MyDrinkApp f: 3.7 p: 35.0 MyHealthyLivingApp f: 12.1 p: 53.3
12	**Provide sufficient but not excessive feedback on system progress** Provide simple and clear feedback on system progress in all interactions	MyHealthyLivingApp f: 4.0 p: 26.7
13	**Make design interaction logical** Design the sequence of interaction elements logical for the users	MyDrinkApp f: 0.4 p: 5.0

Category		Rationale for inclusion
14	**Provide a logical and complete set of options** Ensure all options are logical and complete to enable users to perform their tasks	MyDrinkApp (logical) f: 11.2 p: 75.0 MyHealthyLivingApp f: 1.0 p: 0.6 MyDrinkApp (complete) f: 1.9 p: 15.0 MyHealthyLivingApp f: 4.0 p: 26.7
15	**Provide appropriate functionality** Ensure all interactive functionality that the user is expecting to do to complete a task is provided	MyHealthyLivingApp f: 10.1 p: 40.0 MyHealthyLivingApp f: 1.0 p: 0.6
16	**Minimalist interactivity** Focus on one task at a time per page	MyHealthyLivingApp f: 13.1 p: 53.3

The coverage of issues in the new heuristics was compared with the heuristics proposed by Watkins et al. (2014) and Silva et al. (2015), which were both developed for the evaluation of mobile apps for older adults to support their health and well-being. This comparison is summarized in Table 9.6.

Eleven of the 16 new heuristics do not feature in the Watkins et al. (2014) heuristics. This includes four heuristics in two major categories, Content and Information Architecture, one heuristic from the Physical Presentation category (#3) and six heuristics from the Interactivity category (#11 to #16). Four of the 16 new heuristics do not feature in Silva et al. (2015) heuristics. This includes #4 in Content and three heuristics in the Interactivity category. These are heuristics #11, #14 and #15. In line with recommendations from Nielsen (1995), the new heuristics do not specify particular user issues in too great a detail (Nielsen, 1995). To create as concise a set of heuristics as possible, one heuristics, #10 "avoid excessive effort by users", shares common aspects from more than one of the heuristics in the three major categories (Cognition, Dexterity, and Perception that were related to the physical changes that occur with age) by Silva et al. (2015).

Table 9.6: Comparison of the new tablet computer heuristics for older adults with those proposed by Watkins et al. (2014) and Silva et al. (2015)

Category		Watkins et al. (2014)	Silva et al. (2015)
Physical Presentation			
#1	Use high contrast colour combination of text, images, or interactive elements	W6: Use High Contrast Colour Combinations	S25: Use high-contrast colour combinations of font and/or graphics and background to ensure readability and perceptibility; avoid using blue, green and yellow in close proximity.
#2	Make text and interactive elements large and clear	W5: Increase Text Type Size	S27: Make sure text uses types, styles and sizes appropriate to older adults, that is, for instance, but not exclusively: large-sized fonts, sans serif, non-condensed typefaces, non-italic, and left justified

Category		Watkins et al. (2014)	Silva et al. (2015)
#3	Make changes to content and interactive elements noticeable	N/A	S28: Make links and buttons clearly visible and distinguishable from other user interface elements.
Content			
#4	Provide appropriate and relevant content	N/A	N/A
#5	Provide sufficient but not excessive content	N/A	S10: Write in a language that is simple, clear and adequate to the audience.
#6	Provide clear content	N/A	S10: Write in a language that is simple, clear and adequate to the audience.
Information Architecture			
#7	Make sequence of content logical	N/A	H15: Use consistent and explicit step-by-step navigation.
Interactivity			
#8	Provide sufficient but not excessive instruction	W7: Provide Instruction/Help for Users	S7: Give specific and clear instructions and make help and documentation available. Remember that it is better to prevent an error than to recover from it.
#9	Provide clear labels and instructions	W1: Use Icons with Symbols and Text that Clearly Indicate the Icon's Function	S7: Give specific and clear instructions and make help and documentation available. Remember that it is better to prevent an

			error than to recover from it.
#10	Avoid excessive effort by users	W3: Avoid Interfaces Requiring Users to Execute Multiple Steps to Complete Tasks	Most heuristics from Cognition, Dexterity, and Perception categories
#11	Ease of input entry	N/A	N/A
#12	Provide sufficient but not excessive feedback and system progress	N/A	S8: Provide clear feedback and when presenting error messages make them simple and easy to follow.
#13	Make design interaction logical	N/A	S14: Keep the user interface navigation structure narrow, simple and straightforward.
#14	Provide a logical and complete set of options	N/A	N/A
#15	Provide appropriate functionality	N/A	N/A
#16	Minimalist interactivity	N/A	S1: Focus on one task at a time instead of requiring the user to actively monitor two or more tasks, and clearly indicate the name and status of the task at all times.

9.4 Discussion

This chapter presented the development of a new set of heuristics based on the usability problems users encountered in two evaluations of the MyDrinkApp and MyHealthyLivingApp. The usability problems were categorized and compared with problems identified in expert evaluations conducted as part of two iterations of user-centred design. There were some differences in the distribution of problem types between users and experts, and no correlations between the severity ratings given to the problems by experts and either the number of users encountering those problems or the overall frequency of occurrence of the problems. However, a limitation of these comparisons was that the prototypes evaluated by the experts and users had some differences, due to the iterative nature of user-centred design. Therefore, comparisons were made at a somewhat global level.

On the basis of the problems encountered by users, a new evidence-based set of 16 heuristics for the development and evaluation of tablet computer apps for older adults is proposed. The new heuristics were compared with the heuristics proposed by Watkins et al. (2014) and Silva et al. (2015), which were both developed for the evaluation of mobile apps for older adults to support their health and well-being. One characteristic of heuristics is that they should involve a relatively small number of items that users (i.e. developers and evaluators) can understand and remember easily, or at least find in a checklist easily. Watkins et al. (2014) proposed 8 heuristics, but Silva et al. (2015) proposed 33 heuristics. My set of heuristics is in the middle, and is thus comparable in number with the original set of 10 heuristics proposed by Nielsen (1994).

The heuristics proposed by Watkins et al. (2014) were concise in terms of the number, but missed a number of heuristics that were related to older adults that were identified in this programme of research. For example, Watkins et al. (2014) missed two major categories, Category and Information Architecture, that were developed based on more than 30% of the overall problems encountered by the users in this research. The remaining six heuristics that were missed by Watkins et al. (2014) were related to the Interactivity category, where this is the category with the greatest number of problems identified by the users (these accounted for 55.3% of the problems). Only four heuristics from the new heuristics were not covered by Silva et al. (2015). Of these, a majority (75%) was in the Interactivity category. On the basis that the existing heuristics missed a number of evidence-based problems by the users, these evidence-based heuristics are much needed.

9.5 Conclusions

This chapter presented a set of 16 evidence-based heuristics for the development and evaluation of tablet computer apps specifically for older adults. The development of the heuristics were based on the differences in the distribution of problems between users and experts and the lack of relationship between the severity ratings of experts and the user measures across two prototypes; the experts' concerns in using Silva et al. (2015) in Study 2 to evaluate MyDrinkApp; and finally, lack of research to develop a set of evidence-based heuristics to guide developers and expert evaluators of mobile apps specifically for older adults. Further study is needed to validate these new heuristics. However, due to the limited time in this programme of research, the validation of the new heuristics will be part of my future work.

Chapter 10

General Discussion and Conclusions

10.1 Overview of the programme of research

This programme of research aimed to design and develop an app, MyHealthyLivingApp, to allow older adults to monitor whether they are eating sufficient fruit and vegetables (FV) and drinking sufficient liquid. In order to fulfil this overall aim, I followed a user-centred design lifecycle and conducted six studies, starting with focus groups to understand older people's needs and wishes, through expert and user evaluations, to a two week field study of the use of the app by 15 older people. In addition, using the data from the user evaluations, a new set of evidence-based heuristics for the development and evaluation of tablet apps for older people was developed.

This programme of research also aimed to investigate methodologies that are appropriate for working with older adults to develop technologies. To achieve this, I investigated aspects of the size of focus groups and expert evaluations. On the basis of my experience with these methodologies, I provided reflections on how best to conduct focus groups, in terms of the size, with older adults and experts' experiences in using an existing set of heuristics for evaluating apps.

The evaluation of the first prototype of the app revealed that older adults did not like the picker interaction technique for selecting numbers, in spite of the fact that this is currently a popular technique on smartphones and tablets. Therefore I conducted an additional study which investigated older adults' performance and preferences for the picker and a number of other interaction techniques for number entry on tablets and desktop computers (PCs).

10.2 Contributions of this programme of research

The first contribution of the programme of research is to understanding older adults' needs in relation to drinking sufficient liquid and to eating sufficient FV. It was clear from the two focus groups (Study 1, see Chapter 3) that older adults in this study do have knowledge and are enthusiastic about food preparation and eating healthy. However, they were confused about the amount and type of FV and liquid they should consume each day.

In addition, although they acknowledged the importance of drinking water, some of the older adults preferred not to consume it in their daily life. The outcome of these focus groups confirmed that the lack of nutrition and hydration knowledge in older adults is still an on going problem (Baker & Wardle, 2003; Gille et al., 2016; Godfrey et al., 2012; Power et al., 2014). The focus groups in this programme of research also found that older adults have positive attitudes towards using mobile apps to improve healthy living. They also suggested features that could be included in the app. These positive suggestions about using mobile apps for maintaining health and wellbeing in the future are consistent with the findings in studies by Dhukaram et al. (2011), Parker et al. (2013) and Silveira et al. (2013).

The second contribution of the programme of research is the use of user-centred development and evaluation of MyHealthyLivingApp ("app"), an app to support older adults to monitor their FV and liquid intakes. Four evaluations (Study 2, Study 3, Study 5 and Study 6) were conducted to fulfil this. Both low-fi and web-based prototypes of the app were evaluated by groups of experts and users. A refined version of the app was evaluated at each round of evaluation.

A number of interesting issues were found in the development of the app that can contribute to new knowledge, in particular in the area of older adults' attitudes to using technology. In Study 3 (see Chapter 5), the low-fi prototype was designed following heuristics proposed by Watkins et al. (2014) and Silva et al. (2015), both of which were developed for the evaluation of mobile apps for older adults to support their health and well-being. The user evaluation revealed a disappointing number of usability problems. However, a number of interesting issues were highlighted by this evaluation. The result of the evaluation suggested that older adults only skimmed the instructions and were almost over-eager to complete their tasks, behaviours usually associated with younger users. These findings contradict those of previous studies that found older adults are fearful of using technologies (Barnard et al., 2013; Bhachu et al., 2008) and often require more instructions to successfully complete computer tasks (Hollinworth & Hwang, 2009). In addition, the resistance to using the picker as an interaction technique found in this evaluation was also an interesting result to investigate, and lead to my third contribution (see below).

In the user evaluation of MyHealthyLivingApp (Study 6, see Chapter 8), the app was well received by the participants. Overall, the participants reported that the app was successful in promoting positive dietary changes through the use of the various features in the app. Participants also reported that the app did successfully motivate them to eat and drink healthily, encourage them to self-monitor their diet and it also improved their healthcare knowledge. As outlined in the beginning of this thesis, using apps to monitor dietary intake for at-risk community living older adults is relatively new. Therefore, the top two most motivating features that encourage participants to eat more FV and drink more liquid found in this programme of research, which are the ability to add intakes and viewing overall progress, can contribute to new knowledge in this area. These findings could be useful to researchers who are interested in investigating the technological techniques across other health domain for older adults.

The resistance to the picker as an interaction technique (Study 4, see Chapter 6) lead to the third contribution of this programme of research. Little research had investigated the use of picker, although this is a popular design option for mobile devices. Thus, the outcome of the first user study on the use and acceptability of the picker for number entry with older adults (Study 3, see Chapter 5) is a contribution to new knowledge in the research focusing in interaction techniques for older adults. The overall results showed that the tablet computers did not provide any particular difficulties for older adults for number entry if a keypad or buttons were used. However, the picker interaction technique was found to be problematic. Participants were slower with this interaction technique and liked it least.

The forth contribution of this programme of research is in investigating methods that are appropriate for working with older adults to develop technologies. I investigated the aspects of the size of focus groups and expert evaluations. In relation to focus groups (Study 1, see Chapter 3), some research had investigated the size of focus group with older adults and how this affected the information elicited, but was inconclusive. The findings in this Study 1, in relation to the number of participants per focus groups adds to knowledge about the use of focus groups for eliciting information from older adults to develop technologies. I found that the smaller focus groups (n = 3 - 4) elicited more information per person but the larger groups (n = 6 - 7) elicited more information per unit of time of the focus group. However, the moderator does play an important role in managing groups of either size. The moderator was careful to allocate each participant time to speak and share their thoughts for each topic for approximately the same length of time. The moderator also made sure that the discussions kept reasonably close to on the topic of the discussion. With the groups in this study there was little diverging from the topic by the participants, and very few examples of participants having side discussions. On the basis of these results, it does not seem that the use of larger groups of older adults creates any particular difficulty in generating contributions than smaller groups, particularly when the moderator manages the sessions carefully. These findings contradict previous studies that reported difficulty in managing focus groups either with small or large number of participants (Brondani et al., 2008; Hawthorne et al., 2006; Inglis et al., 2003; Lines & Hone, 2004; Lyons et al., 2013).

Study 2 (see Chapter 4) investigated the use of Collaborative Heuristic Evaluation (CHE) to evaluate a low-fi prototype for the development of the app and particularly the heuristics proposed by Silva et al. (2015) The findings showed that the use of CHE is an effective method to allow experts with different areas of expertise to work together (in particular in this evaluation I had experts in mobile applications and experts in the needs of older adults). Nearly all potential problems identified by the experts were addressed by Silva et al. (2015). However, the experts struggled to use these heuristics. Experts commented that the set of heuristics was very long, with three times as many heuristics as in the original set of heuristics proposed by Nielsen (1994) (33 compared to 10 proposed by Nielsen). The experts also commented that the Silva et al. (2015) set of heuristics has no high level structure, which adds a further layer of difficulty in using them. In addition, the experts raised numerous concerns about the appropriateness, wording and clarity of the heuristics. They also commented that many of the heuristics feature in sets of general usability heuristics such as Nielsen's. It would be helpful to have a set of heuristics which focus on the additional aspects important for older users.

On the basis of the 1) CHE; 2) differences in the distribution of problems between users and experts and the lack of relationship between the severity ratings of experts and the user measures across two prototypes for the development of the app (as reported in Chapter 9); and 3) lack of research to develop a set of evidence-based heuristics to guide developers and expert evaluators of mobile apps specifically for older adults, a new set of 16 evidence-based heuristics for the development and evaluation of tablet apps for older people were developed.

The new heuristics were compared with the heuristics proposed by Watkins et al. (2014) and Silva et al. (2015). There were differences in the total number of heuristics and also the content of the heuristics. In terms of the total number of heuristics, the new heuristics is in the middle, and is thus comparable in number with the original set of heuristics proposed by Nielsen (1994). In terms of content, the existing heuristics missed heuristics that were related to current generation of older adults, as reported in Chapter 9. This perhaps led to the high number of usability problems in the first user evaluation (Study 3, see Chapter 5). I argue that researchers should be wary of heuristics which make broad assumptions about the capabilities and preferences of older users. Thus, these new evidence-based heuristics contribute to a potential useful tool for designing and evaluating tablet computer apps specifically for older adults.

10.3 Limitations and future work

While this programme of research has provided sufficient investigations to answer the research aim as outlined in the introduction, it leaves other alternatives open for future research. For instance, to gain further information related to older adults' concerns on healthy living and technologies development, more participants are needed. Blandford et al. (2016) suggested recruiting at least 10 participants to ensure a saturated return in measurement validity and reliability in HCI qualitative studies, be it for observation, interviews, focus groups or diary studies. Due to drop out in focus group participation, I ended up with only 9 people in the initial focus groups.

Similarly, to gain further insights into older adults' performance, opinions and preferences of different interaction techniques for number entry on tablet and PC, more participants are needed to ensure the generalisability of the results. In this programme of research, it was only possible to recruit 12 older adults. However, in relation to quantitative studies, a power calculation of sample size is needed to detect a difference in the effect size.

The participation in each study in this programme of research was voluntary. Participants self-selected although they met the criteria of age 65 or more, and living independently, either alone or with a partner. Participants were all middle-class and quite well educated, and their views and experiences might differ from those of other socioeconomic and educational backgrounds. Therefore, whether these results can be generalized to other older adults from a wider range of backgrounds is not clear and further research to confirm this is required. In addition, for the final field study (Study 6, see Chapter 8), participants needed to own or have had some experience with tablet computers. Therefore, the findings may differ to older adults who have limited experiences with tablet computers.

Further work is needed to address the usability problems, comments and suggestions given by the participants in Study 6 in order to improve the app. This programme of research revealed that older adults found the ability to add intakes and view overall progress as the most motivational features that encouraged them to eat more FV and drink more liquid. However, the current programme of research focused on methodological issues in working with older adults and the heuristics available for developing apps for older adults. Future research could investigate older adult's motivations for using mobile technologies for hydration and nutrition. For example in my research, participants expressed interest in getting feedback about their interactions with the MyHealthyLivingApp. In addition, future research could investigate using "nudge" theory (Leonard, 2008), which suggests using different types of wording to encourage older adults to drink liquid and eat fruit and vegetables. Another approach would to use Fogg's Behaviour Model (Fogg, 2009) which suggests one should have sufficient motivations and abilities for a behaviour to change. Thus, future research could investigate how to improve the MyHealthyLivingApp to motivate older adults to use it effectively, based on these different theories of motivation and behaviour change.

In the current programme of research it was only possible to conduct a two week field trial, although this did test the app in realistic situations of use. The two week duration is also comparable with other HCI studies with similar aim; to using app to promote healthy living be it to promote physical activities among older adults (Fan et al., 2012) or to monitor diet among overweight older adults (Grimes et al., 2010). However, it is vital to investigate the use of the app in a long term study to investigate behavioural changes based on using the app. It is also aware that all the studies in this programme of research except for Study 4 (Chapter 6) are based on self-report measures, and self-report measures may be susceptible to user bias.

Thus, future research may investigate the effectiveness of using the app in a long-term study by randomising participants in controlled experiment settings and minimising self-report measures. Similar research already exists, but in the domain of overweight adults to promote exercising (Spring et al., 2013). Thus, for example, for future research, in the experiment group, participants used the app to support them to monitor their FV and liquid intakes. In the control group, participants monitor their FV and liquid intakes in a traditional way, say by paper and pen. Future research can measure the effectiveness of the app by comparing between the two groups on the participants' skin moister level (via a skin dehydration analyser tool) or to using oral mucosa to assess for dehydration level before, during and after the investigation.

In the relation to the methodological investigation, for focus groups, it would be interesting to have more data on groups of different sizes, with different compositions (e.g. in relation to gender, age) and type of information required. The results could guide future researchers to define a suitable number of participants for focus groups especially with older adults, an area that is still lacking in the body of literature.

In relation to CHE, further work is needed to establish whether the new heuristics are useful in the development and evaluation of tablet computer apps for older adults. In particular, further research should investigate whether these heuristics improve the ability of CHE or other expert evaluation methods that use heuristics to predict the problems that older users have with apps.

10.4 Conclusions

This programme of research provides empirical insights that focus on the usability of technology for older adults. The outcome of this research presents a number of contributions to the design of a mobile app that can support older adults in relation to drinking more liquid and to eating more fruit and vegetables. The outcome of this research also presents a contribution to the knowledge of older adults' attitudes to mobile technology, methodological knowledge on how to conduct research with older adults, and a set of evidence-based heuristics that is potentially useful for app developers and evaluators.

Appendices

Appendix 1: Method Section for Co – Motion (Study 1)

Participants

The inclusion criteria for the focus groups for the Co-Motion focus groups was to be 55 years or over. Eleven participants took part in two focus groups. Participants were recruited on the basis that they were willing to discuss mobility problems and explore how technology, such as mobile phones and tablet devices, may be used to support people to get out and about in their local area. Participants do not have to have technology experiences to participate in the focus groups. The demographics of the participants, in terms of gender compositions and age are summarized in Table App.1 below.

Table App.1: Demographics of the Co-Motion participants

Characteristics:	**Large focus groups**	**Small focus groups**
Gender	3 women, 4 men	3 women, 1 man
Age	56 – 82 years	57 – 86 years

Materials

Each participant received an information sheet (see Appendix 6), an informed consent form (see Appendix 7) and a background information questionnaire (see Appendix 8). Participants also viewed and shared a series of eight conceptual design solutions broadly related to journey planning, navigation, social interaction with the built environment. These concepts were illustrated by images depicting how mobile phone and tablet devices might support mobility and wellbeing in older adults. See Appendix 9 for examples of the design concepts.

Procedure

The overall procedure for Co-Motion discussions was similar as the Healthy Living discussions. However, in Co-Motion, Dave Swallow acted as the moderator and Andrew Lewis was the assistant moderator. Participants were also offered a gift voucher worth £25 to thank them for their time and efforts. In Co-Motion, the time duration for the large focus group was 54 minutes and for the small focus group was 80 minutes.

Appendix 2: Informed Consent Form (Study 1)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

UNIVERSITY *of York*

Before you participate in the discussion group, please read and complete Section A, printing your name in the first space and then sign at the end.

Once the discussion group is over, and you have been debriefed, you will be asked to initial the three statements in Section B, to indicate your agreement.

Section A

I, ____, voluntarily give my consent to participate in the discussion group about "Eating well and staying fit".

The purpose of this study is to explore with issues around nutrition, eating habits and staying fit how these might be addressed with new technologies like iPads.

I have received information about this study and I understand that I am free to ask questions or seek further clarification about this study if I need to.

I give my permission for the study to be audio-taped. I understand that all information collected is confidential and anonymous. Only Zaidatol Haslinda Abdullah Sani, and Helen Petrie will have access to the data collected today in its original format. Any information from the study will only be made public (e.g. in Linda's PhD thesis) in an anonymous group format, so that individuals will not be identifiable.

I understand that I may withdraw from the study at any time without prejudice.

Signature :

Date :

Section B

Please initial each of the following statements when the discussion group has been completed and you have been debriefed.

I have been adequately debriefed.	Your initials: _______
I was not forced to complete the group.	Your initials: _______
All my questions have been answered.	Your initials: _______

Appendix 3: Background Information Questionnaire for Healthy Living (Study 1)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix. This questionnaire is also given to participants in Study 3, Study 4 and Study 6.

Background information Questionnaire

Your name: ________________________________

Please tick (P) in the appropriate boxes for your answers

Part A: About the technologies you use

1. Have you ever used any of the following technologies:

1a. Mobile phone Yes □ No □

If you answered yes:

If you know the brand and/or model, please give it here:

Approximately how long have you been using a mobile phone? (approximate number of years is fine)

If you are no longer using it, why is that?

1b. Smart phone Yes □ No □

If you answered yes:

If you know the brand and/or model, please give it here:

Approximately how long have you been using a smart phone? (approximate number of years is fine)

If you are no longer using it, why is that?

1c. Desktop computer Yes □ No □

If you answered yes:

If you know the brand, model, please give it here:

Approximately how long have you been using a desktop computer?

If you are no longer using it, why is that?

1d. Laptop computer Yes □ No □

If you answered yes:

If you know the brand, model, please give it here:

Approximately how long have you been using a laptop computer?

If you are no longer using it, why is that?

1e. Tablet computer (e.g. iPad) Yes □ No □

If you answered yes:

If you know the brand, model, please give it here:

Approximately how long have you been using a tablet computer?

If you are no longer using it, why is that?

2. For those technologies that you currently use, how often do you use them? (for those that you do not use, just leave that line blank)

	Once a week or less	Twice a week	3 – 5 times per week	Every day	N/A
Mobile phone	□	□	□	□	□
Smartphone	□	□	□	□	□
Desktop computer	□	□	□	□	□
Laptop computer	□	□	□	□	□
Tablet computer	□	□	□	□	□

3. Do you use the Internet/World Wide Web? Yes □ No □

If you answered yes:

Approximately how long have you been using the Internet/World Wide Web?

If you are no longer using it, why is that?

How often do you use it?

	Once a week or	Twice a week	3 – 5 times per	Every day	N/A

	less		week		
Internet/World Wide Web	☐	☐	☐	☐	☐

Part B: Your attitudes to mobile phone and computer technology

4. Which of these technologies (mobile phone, smartphone, desktop computer, laptop computer, tablet computer), if any, do you find most useful and why?

5. Which of these technologies (mobile phone, smartphone, desktop computer, laptop computer, tablet computer), if any, do you find most fun and why?

6. If you use mobile phones, how comfortable do you feel using them?

Not at all comfortable	☐	☐	☐	☐	☐	Very comfortable

Why do you feel that level of comfort?

7. If you use smartphones, how comfortable do you feel using them?

Not at all comfortable	☐	☐	☐	☐	☐	Very comfortable

Why do you feel that level of comfort?

8. If you use desktop computers, how comfortable do you feel using them?

Not at all comfortable	☐	☐	☐	☐	☐	Very comfortable

Why do you feel that level of comfort?

9. If you use laptop computers, how comfortable do you feel using them?

Not at all comfortable	☐	☐	☐	☐	☐	Very comfortable

Why do you feel that level of comfort?

10. If you use tablet computers, how comfortable do you feel using them?

Not at all comfortable	☐	☐	☐	☐	☐	Very comfortable

Why do you feel that level of comfort?

11. If you use mobile phones, how expert would you say you are in using them?

Not at all expert	☐	☐	☐	☐	☐	Very expert

12. If you use smartphones, how expert would you say you are in using them?

Not at all expert	☐	☐	☐	☐	☐	Very expert

13. If you use desktop computers, how expert would you say you are in using them?

Not at all expert	☐	☐	☐	☐	☐	Very expert

14. If you use laptop computers, how expert would you say you are in using them?

Not at all expert	☐	☐	☐	☐	☐	Very expert

15. If you use tablet computers, how expert would you say you are in using them?

Not at all expert	☐	☐	☐	☐	☐	Very expert

16. If you use the Internet/World Wide Web, how expert would you say you are in using them?

Not at all expert	☐	☐	☐	☐	☐	Very expert

Part C: Some questions about yourself

1. Are you …
   □ Single
   □ Married
   □ Widowed
   □ Divorced

2. Do you …
   □ Live alone
   □ Live with spouse
   □ Live with children
   □ Live with spouse and children
   □ other, please specify ____________________________

3. Your highest education attainment
   □ Primary school
   □ Secondary school
   □ Bachelor degree
   □ Post-graduate
   □ Other e.g. Diploma / Professional Certificate

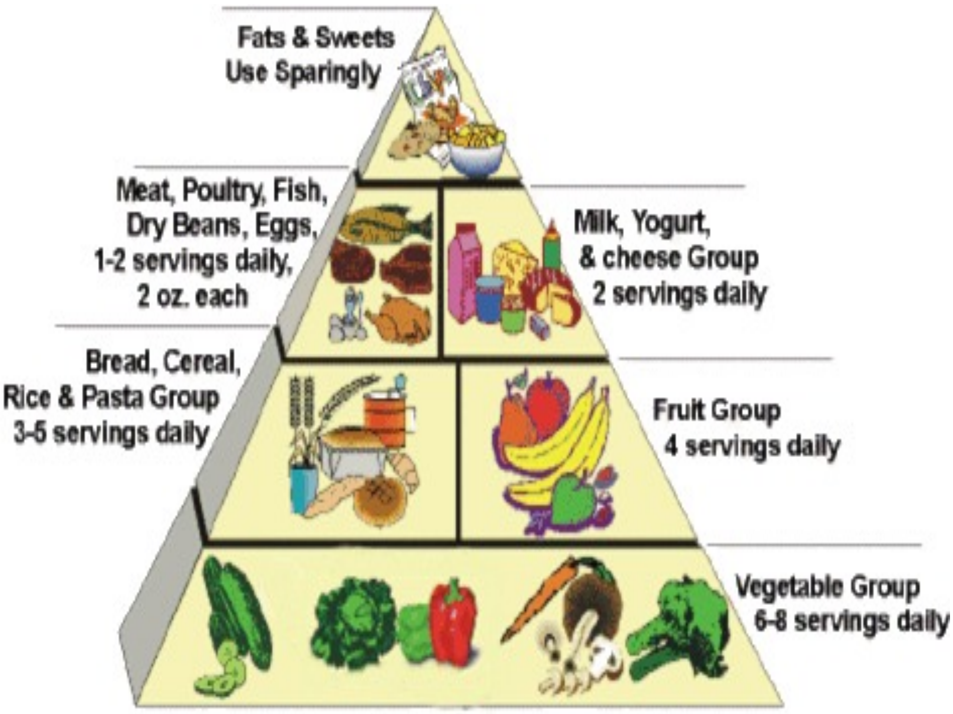
4. Your current employment status
   □ Retired
   □ Full time employment
   □ Part time employment
   □ Private worker
   □ other(s), please specify: ___________________________

Your age : _______ years

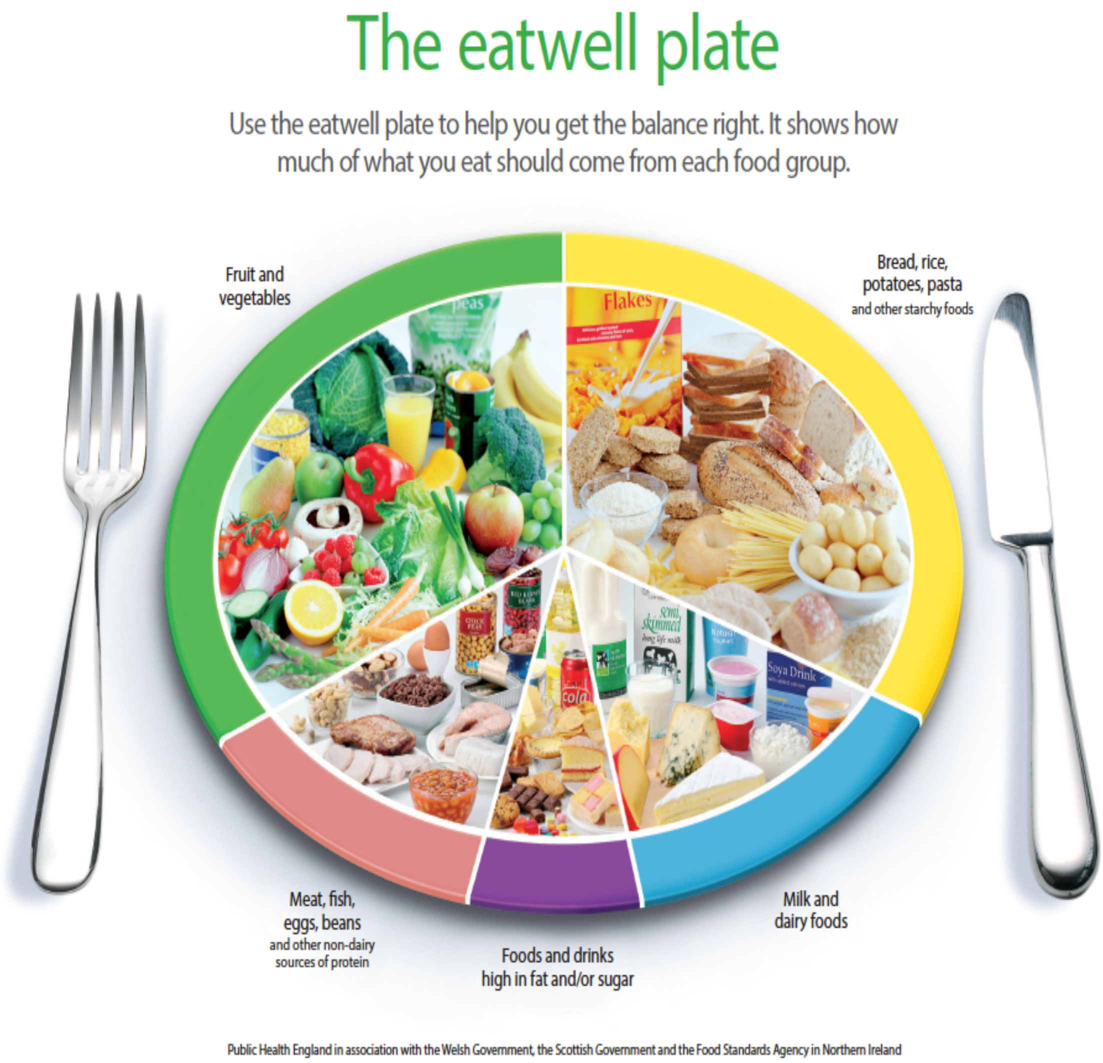
Your gender : □ Male □ Female

Thank you!

Appendix 4: Food Pyramid (Study 1)



Appendix 5: Eatwell Plate (Study 1)



Appendix 6: Information Sheet for Co-Motion (Study 1)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

Information Sheet

Thank you for your interest in the Co-Motion Project. To decide whether to take part in the workshop it is important that you understand why the research is being done and what participation in the workshop will involve. Please take time to read this leaflet and contact David Swallow if you have any questions (contact details are at the end).

The purpose of the workshop and what will be involved

Being able to get out and about as we grow older is key to our sense of self, and how well we feel. If we are to live well, feel well, and live independently we need to be able to get to different places to access services, take part in events and activities, and spend time with family and friends. The Co-Motion project is exploring how easily people can get out and about when they have experienced changes in their lives, and how they feel about life generally.

In this stage of the project, we are particularly interested in how technology, such as mobile phones and tablet devices, may be used to support people to get out and about in their local area. To explore this in more detail, we are holding co-design workshops. These are group sessions in which researchers and potential users work together to discuss problems and solutions. The workshops will allow you to share your experiences of getting out and about and to discuss any problems you may have encountered. You will also have the opportunity to contribute to the design of a number of "apps" (applications) for mobile phone and tablet devices.

Each workshop will involve 8-10 people. You will engage in a series of fun and interesting activities with the aim of discussing problems and designing mobile phone and tablet applications for supporting and promoting physical activity and wellbeing. It is important to stress that no previous experience with mobile phone or tablet devices is necessary. The workshops will last approximately two and quarter hours and will be tape-recorded (audio-only). Tea, coffee and refreshments will be provided. If you would like a family member or friend to attend the workshop with you, that would be fine.

Benefits and disadvantages of taking part

While there are no immediate benefits to you from taking part in the study, we believe that the Co-Motion project will help older people in the future by making recommendations for improved travel facilities. We hope that you will enjoy taking part and as a thank-you we will also give you a voucher for £30 that can be spent at a range of high street shops.

It is very unlikely that you would experience any harm taking part in this study. If you do find that taking part causes you any distress or concern, or you no longer wish to continue, you are free to withdraw at any time.

Confidentiality of information
Everything you say and do in the workshop is completely confidential and anonymous and will be stored securely. The information you give may be used for writing research reports, but it will not be possible to identify you in any way. We would never share your contact details with any other organisation.

Funding the Co-Motion Project
The Co-Motion project is led by the Centre for Housing Policy at the University of York, collaborating with other University of York centres including the Computer Science, and with departments from other universities, including the Universities of Leeds, Northumbria, and Newcastle.

This research has been jointly funded by the Engineering and Physical Science Research Council, Economic and Social Research Council (ESRC), and the Arts and Humanities Research Council (AHRC) as part of a large research programme: Design for Well-being: Ageing and Mobility in the Built Environment.

Please keep this information sheet and feel free to discuss with family or friends. If you would like to know more about the study before you decide whether to take part, please contact:

David Swallow
Department of Computer Science, University of York, York, YO10 5GH
Telephone: 01904 325604 **Email:** david.swallow@york.ac.uk

Appendix 7: Informed Consent Form for Co-Motion (Study 1)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

Consent Form

Participant Identification Number for this study:

Name of Principal investigator(s): Professor Helen Petrie

PLEASE INITIAL THE APPROPRIATE BOX INDICATING WHETHER YOU ANSWER YES OR NO TO THE FOLLOWING STATEMENTS

	YES	*NO*
I confirm that I have read and understood the information sheet dated January 2016 for the above study and have had the opportunity to ask questions.	☐	☐
I confirm that I have had sufficient time to consider whether or not I want to be included in the study.	☐	☐
I understand that I do not have to take part in this research and I can change my mind at any time.	☐	☐
I agree to the workshop being audio taped.	☐	☐
I agree that the research data can be kept and used for further research purposes.	☐	☐
I agree to take part in the study.	☐	☐

Name of participant ______________________________________

Date___________________ Signature ____________________

Name of person taking consent ____________________________

Date___________________ Signature ____________________

Appendix 8: Background Information Questionnaire for Co-Motion (Study 1)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

Mobility and well-being

CO-MOTION

Co-Motion Co-Design Workshop Questionnaire

Your name……………………………………………

1. How is your health in general?

(Please tick one)

Very good	
Good	
Fair	
Bad	
Very bad	

2. Are your day-to-day activities limited because of a health problem or disability which has lasted, or is expected to last, at least 12 months? (Include problems related to old age)

(Please tick one)

Yes, limited a lot	
Yes, limited a little	
No	

3. How often do you use any of the following equipment?

(Please tick all that apply)

	Daily	Weekly	Occasionally	Never
Glasses/contact lenses				
Magnifying glass or other low-vision aid				
Hearing aid				
Cane or walking stick				
Walker or Zimmer frame				
Crutches				
Manual wheelchair				
Electric wheelchair				

4. What is your gender?

(Please tick one)

Male	
Female	

5.What is your year of birth?
(Please write in)

Year	

6. What is your marital status?
(Please tick one)

Never married	
Married/civil partnership	
Separated but still legally married	
Divorced	
Widowed	

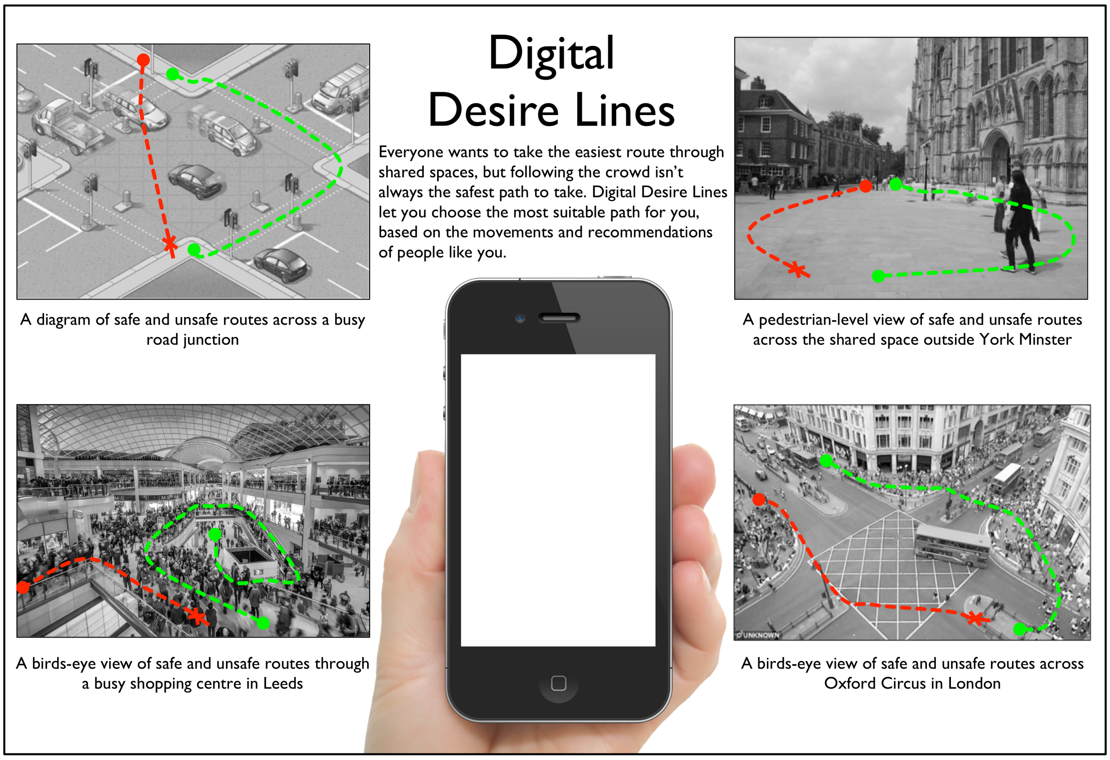
7. Which of these qualifications do you have?
(Please tick all that apply)

School Certificate	
O' level/s and/or CSE/s	
A' levels	
Professional qualification eg accountancy, nursing	
Other vocational qualifications	
Degree	
Higher degree	
Foreign qualifications	
None of the above	

8. What is your current employment status?
(Please tick one)

Working	
Not working because retired	
Not working because long-term sick or disabled	
Not working because looking after home and family	

Appendix 9: Examples of Design Concept for Co-Motion



Appendix 10: List of 20 Nutrition Apps from UK App Store

1. Calorie Counter & Diet Tracker by MyFitnessPal
2. Nutrition Quiz: 600+ Facts, Myths & Diet Tips for Healthy Living
3. BigOven 350,000 Recipes and Grocery List
4. A-Z Food Nutrition Facts lite
5. Food & Nutrition: Facts & Tips
6. Diet Buzz
7. Nutrition Tips FREE
8. MyPlate Calorie Tracker
9. Calorie Counter and Diet Tracker by Calorie Count
10. Restaurant Nutrition
11. Yummy Recipes & Grocery Shopping List
12. My Diet Diary Calorie Counter App
13. My Slim Down Coach
14. A+ Lose It Now
15. Calorie Counter by FatSecret
16. My Nutrition UK
17. Diet App 6 Weeks to Fat Loss
18. MealLogger
19. The personal diet by Nutrino
20. The British Heart Foundation Recipe Finder

Appendix 11: List of Tasks and Scenario (Study 2)

iPhone

Task No	Options		Scenario
	1	2	
1	✓	✓	Alice maintained her weight to 50kg for the past three months. Set her weight in the app.

iPad

Task No	Options		Scenario
	1	2	
1	✓		Alice's favourite glass is the 200ml tall glass her daughter gave to her. Set the volume per glass in the app.

Appendix 12: Silva et al. (2015) Heuristics

Heuristic Number	Heuristic Description
Cognition	
H1	Focus on one task at a time instead of requiring the user to actively monitor two or more tasks, and clearly indicate the name and status of the task at all times.
H2	Avoid the use of interaction timeouts and provide ample time to read information.
H3	Avoid the use of animation and fast-moving objects.
H4	Leverage mental models familiar to older adults.
H5	Reduce the demand on working memory by supporting recognition rather than recall.
H6	Aim at creating an aesthetical user interface, by using pictures and/or graphics purposefully and adequately to minimize user interface clutter and avoid extraneous details.
Content	
H7	Give specific and clear instructions and make help and documentation available. Remember that it is better to prevent an error than to recover from it.
H8	Provide clear feedback and when presenting error messages make them simple and easy to follow.
H9	Make sure they are descriptive and use meaningful words and verbs when requiring an action.
H10	Write in a language that is simple, clear and adequate to the audience.
Dexterity	
H11	Avoid pull down menus.
H12	Avoid the use of scrolling.
H13	Enlarge the size of user interface elements in general; targets should be at least 14mm square.
Navigation	
H14	Keep the user interface navigation structure narrow, simple and straightforward.
H15	Use consistent and explicit step-by-step navigation.

H16	Make sure that the "Back" button behaves predictably.
H17	Support user control and freedom.
H18	Disable inactive user interface objects.
Perception	
H19	Do not rely on color alone to convey information. Be aware of color blindness.
H20	Provide not only visual feedback, but also tactile and auditory.
H21	Make information accessible through different modalities.
H22	Use lower frequencies to convey auditory information such as confirmation tones and alerts.
H23	Do not use pure white or rapidly changing contrast backgrounds.
H24	Make it easy for people to change the text size directly from the screen.
Visual Design	
H25	Use high-contrast color combinations of font and/or graphics and background to ensure readability and perceptibility; avoid using blue, green and yellow in close proximity.
H26	Use color conservatively, limiting the maximum number of colors in use to four
H27	Make sure text uses types, styles and sizes appropriate to older adults, that is, for instance, but not exclusively: large-sized fonts, sans serif, non-condensed typefaces, non-italic, and left justified
H28	Make links and buttons clearly visible and distinguishable from other user interface elements.
H29	Make information easy to read, skim (or) and scan.
H30	Group information visually (make good use of color, text, topics, etc.).
H31	Allow sufficient white space to ensure a balanced user interface design.
H32	Use user interface elements consistently and adhere to standards and conventions if those exist.
H33	Use simple and meaningful icons.

Appendix 13: List of problems identified by experts in iPhone prototype and its mean severity ratings (Study 2)

Note: (* = matches two heuristic by Petrie and Power, 2012)

No	Problem	TaskNo / OptionNo / PageNo	Mean Severity
1.	black and white not good - need colours	1/1/1	1.25
2.	images is too small	1/1/main	1.50
3.	heart image - what does this mean?	1/1/main	1.50
4.	screen should have a welcoming message "hi Blaithin etc"	1/1/main	1.50
5.	users might click on "home" from here, not realizing they are on home*	1/1/main	1.50
6.	why not use the calculator numpad layout	1/1/2	1.63
7.	message for opening of the day could be better worded e.g. you haven't drunk anything yet	1/1/main	1.75
8.	why so much blank space	1/1/2	1.75
9.	contrast in image not sufficiently high	1/1/main	1.75
10.	save not prominent enough	1/1/2	1.88
11.	inconsistency between text message 0 drinks, yet the glasses on the screen are all full	1/1/main	2.00
12.	"weight" could be more informative and friendly e.g. my current weight	1/1/1	2.00
13.	what order will be most natural for older people - units or selecting kg/lbs	1/1/2	2.00
14.	input is technical language not clear for older users	1/1/2	2.00
15.	is it necessary to have an input field?	1/1/2	2.00
16.	blank space	1/2/2	2.00
17.	notification - alarm confusing	1/1/1	2.00

18.	text at top very small	1/1/main	2.25
19.	display previously entered weight	1/1/2	2.25
20.	user probably wants confirmation (e.g. pop up of new weight)	1/1/2	2.25
21.	users may need instructions on scrolling	1/2/2	2.25
22.	user probably wants confirmation (e.g. pop up of new weight)	1/2/2	2.25
23.	italics not good for older people	1/1/2	2.25
24.	need to make it clearer that the kg and gm are separately scrollable	1/2/2	2.25
25.	what does each/total glass represent?	1/1/main	2.50
26.	need an information page	1/1/main	2.50
27.	no welcome - explaining msg.. what can I do here?	1/1/1	2.50
28.	active level etc - not clear	1/1/1	2.50
29.	volume - not clear	1/1/1	2.50
30.	additional volume required - confusing	1/1/1	2.50
31.	no call to action	1/2/2	2.50
32.	no home	1/2/2	2.50
33.	the user will not know that "settings" takes her to user profile for entering info such as weight	1/1/main	2.75
34.	text too small	1/1/1	2.75
35.	clickable area very small	1/1/1	2.75
36.	users may have difficulty scrolling	1/2/2	2.75
37.	spacing between kg and gm should be wider, as users may have difficulty moving them separately	1/2/2	2.75
38.	too much on the screen, need to split up	1/1/1	2.75
39.	general - not clear	1/1/1	2.75
40.	keyboard not complete	1/1/2	2.75
41.	faded text not good for older people	1/2/2	2.75
42.	does the set of glasses represent 100% of	1/1/main	3.00

	daily intake?		
43.	what are my options with this app?	1/1/main	3.00
44.	no call to action	1/1/1	3.00
45.	default settings could be be confusing	1/1/1	3.00
46.	no instructions	1/1/2	3.00
47.	no call to action	1/1/3	3.00
48.	what am I supposed to do? no call to action	1/1/main	3.25
49.	for UK should include stone/lb setting*	1/1/2	3.25
50.	not possible to enter a fraction of a kg/lb*	1/1/2	3.25
51.	units need to be selectable	1/2/2	3.50

Appendix 14: List of problems identified by experts in iPad prototype and its mean severity ratings (Study 2)

Note: (* = matches two heuristics by Petrie and Power, 2012)

No	Problem	TaskNo / OptionNo / PageNo	Mean Severity
1.	no orientation to the app (e.g. logo in corner)	1/1/2	1.50
2.	a lot white space wasted and could be confusing (is something loading?)	1/1/1	1.75
3.	no personal/friendly messages	1/1/2	1.75
4.	oz/ml settings are confusing, you do not change them on this screen, these are the set values, but look changeable	1/1/1	2.00
5.	too many options/tasks presented at once	1/1/1	2.25
6.	why is daily goal here at all (excessive number of options)	1/1/2	2.25
7.	language is too tech jargon	1/1/1	2.50
8.	"default glass size" confusing	1/1/1	2.50
9.	no back/cancel option	1/1/2	2.50
10.	oz/ml need to go together for all measurements	1/1/1	2.75
11.	Alice may wish to set a number of cup/glass sizes/measures, why not allow this?*	1/1/1	2.75
12.	not clear which task will happen if Alice enters a number, relies on her recalling her tasks	1/1/2	2.75
13.	why not give users some typical options of sizes of glasses/mugs/cups etc?*	1/1/2	2.75
14.	no feedback that she picked the glass size task	1/1/2	3.00
15.	no instruction on how to change the glass size	1/1/2	3.00
16.	not clear what to do to set a glass size from this screen	1/1/main	3.25
17.	it would not be clear to Alice how to proceed (i.e. no instructions or clear call to action)	1/1/1	3.50

Appendix 15: List of problems not addressed by the Silva et al. (2015) Heuristics (Study 2)

No	Problem	TaskNo / OptionNo / PageNo	Mean Severity
iPhone			
1.	what am I supposed to do? no call to action	1/1/main	3.25
2.	users might click on "home" from here, not realizing they are on home	1/1/main	1.50
iPad			
3.	Alice may wish to set a number of cup/glass sizes/measures, why not allow this?	1/1/1	2.75

Appendix 16: List of Tasks (Study 3)

iPad	
Task No	**Task Description**
T1	Set unit of measurements for weight
T2	Set weight
T3	Set active level
T4	Set daily liquid goal – system recommendation
T5	Set daily liquid goal – own value
T6	Calculate current daily liquid intake
T7	Set email
T8	Login with username and password
T9	Add liquid via measurement
T10	Add liquid via own value
T11	View liquid intake history
T12	Read tips
T13	Set reminder

iPhone	
Task No	**Task Description**
T14	Login with username and password
T15	Add liquid via measurement
T16	Add liquid via own value

Condition:

1. All participant to do either T9, T10, T15 or T16
2. No participant to do T2 and T5 together
3. No participant to do T8 and T14 together

Task Distribution:

Participant No	**Task No (T)**			
P1	1	5	9	13
P2	2	6	10	14
P3	3	7	11	15
P4	4	8	12	16
P5	1	5	9	13
P6	2	6	10	14
P7	3	7	11	15
P8	4	8	12	16
P9	1	5	9	13
P10	2	6	10	14
P11	3	7	11	15
P12	4	8	12	16
P13	1	5	9	13
P14	2	6	10	14
P15	3	7	11	15
P16	4	8	12	16
P17	1	5	9	13
P18	2	6	10	14
P19	3	7	11	15
P20	4	8	12	16

Appendix 17: List of Participants (Study 3)

Participant No	Age	Gender
P1	67	female
P2	69	female
P3	67	male
P4	68	female
P5	67	female
P6	70	male
P7	67	female
P8	69	female
P9	77	female
P10	77	female
P11	79	male
P12	65	female
P13	72	male
P14	68	female
P15	67	male
P16	68	male
P17	75	male
P18	71	male
P19	71	male
P20	67	female

Appendix 18: Information Sheet (Study 3)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

INFORMATION SHEET

An "app" to help people track how much they drink and avoid dehydration

INVITATION

You are being asked to take part in a study on the design of an "app" for tablet computers and mobile phones to help people keep track of how much they drink during the day, so they can drink enough and remain hydrated, which is very important for good health. The app will also help people drink enough early in the day, so they can avoid trips to the toilet at night.

This research is being conducted by Zaidatol Haslinda "Linda" Abdullah Sani as part of her PhD in the Department of Computer Science at the University of York. This study has received the ethics approval from the Physical Sciences Ethics Committee at the University.

WHAT WILL HAPPEN

In this study, you will be shown a paper version of the design of the drink tracking mobile application ("app"), which will be both on an iPad (tablet computer) and an iPhone (smartphone). Linda will guide you through how the app will be used. You will be asked what you think about different aspects of the design, and at some points there will be a number of possibilities that are being considered.

There are no right or wrong answers, Linda is interested to find out the opinions of possible users of the app before she actually starts the work of implementing the app. This way the app will meet the needs of users better. So feel free to make as many comments and suggestions as you wish. She will also be conducting evaluations of the working app to ensure that it does meet people's needs, and you might be interested in participating in those evaluations so you can see how it has developed.

This session will be audio recorded. All comments you make will be totally confidential and anonymous. Comments you make might be quoted in Linda's thesis or articles that she writes, but they will be made in ways that completely protect the identity of the individuals making them. 20 people will take part in this study, so there will be comments from lots of different people.

At the end of the session, Linda will tell you more about the purpose of the study.

TIME COMMITMENT

The session typically takes 75 minutes, and there will be multiple breaks.

PARTICIPANTS' RIGHTS

As a participant, you may decide to stop being a part of the study at any time without explanation, if you are uncomfortable in any way. You have the right to ask that any data you have supplied to that point be destroyed.

You will still be rewarded with the cash voucher for your contribution.

You have the right to not answer any question that is asked.

If you have any questions, please ask Linda before the session begins.

BENEFITS AND RISKS

There are no known benefits or risks for you in this study.

COST, REIMBURSEMENT AND COMPENSATION

Your participation in this study is voluntary. You will receive a gift voucher for £25 for Mark & Spencer or Amazon, as you prefer.

CONFIDENTIALITY AND ANONYMITY

All information you provide (e.g. name) will be stored securely and confidentiality is assured. It may be published in academic outlets such as conference-style paper or research books.

FURTHER INFORMATION

If you would like to be informed about the final results of this study, please let Linda know and she will email you a summary of the results.

Thank you.

Appendix 19: Informed Consent Form (Study 3)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

UNIVERSITY of York

Before you participate in the design evaluation study, please read and complete Section A, printing your name in the first space and then sign at the end.

Once the study is over, and you have been debriefed, you will be asked to initial the three statements in Section B, to indicate your agreement.

Section A

I, ____, voluntarily give my consent to participate in this study to evaluate the design of a liquid monitoring application on iPad and iPhone.

I have received information about this study and I understand that I am free to ask questions or seek further clarification about this study if I need to.

I give my permission for the study to be audio-taped. I understand that all information collected is confidential and anonymous. Only Zaidatol Haslinda Abdullah Sani and Helen Petrie will have access to the data collected today in its original format. Any information from the study will only be made public (e.g. in Linda's PhD thesis) in an anonymous group format, so that individuals will not be identifiable.

I understand that I may withdraw from the study at any time without prejudice.

Signature :

Date :

Section B

Please initial each of the following statements when the design evaluation has been completed and you have been debriefed.

I have been adequately debriefed.	Your initials: _______
I was not forced to complete the group.	Your initials: _______
All my questions have been answered.	Your initials: _______

Appendix 20: Information Sheet (Study 4)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

INFORMATION SHEET

PROJECT TITLE

To investigate people's preferences for different ways of entering numbers on a PC and an iPad

INVITATION

You are being asked to take part in a research study to evaluate different ways of entering numbers on an iPad and a PC, for example by using the keypad and using buttons.

This research is being conducted by Zaidatol Haslinda "Linda" Abdullah Sani as part of her PhD in the Department of Computer Science at the University of York. This study has received the ethics approval from the Physical Sciences Ethics Committee at the University.

WHAT WILL HAPPEN

In this study, you will be given a series of numbers to enter on an iPad and a PC. You will enter these numbers using different methods such as the keypad, buttons, 'picker' and pull-down. You will be given a practice session for both the iPad and the PC prior the main study session. The main session will be recorded, for later analysis.

At the end of the study, you will be asked to complete a questionnaire about the different ways of entering the numbers, and some questions about yourself. You will also be debriefed on the purpose of the study.

TIME COMMITMENT

The session typically takes 60 minutes, and there will be multiple breaks.

PARTICIPANTS' RIGHTS

As a participant, you may decide to stop being a part of the study at any time without explanation, if you are uncomfortable in any way. You have the right to ask that any data you have supplied to that point be destroyed.

You will still be rewarded with the cash voucher for your contribution.
You have the right to to not answer any question that is asked.
If you have any questions, please ask Linda before the session begins.

BENEFITS AND RISKS

There are no known benefits or risks for you in this study.

COST, REIMBURSEMENT AND COMPENSATION

You will receive a gift voucher of £20 from Mark & Spencer in return of your participation.

CONFIDENTIALITY AND ANONYMITY

All information you provide (e.g. name) will be stored securely and confidentiality is assured. It may be published in academic outlets such as conference-style paper or research books.

FURTHER INFORMATION

If you would like to be informed about the final results of this study, please let Linda know and she will email you a summary of the results.

Thank you.

Appendix 21: Informed Consent Form (Study 4)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

UNIVERSITY of York

Before you participate in the design evaluation study, please read and complete Section A, printing your name in the first space and then sign at the end.

Once the study is over, and you have been debriefed, you will be asked to initial the three statements in Section B, to indicate your agreement.

Section A

I, ____, voluntarily give my consent to participate in this study to investigate people's preferences for different ways of entering numbers on an iPad and a PC.

I have received information about this study and I understand that I am free to ask questions or seek further clarification about this study if I need to.

I give my permission for the study to be recorded. I understand that all information collected is confidential and anonymous. Only Zaidatol Haslinda Abdullah Sani and Helen Petrie will have access to the data collected today in its original format. Any information from the study will only be made public (e.g. in Linda's PhD thesis) in an anonymous group format, so that individuals will not be identifiable.

I understand that I may withdraw from the study at any time without prejudice.

Signature :   Date :

Section B

Please initial each of the following statements when the design evaluation has been completed and you have been debriefed.

I have been adequately debriefed.	Your initials: _______
I was not forced to complete the study.	Your initials: _______
All my questions have been answered.	Your initials: _______

Appendix 22: NASA-TLX Rating Scale Definition (Study 4)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

NASA-TLX Rating Scale Definition

Title	Endpoints	Descriptions
Mental Demand	Low / High	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand	Low / High	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	Low / High	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Poor / Good	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Low / High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration	Low / High	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Comparison Card

Circle **ONE** scale that represents the more important contributor to workload for the tasks you just performed.

Effort **Or** **Performance**	**Temporal Demand** **Or** **Frustration**	**Temporal Demand** **Or** **Effort**	**Physical Demand** **Or** **Frustration**	**Performance** **Or** **Frustration**
Physical Demand **Or** **Temporal Demand**	**Physical Demand** **Or** **Performance**	**Temporal Demand** **Or** **Mental Demand**	**Frustration** **Or** **Effort**	**Performance** **Or** **Mental Demand**
Performance **Or** **Temporal Demand**	**Mental Demand** **Or** **Effort**	**Mental Demand** **Or** **Physical Demand**	**Effort** **Or** **Physical Demand**	**Frustration** **Or** **Mental Demand**

Participant ID:

Rating Sheet

(Note: To fill in separately for six interaction techniques)

For each items below, please write an 'X' to indicate your response that best describes the task just now. For example:

Mental Demand

			X						

Low **High**

Mental Demand

Low **High**

Physical Demand

Low **High**

Temporal Demand

Low **High**

Performance

Poor **Good**

Effort

Low **High**

Frustration

Low **High**

Appendix 23: Post Study Questionnaire (Study 4)

(Note: To fill in separately for six interaction techniques)

iPad Button

I felt confident in entering the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

I felt I was accurate in entering the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

I felt it was easy to enter the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

I felt I was fast in entering the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

I am satisfied in entering the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

iPad Keypad

I felt confident in entering the numbers using the keypad.

Strongly Disagree **Strongly Agree**

I felt I was accurate in entering the numbers using the keypad.

Strongly Disagree **Strongly Agree**

I felt it was easy to enter the numbers using the keypad.

Strongly Disagree **Strongly Agree**

I felt I was fast in entering the numbers using the keypad.

Strongly Disagree **Strongly Agree**

I am satisfied in entering the numbers using the keypad.

Strongly Disagree **Strongly Agree**

iPad / Picker

I felt confident in entering the numbers using the picker.

Strongly Disagree **Strongly Agree**

I felt I was accurate in entering the numbers using the picker.

Strongly Disagree **Strongly Agree**

I felt it was easy to enter the numbers using the picker.

Strongly Disagree **Strongly Agree**

I felt I was fast in entering the numbers using the picker.

Strongly Disagree **Strongly Agree**

I am satisfied in entering the numbers using the picker.

Strongly Disagree **Strongly Agree**

PC Button

I felt confident in entering the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

I felt I was accurate in entering the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

I felt it was easy to enter the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

I felt I was fast in entering the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

I am satisfied in entering the numbers using the plus and minus buttons.

Strongly Disagree **Strongly Agree**

PC Keypad

I felt confident in entering the numbers using the keypad.

Strongly Disagree **Strongly Agree**

I felt I was accurate in entering the numbers using the keypad.

Strongly Disagree **Strongly Agree**

I felt it was easy to enter the numbers using the keypad.

Strongly Disagree **Strongly Agree**

I felt I was fast in entering the numbers using the keypad.

Strongly Disagree **Strongly Agree**

I am satisfied in entering the numbers using the keypad.

Strongly Disagree **Strongly Agree**

PC Pull-down menu

I felt confident in entering the numbers using the pull-down menu.

Strongly Disagree **Strongly Agree**

I felt I was accurate in entering the numbers using the pull-down menu.

Strongly Disagree **Strongly Agree**

I felt it was easy to enter the numbers using the pull-down menu.

Strongly Disagree **Strongly Agree**

I felt I was fast in entering the numbers using the pull-down menu.

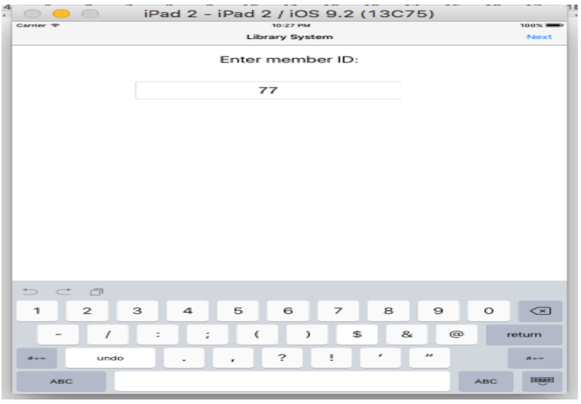
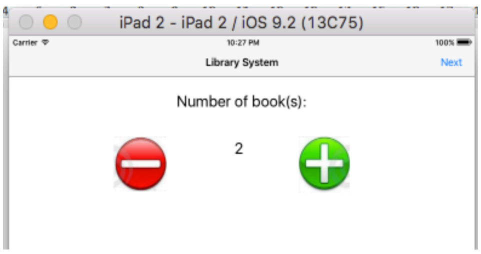
Strongly Disagree **Strongly Agree**

I am satisfied in entering the numbers using the pull-down menu.

Strongly Disagree **Strongly Agree**

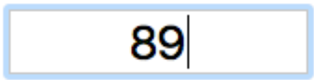
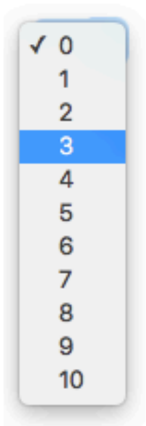
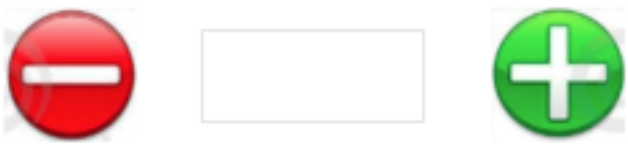
Please rank the following ways to enter numbers on iPad in order of your preference, with

1. **Most preferred**
2. **Somewhat preferred**
3. **Least preferred**

Please rank the following ways to enter numbers on PC in order of your preference, with

1 **Most preferred**
2 **Somewhat preferred**
3 **Least preferred**

Please rank the following ways to enter numbers on iPad and PC in order of your preference, with 1 being your most preferred option.

Overall Preference

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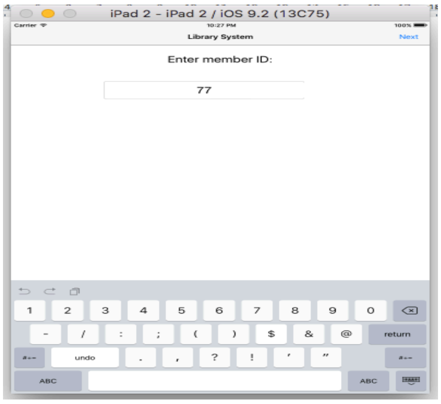
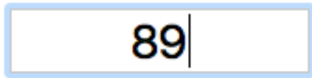
<tr><td>
</td><td></td><td>
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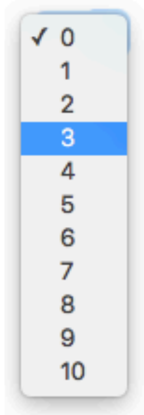
</td><td></td><td>
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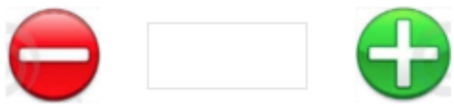
</td><td></td><td></td><td></td></tr>
</table>

Thank you. ☺

Appendix 24: List of Tasks and Scenario (Study 5)

Task No	Scenario
1	Alice usually drinks from her glass. Create an account for Alice. Her given username is ‘HP’.
2	Alice had a banana with her morning cereal today. Add this serving of fruit to the app.
3	Alice had one glass of water and one glass of orange juice for her mid-morning snack. Add these drinks to the app.
4	Alice wants to compare her liquid intake between today and yesterday. View the daily liquid intakes in the app.
5	Alice want to know more information about 5-a-day. Read about this topic.

Appendix 25: Petrie and Power (2012) Heuristics

Heuristic Number	PHYSICAL PRESENTATION
1	**Make text and interactive elements large and clear enough** Default and typically rendered sizes of text and interactive elements should be large enough to be easy to read and manipulate
2	**Make page layout clear** Make sure that the layout of information on the page is clear, easy to read and reflects the organization of the material.
3	**Avoid short time-outs and display times** Provide time-outs that are long enough for users to complete the task comfortably, and if information is displayed for a limited time, make sure it is long enough for users to read comfortably
4	**Make key content and elements and changes to them salient** Make sure the key content and interactive elements are clearly visible on the page and that changes to the page are clearly indicated.
CONTENT	
5	**Provide relevant and appropriate content** Ensure that content is relevant to users' task and that it is appropriately and respectfully worded.
6	**Provide sufficient but not excessive content** Provide sufficient content (including Help) so that user can complete their task but not excessive amounts of content that they are overwhelmed.
7	**Provide clear terms, abbreviations, avoid jargon** Define all complex terms, jargon and explain abbreviations.
INFORMATION ARCHITECTURE	
8	**Provide clear, well-organized information structures** Provide clear information structures that organize the content on the page and help users complete their task.
INTERACTIVITY	
9	**How and why** Provide users with clear explanations of how the interactivity works and why things are happening.
10	**Clear labels and instructions**

	Provide clear labels and instructions for all interactive elements. Follow web conventions for labels and instructions (e.g. use of asterisk for mandatory elements).
11	**Avoid duplication/excessive effort by users** Do not ask users to provide the same information more than once and do not ask for excessive effort when this could be achieved more efficiently by the system.
12	**Make input formats clear and easy** Make clear in advance what format of information is required from users. Use input formats that are easy for users, such as words for months rather than numbers.
13	**Provide feedback on user actions and system progress** Provide feedback to users on their actions and if a system process will take time, on its progress.
14	**Make the sequence of interaction logical** Make the sequence of interaction logical for users (e.g. users who are native speakers of European languages typically work down a page from top left to bottom right, so provide the Next button at the bottom right).
15	**Provide a logical and complete set of options** Ensure that any set of options includes all the options users might need and that the set of options will be logical to users
16	**Follow conventions for interaction** Unless there is a very particular reason not to, follow web and logical conventions in the interaction (e.g. follow a logical tab order between interactive elements).
17	**Provide the interactive functionality users will need and expect** Provide all the interactive functionality that users will need to complete their task and that they would expect in the situation (e.g. is a search needed or provided?).
18	**Indicate if links go to an external site or to another webpage** If a link goes to another website or opens a different type of resource (e.g. PDF document) indicate this in advance.
19	**Interactive and non-interactive elements should be clearly distinguished**

	Elements which are interactive should be clearly indicated as such, and element which are not interactive should not look interactive.
20	**Group interactive elements clearly and logically** Group interactive elements and the labels and text associated with them in ways that make their functions clear.
21	**Provide informative error messages and error recovery** Provide error messages that explain the problem in the users’ language and ways to recover from errors.

Appendix 26: List of problems identified by experts in MyHealtyLivingApp and its mean severity ratings (Study 5)

No	Problem	Mean Severity
1	font not consistent (perhaps stick to SS)	1.33
2	font not suitable – use sans serif fonts	1.67
3	"about" not welcoming enough	2.00
4	it's "pint glass"	2.00
5	profile / setting inconsistent	2.00
6	can we drop name?	2.67
7	can we drop gender?	2.67
8	login - logout	2.67
9	not very welcoming	3.00
10	"settings" too technical	3.00
11	add - previously link, now buttons	3.00
12	tips changes too often	3.00
13	why a second start page (suggest to combine)	3.33
14	buttons too small	3.33
15	need to be told what's happening next	3.67
16	needs to be action oriented	3.67
17	too many pages	3.67
18	tips need identification	3.67
19	a lot of text	4.00
20	sub-app is too technical	4.00
21	need better linking	4.00
22	liquid not visible for pints / cups	4.00
23	why am I being asked about glasses?	4.33
24	text must be bigger	4.33

Appendix 27: Information Sheet (Study 6)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

INFORMATION SHEET

PROJECT TITLE

Using Web-Based Application To Support Healthy Living

INVITATION

You are being asked to take part in a research study on how to encourage and facilitate people to live healthy in terms of eating fruits and vegetables and to drink water. This research is being conducted by Zaidatol Haslinda "Linda" Abdullah Sani as part of her PhD in the Department of Computer Science at the University of York. This research is supervised by Prof. Helen Petrie.

WHAT WILL HAPPEN

In this study, you will be asked to use a web-based application ("app") on your tablet computer (e.g. iPad). You will be asked to use the app each day for a period of two weeks. Your task during the study will be to update your fruits, vegetables and liquid intake. This will only take a couple of minutes a day and can be done at any time of the day. At the end of the study, you will be asked you will be asked to join a one-to-one short post-interview session about the app, to complete a questionnaire about the app, and some questions about yourself. You will also be debriefed on the purpose of the study.

TIME COMMITMENT

The study will be a few minutes a day for two weeks. The study can be done at any time of the day as long as there is Internet connection.

PARTICIPANTS' RIGHTS

As a participant, you may decide to stop being a part of the study at any time without explanation, if you are uncomfortable in any way. You have the right to ask that any data you have supplied to that point be destroyed.

You will still be rewarded with the cash voucher for your contribution.

You have the right to to not answer any question that is asked.

If you have any questions as a result of reading this information sheet, please ask Linda.

BENEFITS AND RISKS

There are no known benefits or risks for you in this study.

COST, REIMBURSEMENT AND COMPENSATION

You will receive a gift voucher of £50 from Mark & Spencer in return of your participation.

CONFIDENTIALITY AND ANONYMITY

All information you provide (e.g. name) will be stored securely and confidentiality is assured. It may be published in academic outlets such as conference-style paper or research books.

FURTHER INFORMATION

Linda will be glad to answer any questions about this study at any time. You may contact her at zas508@york.ac.uk or +44 7474 427427.

If you would like to be informed about the final results of this study, please let Linda know and she will email you a summary of the results.

Thank you.

Appendix 28: Informed Consent Form (Study 6)

Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

UNIVERSITY of York

Project Title: Using Web-Based Application To Support Healthy Living

Before you participate in the study, please read and print your name in the first space and then sign at the end.

I, ____, voluntarily give my consent to participate in this study to use a web-based application to support healthy living, in terms of eating fruits and vegetables, and to drink water.

I have received information about this study and I understand that I am free to ask questions or seek further clarification about this study if I need to.

I understand that all information collected is confidential and anonymous. Only Zaidatol Haslinda Abdullah Sani and Helen Petrie will have access to the data collected today in its original format. Any information from the study will only be made public (e.g. in Linda's PhD thesis) in an anonymous group format, so that individuals will not be identifiable.

I understand that I may withdraw from the study at any time without prejudice.

Signature :

Date :

UNIVERSITY of York

Project Title: Using Web-Based Application To Support Healthy Living

The study is now over. Please initial each of the following statements when the study has been completed and you have been debriefed.

I have been adequately debriefed. Your initials: ______

I was not forced to complete the study. Your initials: ______

All my questions have been answered. Your initials: ______

Thank you.

Appendix 29: User Instruction for MyHealthyLivingApp (Study 6)

User Instruction for My Healthy Living App

For any query about this User Instruction, please email Linda at zas508@york.ac.uk or text her at +44 7474 427427.

Introduction

"My Healthy Living App" aims to help you eat a healthy amount of fruit and vegetables each day and keep hydrated.

The National Health Services (NHS) recommends eating at least five servings of fruit and vegetables daily. This is also known as the "5-a-day". A serving is approximately 80 grams (2.8 ounces). For example, a medium size apple or two broccoli spears are a serving. For more information about serving sizes, read the "Read Tips on Healthy Living" section.

The British Nutrition Foundation (BNF) recommends drinking 1.6 litres (56 fluid ounces) of liquid for women and 2 litres (70 fluid ounces) of liquid for men. As a rough guide, a woman should drink atleast 8 glasses of liquid and a man should drink at least 10 glasses of liquid. Nearly all liquids that you drink count, including normal strength beers, apart from stronger alcoholic drinks such as wine and spirits

With My Healthy Living App, you can easily update and track your daily consumption of fruit and vegetables and liquid. You can also learn about the benefits of eating fruit and vegetables and keeping hydrated. In the "Read Tips on Healthy Living" section there are ideas about how to incorporate them in your daily diet!

Disclaimer:

My Healthy Living App is not intended to treat, diagnose, cure or prevent any disease. All material and information provided on this app is provided for information purposes only. Always seek advice of your doctor or other qualified health care provider with any questions you have regarding a medical condition.

First time using My Healthy Living App

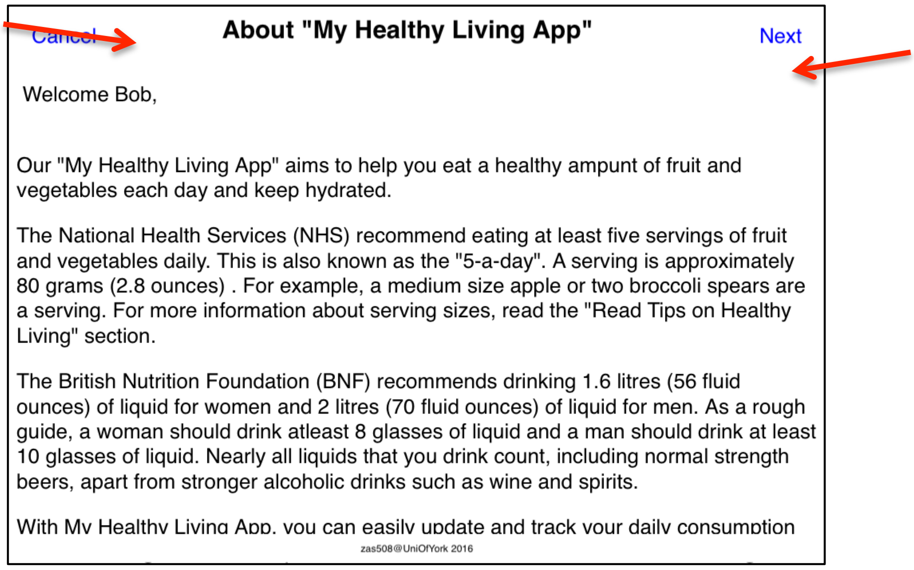
For the first time using My Healthy Living App, you will be asked to choose your preferred measurement option to measure your liquid intake. The available options are glass, cup and pint glass.

Please follow the steps below to set your preferred measurement option.

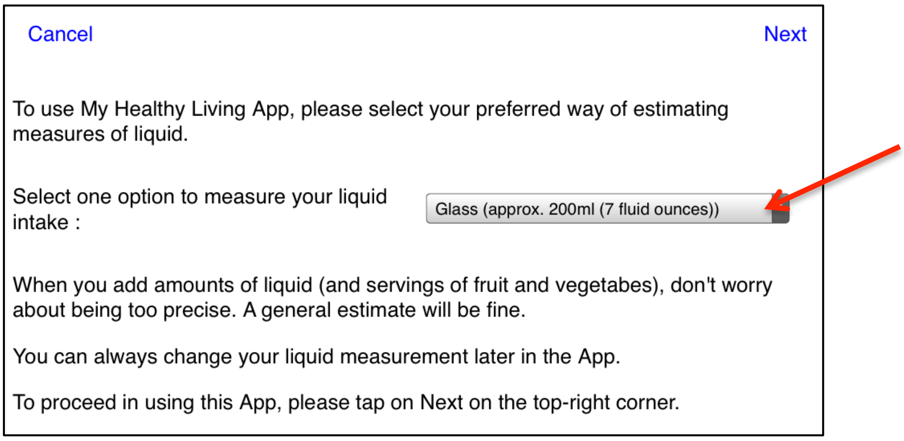
1. To use the app, enter your given name and then tap “Login”. See the figure below.

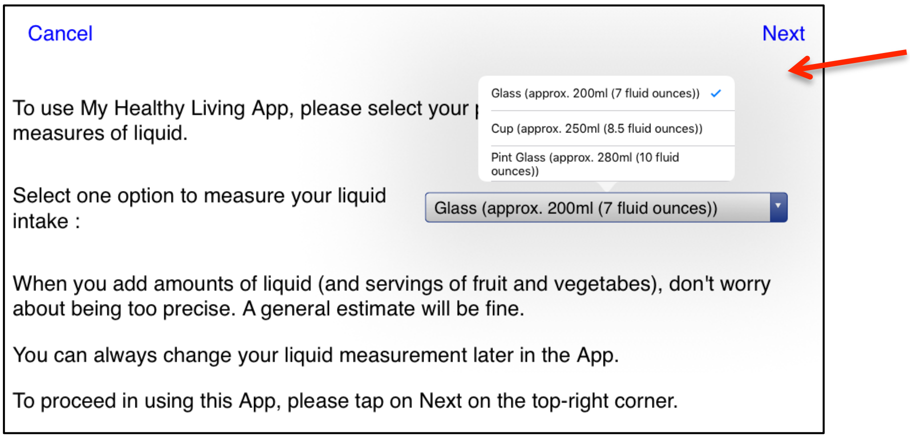
2. If you entered your name incorrectly, a message will appear. To proceed in using the app, re-enter your given name and then tap “Login”.

3. You will be directed to an information page about the “My Healthy Living App”. Please read this page to further understand about this app. To proceed in using the app, tap “Next”. To set your preferred measurement option in a later time, tap ‘Cancel’.



4. As noted above, My Healthy Living App allows you to choose your own preferred measurement to measure the liquid you drink. The available measurements are glass, cup and pint glass. Select one option from the list, and then tap “Next”. You can always change the options later whilst using the app.





5. Upon completing these steps, you have successfully chosen your preferred measurement option to measure your liquid intake. You will be directed to the My Healthy Living Home Page.

My Healthy Living Home Page

At this page, you are supposed to see your name. Please see the figure below.

If at any case your name does not appear (see the photo below), please reload the page.

There are three main things that you can do in this page.

1. Main Features
2. Additional Features
3. Log Out

Please read the description below for further understand each feature.

Main Features

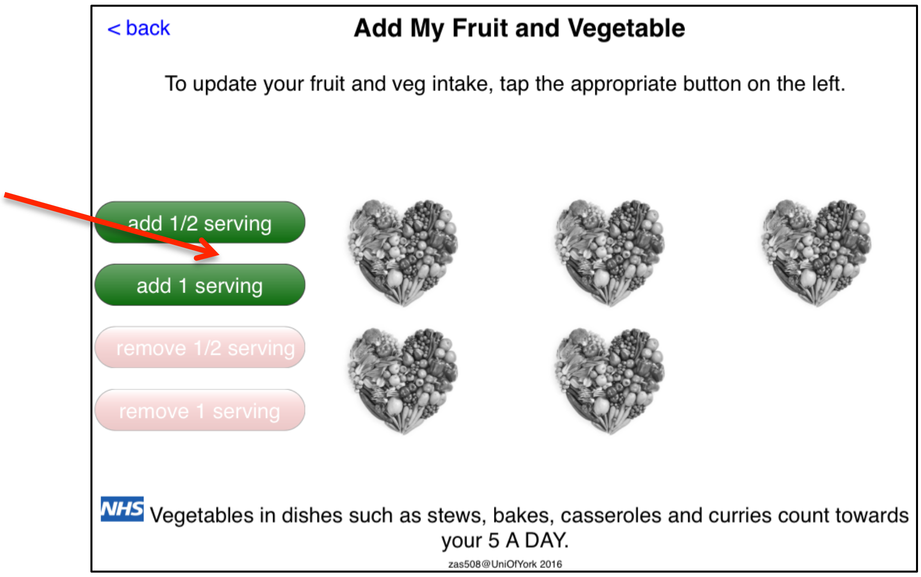
In Main Features, there are four things that you can do.

1. Add a fruit or vegetable
2. Add some liquid
3. View your healthy living progress
4. Read tips on healthy living

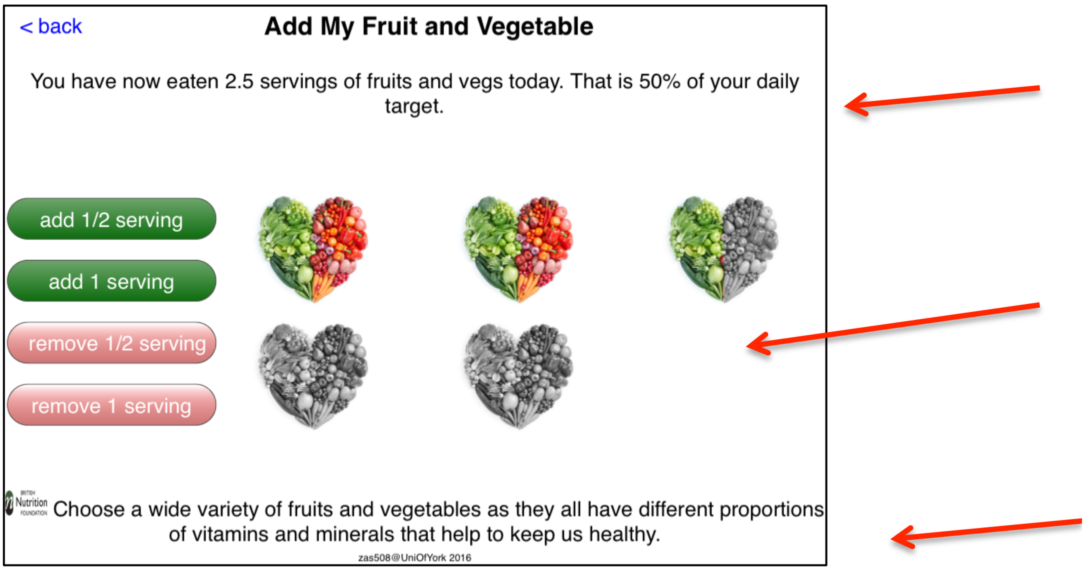
Add a fruit or vegetable

1. To add a fruit or vegetable, tap on the "Add a Fruit or Vegetable" button. This will direct you to the Add My Fruit and Vegetable page.

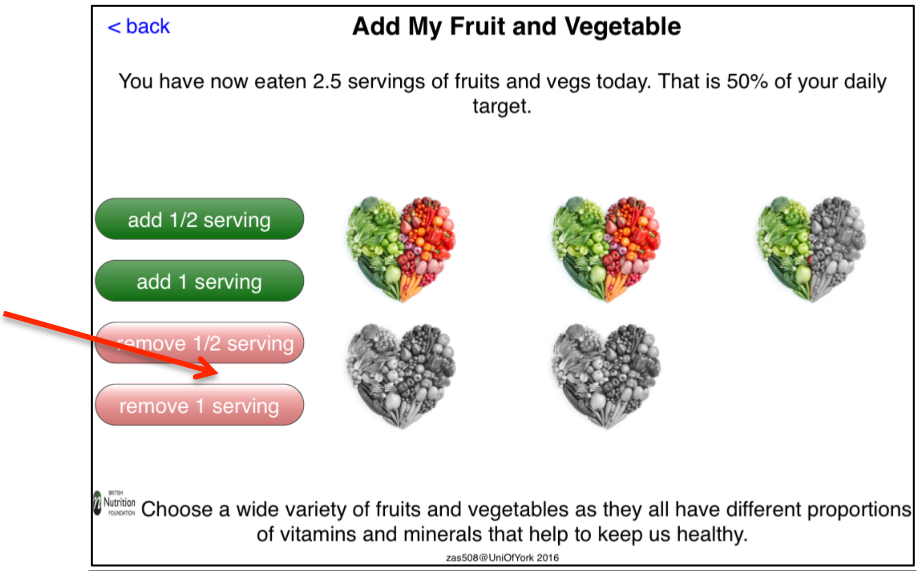
2. To add your fruit and vegetables intake, tap "add ½ serving" or "add 1 serving". There is no specific time to add your intake. You can use the app throughout the whole day.



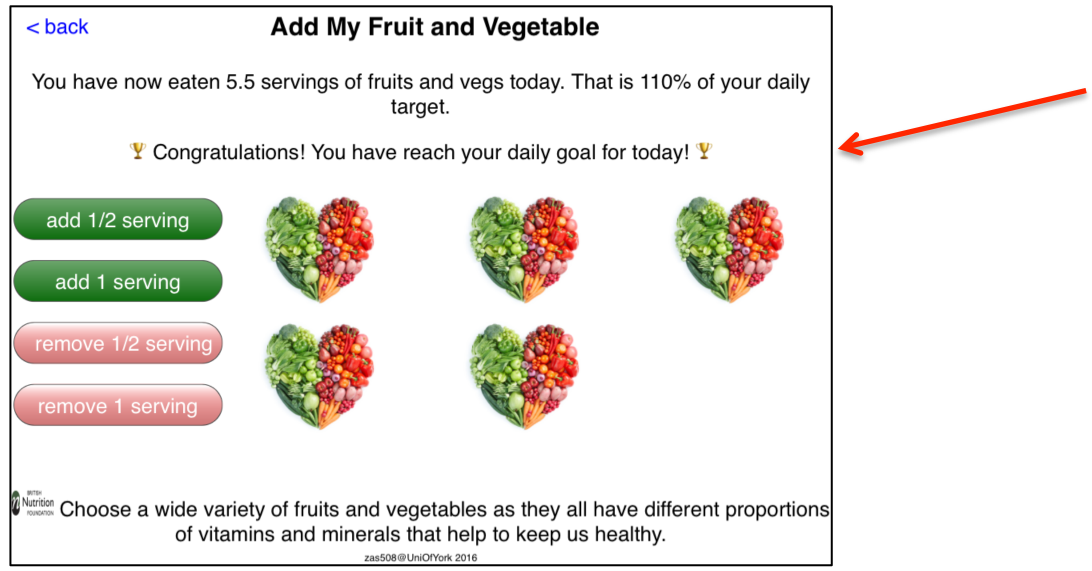
3. The images and message will update base on your intake. The tips at the bottom of the page will also change each time you update your intake.



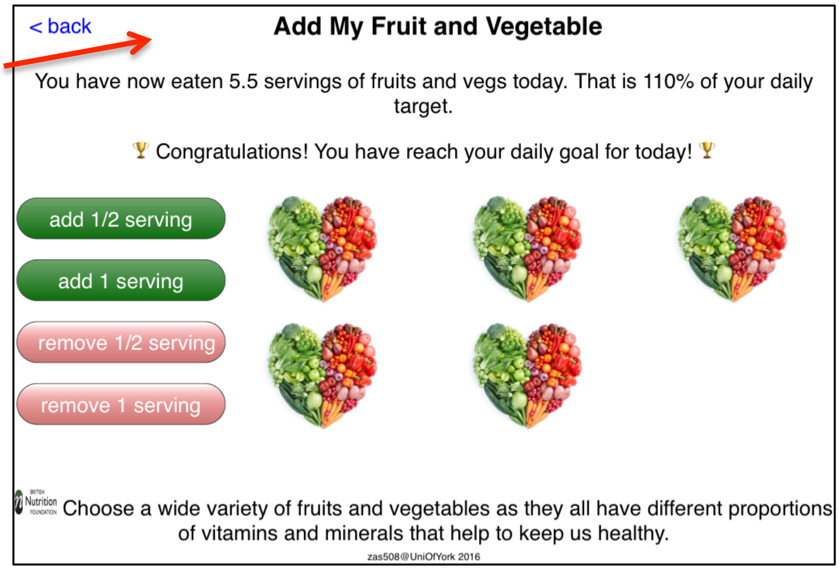
4. To remove your fruit or vegetables intake, tap "remove ½ serving" or "remove 1 serving".



5. Once you have reached your daily goal, a congratulations message will appear. Although you have reached your daily goal, you can still add your fruit and vegetables intake for that day.



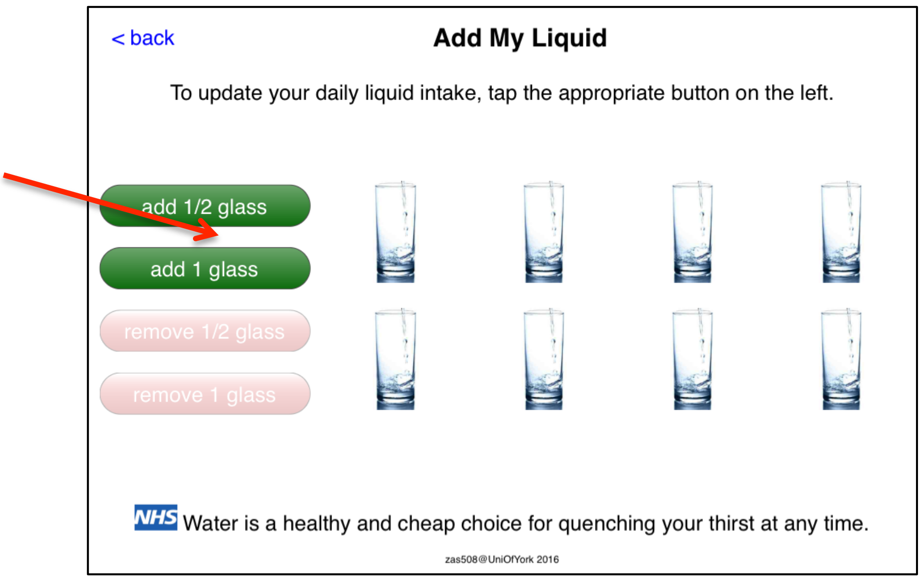
6. Tap "back" to return to the My Healthy Living App page.



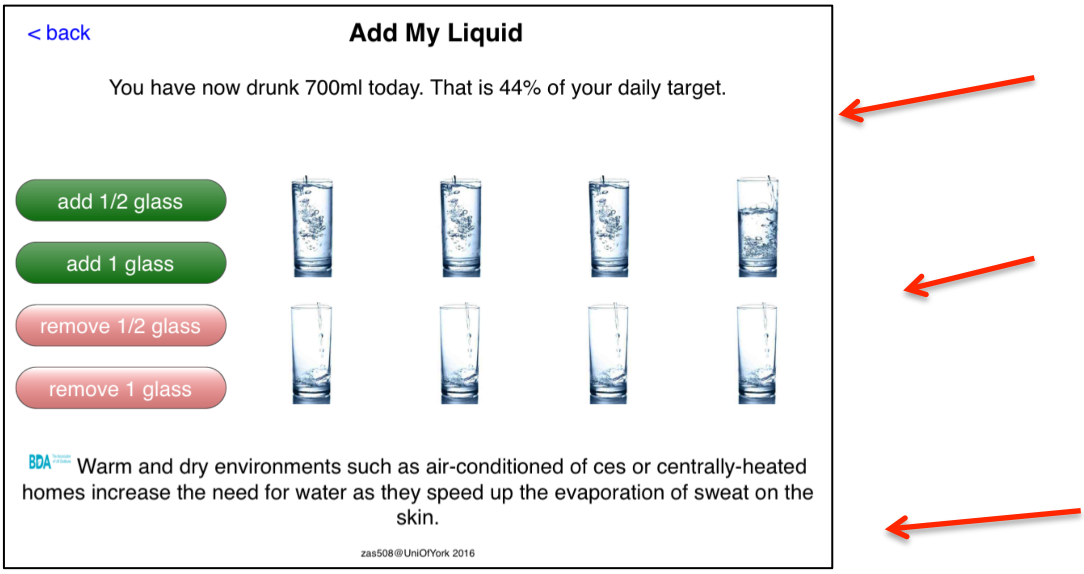
Add some drink

1. To add your liquid intake, tap on the "Add Some Liquid" button. This will direct you to the Add My Liquid page.

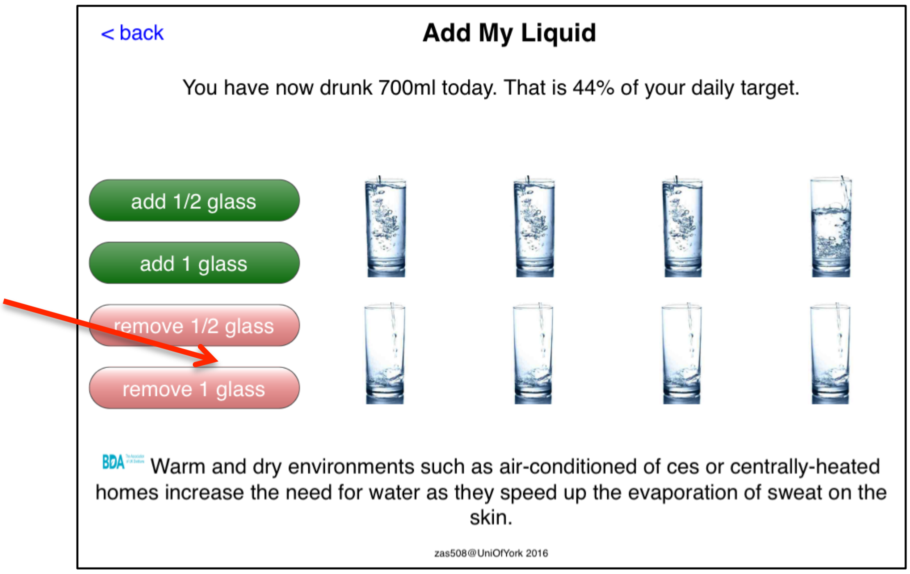
2. To add your liquid intake, tap "add ½ glass" or "add 1 glass". The images are based on your preferred option. The example shown below is for the glass option. The other options are cups and pints. There is no specific time to add your intake. You can use the app throughout the whole day.



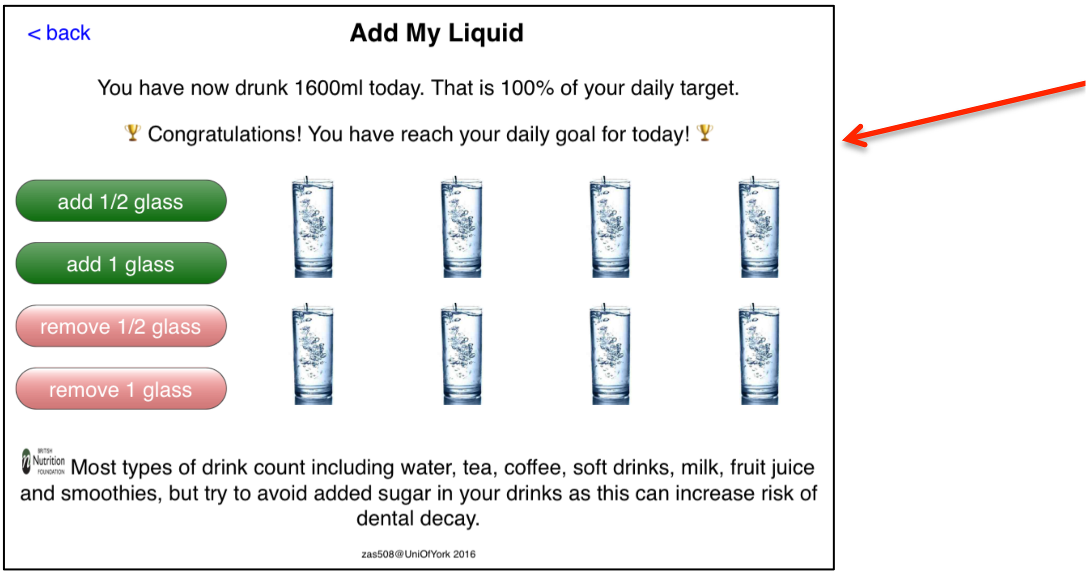
3. The images and message will update base on your intake. The tips at the bottom of the page will also change each time you update your intake.



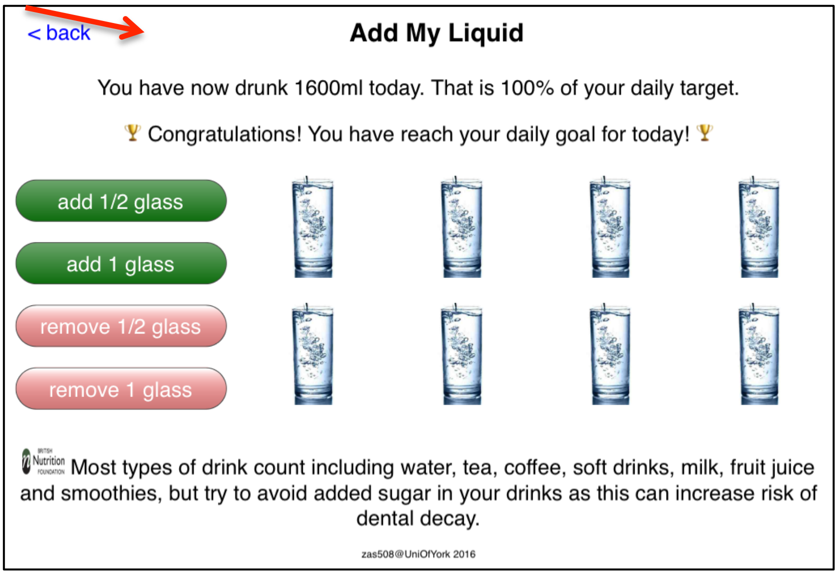
4. To remove your liquid intake, tap “remove ½ glass” or “remove 1 glass”.



5. Once you have reached your daily goal, a congratulations message will appear. Although you have reached your daily goal, you can still add your liquid intake for that day.



6. Tap "back" to return to the My Healthy Living App page.



View your healthy living progress

1. To view your healthy living progress, tap on the "View Your Healthy Living Progress" button. This will direct you to the Your Healthy Living Progress page.

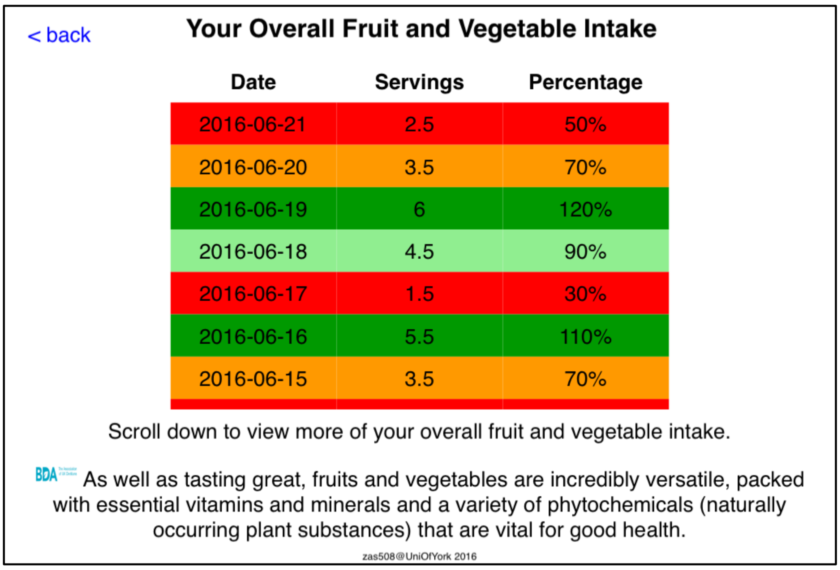
Here, there are four things that you can do.

1. View your overall fruit and vegetables intake
2. View your last 1-week of fruit and vegetables intake
3. View your overall liquid intake
4. View your last 1-week of liquid intake

View your overall fruit and vegetables intake

This page will show you a list of your overall fruit and vegetables intake. The list is coloured and sorted with the current date at the top. You can scroll up and down to view your overall fruit and vegetables intake.

The colour represents your fruit and vegetables intake. Red indicates that you have consumed up to 2.5 servings for that day. Amber or orange indicates 3 to 3.5 servings. Light Green indicates 4 to 5 servings a day and a Dark Green indicates more than 5 servings a day.



Note: This study starts from 25th July onwards. Thus, the date list will be from the 25th July. You may see a few red rows by default if you were to start the study on a later date (than the 25th July). This is not a mistake to the app. See the figure below for further understanding (example shown for the pre-study data for the date starting on 17th July).

< back

Your Overall Fruit and Vegetable Intake

Date	Servings	Percentage
2016-07-24	5.5	110%
2016-07-23	0	0%
2016-07-22	0	0%
2016-07-21	0	0%
2016-07-20	0	0%
2016-07-19	0	0%
2016-07-18	0	0%
2016-07-17	0	0%

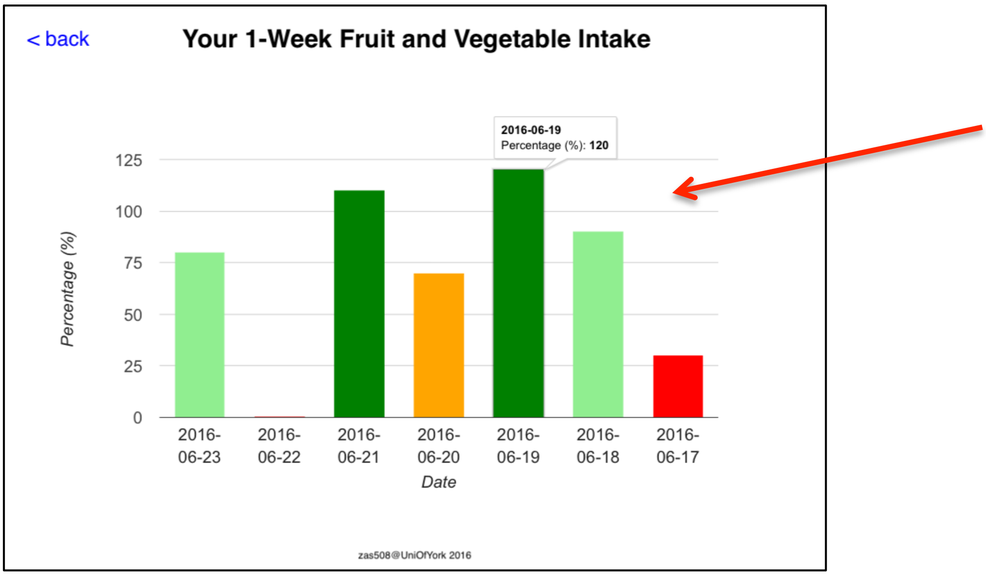
Scroll down to view more of your overall fruit and vegetable intake.

NHS Include a wide variety of fruit and vegetables in your 5 A DAY, to get the most nutritional benefit.

zas508@UniOfYork 2016

<u>**View your last 1-week of fruit and vegetables intake**</u>

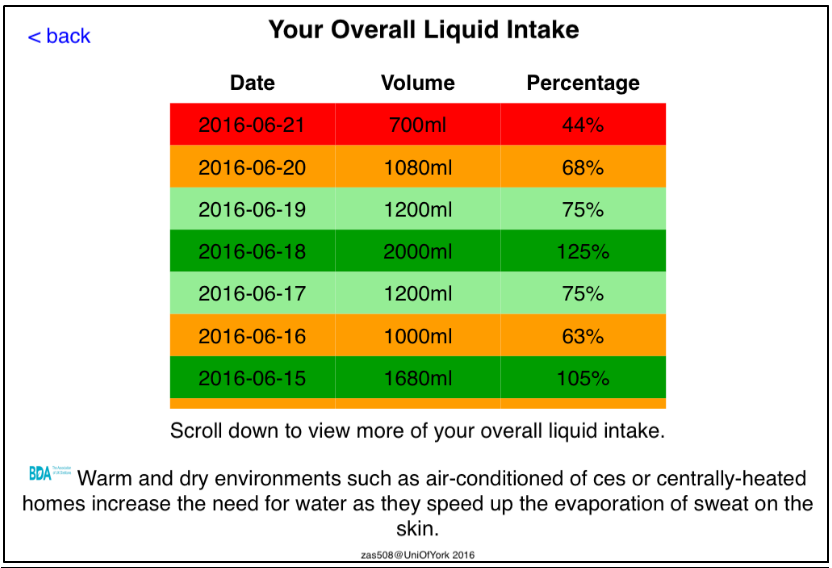
This page will show you a chart of your fruit and vegetables intake for the last seven days only. The colour represents your fruit and vegetables intake, similar to the list view. To view the specific detail of your intake for each day, tap on the coloured bar.



View your overall liquid intake

This page will show you a list of your overall liquid intake. The list is coloured and sorted with the current date at the top. You can scroll up and down to view your overall liquid intake.

The colour represents your liquid intake. Red indicates that you have consumed up to 50% of your recommended liquid intake for that day. Amber or orange indicates 21% to 70%. Light Green indicates 71% to 100% and a Dark Green indicates more than 100% of liquid intake per day.


< back

Your Overall Liquid Intake

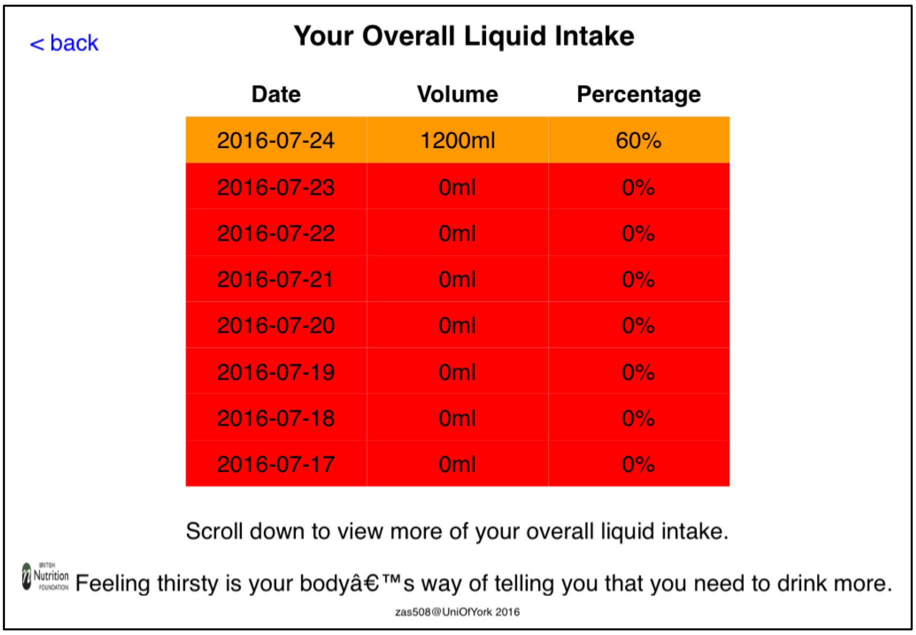
Date	Volume	Percentage
2016-06-21	700ml	44%
2016-06-20	1080ml	68%
2016-06-19	1200ml	75%
2016-06-18	2000ml	125%
2016-06-17	1200ml	75%
2016-06-16	1000ml	63%
2016-06-15	1680ml	105%

Scroll down to view more of your overall liquid intake.

BDA Warm and dry environments such as air-conditioned of ces or centrally-heated homes increase the need for water as they speed up the evaporation of sweat on the skin.

zas508@UniOfYork 2016

Note: This study starts from 25th July onwards. Thus, the date list will be from the 25th July. You may see a few red rows by default if you were to start the study on a later date (than the 25th July). This is not a mistake to the app. See the figure below for further understanding (example shown for the pre-study data for the date starting on 17th July).


< back

Your Overall Liquid Intake

Date	Volume	Percentage
2016-07-24	1200ml	60%
2016-07-23	0ml	0%
2016-07-22	0ml	0%
2016-07-21	0ml	0%
2016-07-20	0ml	0%
2016-07-19	0ml	0%
2016-07-18	0ml	0%
2016-07-17	0ml	0%

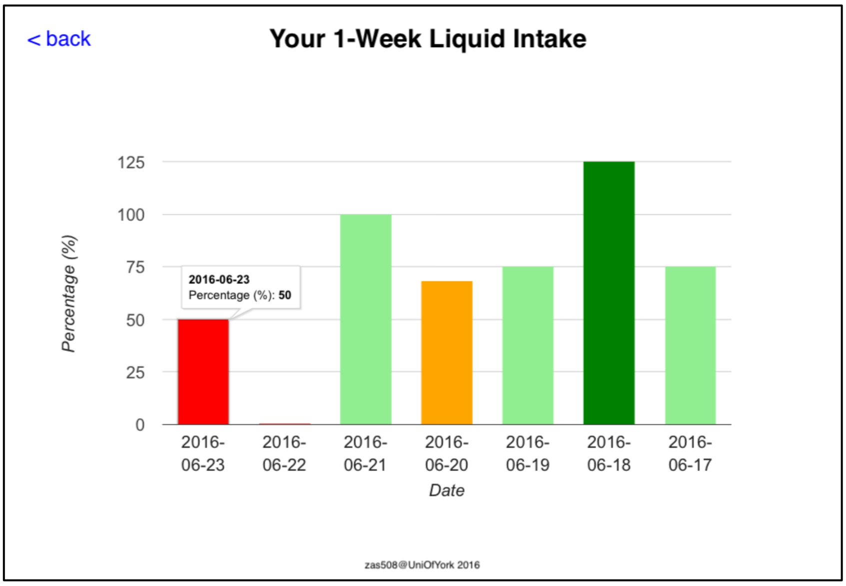
Scroll down to view more of your overall liquid intake.

Feeling thirsty is your bodyâ€™s way of telling you that you need to drink more.

zas508@UniOfYork 2016

<u>**View your last 1-week of liquid intake**</u>

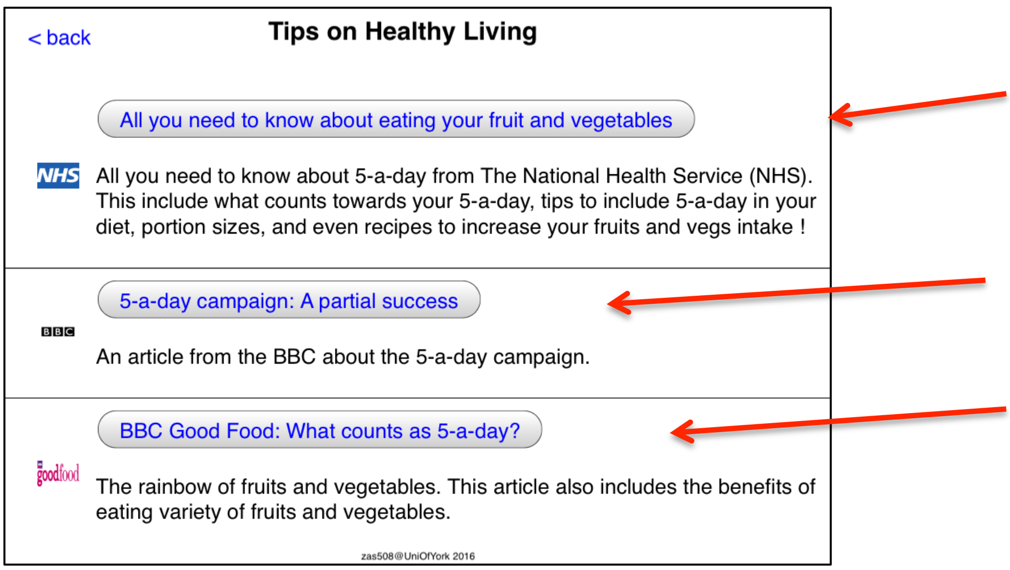
This page will show you a chart of your liquid intake for the last seven days only. The colour represents your liquid intake, similar to the list view. To view the specific detail of your intake for each day, tap on the coloured bar.


< back
Your 1-Week Liquid Intake
Percentage (%)
125
100
75
50
25
0
2016-06-23
Percentage (%): 50
2016-06-23
2016-06-22
2016-06-21
2016-06-20
2016-06-19
2016-06-18
2016-06-17
Date
zas508@UniOfYork 2016

Read tips on healthy living

1. To read tips on healthy living, tap on the "Read Tips on Healthy Living" button. This will direct you to the Tips on Healthy Living page.

2. There are seven buttons on this page. To view all of the buttons, scroll up or down. Each button will direct you to an external website to learn about healthy living.



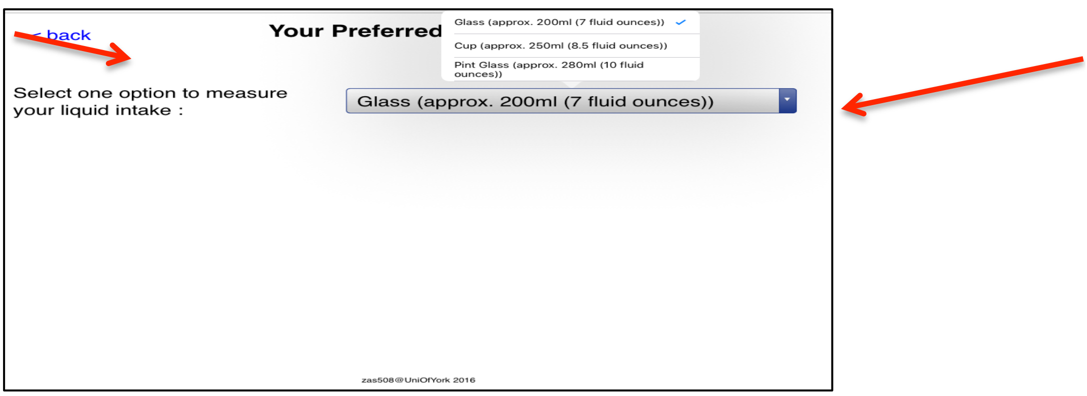
Additional Features

In Additional Features, there are three features that you can do. Tap on any

1 Change your preferred liquid measurement
2 Learn about iPad and its features
3 Read more about My Healthy Living App

Change your preferred liquid measurement

To change your preferred liquid measurement, select one option, and then tap "back". This will save the changes you made and will direct you to the Additional Features page. You do not have to make changes if you do not intend too.

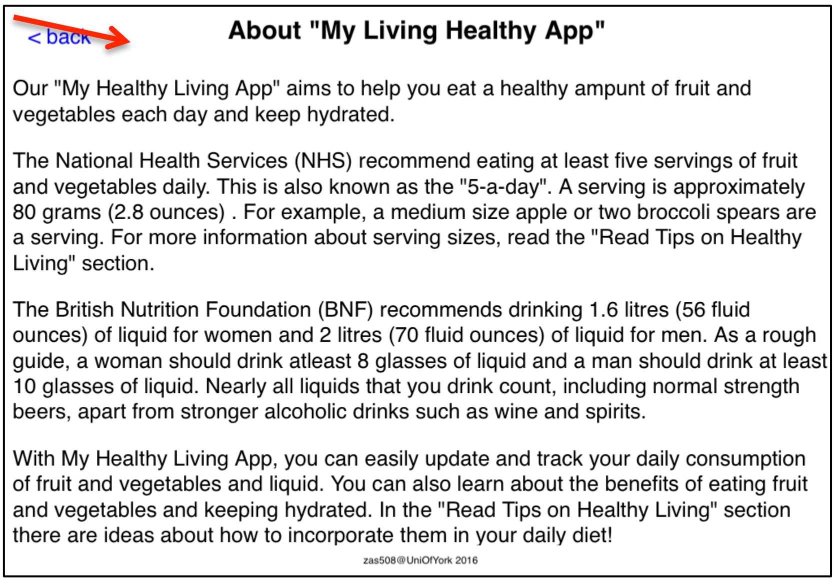


Learn about iPad and its features

This page will direct you to an external website to learn about iPad and its functionality.

Read more about My Healthy Living App

This page will direct you to the information page about the App. Tap “back” to return to the Additional Features page.



Log Out

To log out from the App, tap “Log Out” at the top left corner of the page.

End of User Instruction

Appendix 30: Post Study Questionnaire (Study 6)

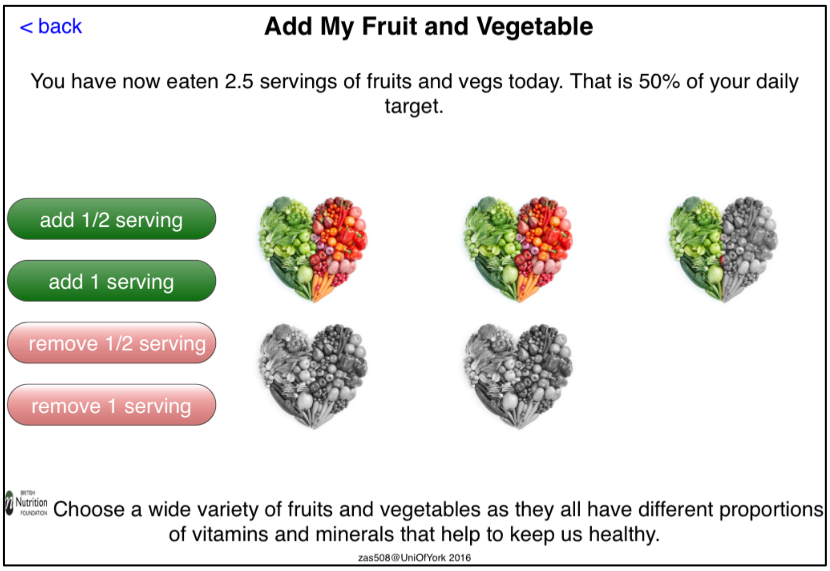
Note: The original font type is Arial and font size is 16. The font / size has been changed for the purpose of the Appendix.

Using Web-Based Application To Support Healthy Living

Thank you for your time to complete this questionnaire as the final part of the study. I would like to gather your thoughts and opinions in order to better understand your experience in using My Healthy Living App. For each question below, please write an 'X' to indicate your response.

Part A: Your opinion on the main features of My Healthy Living App

For Question 1 – 7, please refer the image below.



1. How easy was it to update your fruit and vegetables intake?

Very Difficult Very Easy

2. To update your fruit and vegetables intake, which option(s) did you use? Please select all that apply.

	add ½ serving		remove ½ serving
	add 1 serving		remove 1 serving

☐	a mixture of both (add)	☐	a mixture of both (remove)
☐	a mixture of all (add and remove)		

3. Was having the option ‘add ½ serving’ useful?

Not at all useful Very Useful

4. Was having the option ‘add 1 serving’ useful?

Not at all useful Very Useful

5. Was having the option ‘remove ½ serving’ useful?

Not at all useful Very Useful

6. Was having the option ‘remove 1 serving’ useful?

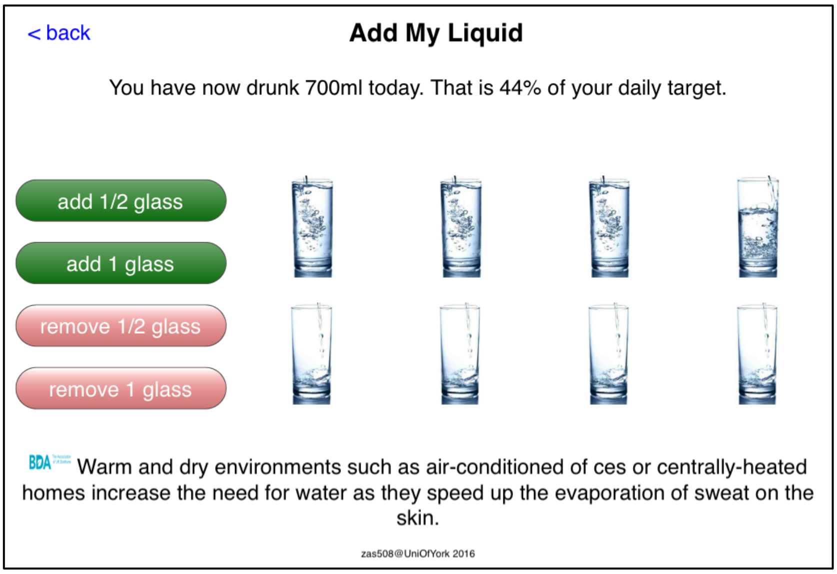
Not at all useful Very Useful

7. Do you have any comments about the fruit and vegetables intake feature?

____

____

For Question 8 – 13, please refer the image below (e.g. using the glass option to update liquid intake).



8. How easy was it to update your liquid intake?

Very Difficult — Very Easy

9. To update your liquid intake, which option(s) did you use? Please select all that apply.

	add ½ glass (cup / pint)		remove ½ glass (cup / pint)
	add 1 glass (cup)		remove 1 glass (cup)
	a mixture of both (add)		a mixture of both (remove)
	a mixture of all (add and remove)		

10. Was having the option ‘add ½ glass (cup / pint)’ useful?

Not at all useful — Very Useful

11. Was having the option ‘add 1 glass (cup)’ useful?

Not at all useful — Very Useful

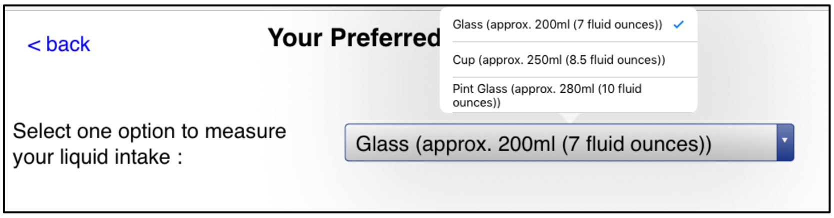
12. Was having the option ‘remove ½ glass (cups / pint)’ useful?

Not at all useful Very Useful

13. Was having the option 'remove 1 glass (cups / pint)' useful?

Not at all useful Very Useful

For Question 14 – 19, please refer the image below.



14. Did you change your liquid measurement option to update your liquid intake?

Never Very Frequently

15. If you answered 'Never' in Q14, please state your reasons.

____

____

16. If you did change your liquid measurement option,

    a. How easy was it to change your liquid measurement?

Very Difficult Very Easy

    b. Why did you change your liquid measurement?

    ____

    ____

17. How useful was it to change your liquid measurement?

Not at all useful Very Useful

18. Would you have liked other options for the liquid measurements? If yes, please state your suggestions.

____

____

19. Do you have any comments about the liquid intake feature?

____

____

Part B

A number of features were added to the app to raise awareness and to motivate you to eating more fruits and vegetables and to drink more liquid. This include:

Viewing your healthy living progress

For Question 20 – 21, please refer the image below.

20. Did you view your healthy living progress?

Never Very Frequently

21. If you answered 'Never' in Q20, please state your reason.

For Question 22 – 24, please refer the image below.

< back **Your Overall Fruit and Vegetable Intake**

Date	Servings	Percentage
2016-06-21	2.5	50%
2016-06-20	3.5	70%
2016-06-19	6	120%
2016-06-18	4.5	90%
2016-06-17	1.5	30%
2016-06-16	5.5	110%
2016-06-15	3.5	70%

Scroll down to view more of your overall fruit and vegetable intake.

BDA As well as tasting great, fruits and vegetables are incredibly versatile, packed with essential vitamins and minerals and a variety of phytochemicals (naturally occurring plant substances) that are vital for good health.

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22. If you did view your healthy living progress,

    a. Did having a coloured list of your fruit and vegetables intake raise your awareness about eating fruit and vegetables?

Not at all A great deal

    b. Did having a coloured list of your fruit and vegetables intake motivate you to eat more fruits and vegetables?

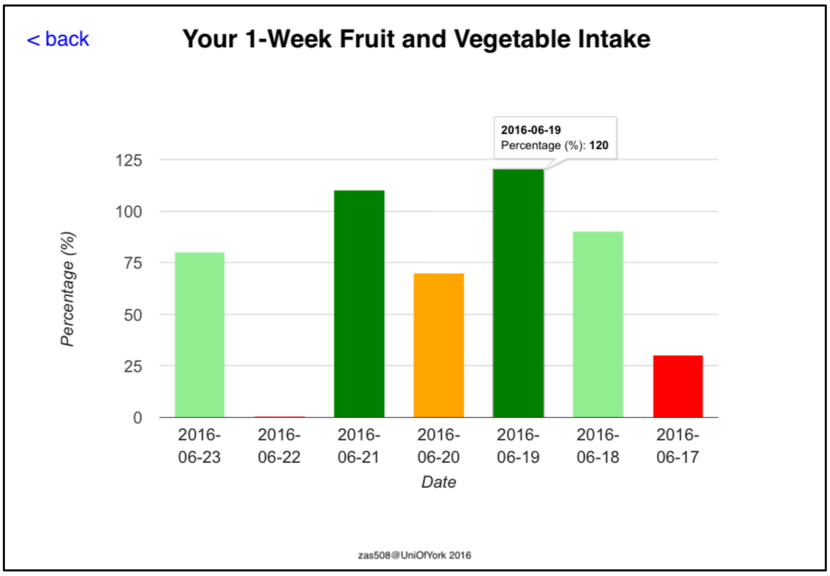
Not at all A great deal

23. How useful was this feature?

Not at all useful Very Useful

24. Do you have any comments about this feature?

For Question 25 – 27, please refer the image below.



25. If you did view your healthy living progress,

    a. Did having a coloured chart of your last seven fruit and vegetables intake raise your awareness about eating fruit and vegetables?

Not at all A great deal

    b. Did having a coloured chart of your last seven fruit and vegetables intake motivate you to eat more fruit and vegetables?

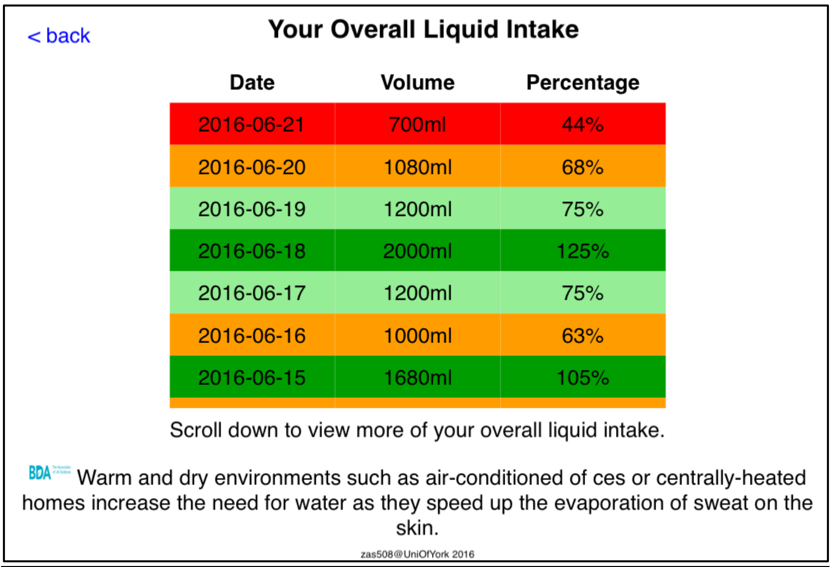
Not at all A great deal

26. How useful was this feature?

Not at all useful Very Useful

27. Do you have any comments about this feature?

For Question 28 – 30, please refer the image below.



Date	Volume	Percentage
2016-06-21	700ml	44%
2016-06-20	1080ml	68%
2016-06-19	1200ml	75%
2016-06-18	2000ml	125%
2016-06-17	1200ml	75%
2016-06-16	1000ml	63%
2016-06-15	1680ml	105%

28. If you did view your healthy living progress,

    a. Did having a coloured list of your liquid intake raise your awareness about drinking more liquid?

Not at all A great deal

    b. Did having a coloured list of your liquid intake motivate you to drink more liquid?

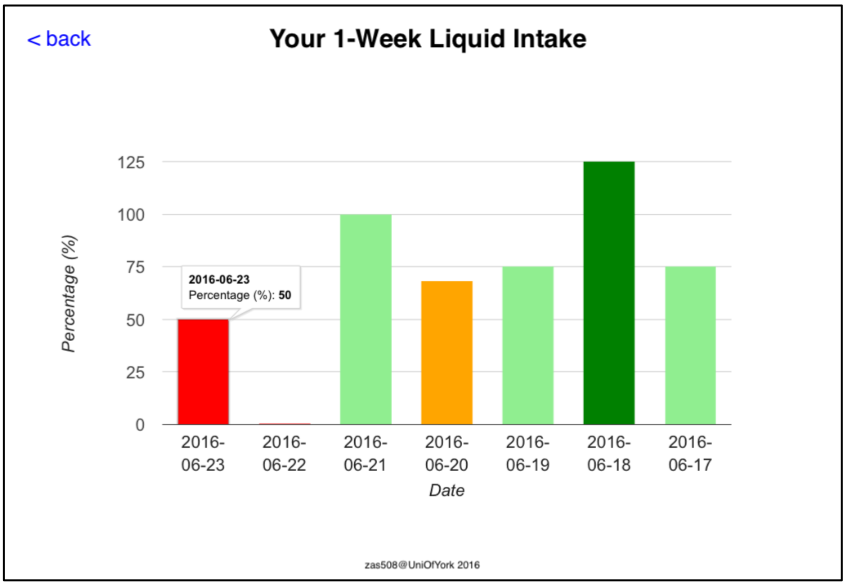
Not at all A great deal

29. How useful was this feature?

Not at all useful Very Useful

30. Do you have any comments about this feature?

For Question 31 – 33, please refer the image below.



31. If you did view your healthy living progress,

    a. Did having a coloured chart of your last seven liquid intakes raise your awareness about drinking more liquid?

Not at all A great deal

    b. Did having a coloured chart of your last seven liquid intakes motivate you to drink more liquid?

Not at all A great deal

32. How useful was this feature?

Not at all useful Very Useful

33. Do you have any comments about this feature?

Reading tips on healthy living

For Question 34 – 43, please refer the image below.

34. Did you read the tips and information about fruit and vegetables intake?

Never   Very Frequently

35. If you answered 'Never' in Q34, please state your reason.

____

____

36. If you did read the tips and information about fruit and vegetables intake,

   a. Did having a list of tips and information about fruit and vegetables raise your awareness about eating fruit and vegetables?

Not at all   A great deal

   b. Did having a list of tips and information about fruit and vegetables motivate you to eat more fruit and vegetables?

Not at all   A great deal

37. How useful was this feature?

Not at all useful Very Useful

38. Do you have any comments that you like to make about the tips and information on fruit and vegetables intake feature?

____

____

39. Did you read the tips and information about liquid intake?

Never Very Frequently

40. If you answered 'Never' in Q39, please state your reason.

____

____

41. If you did read the tips and information about liquid intake,

a. Did having a list of tips and information about liquid intake raise your awareness about drinking more liquid?

Not at all A great deal

b. Did having a list of tips and information about liquid intake motivate you to drink more liquid?

Not at all A great deal

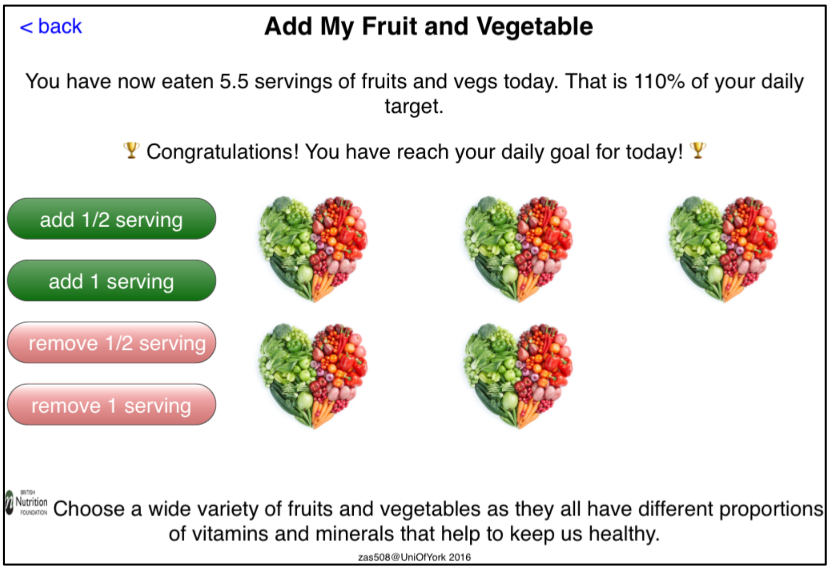
42. How useful was this feature?

Not at all useful Very Useful

43. Do you have any comments that you like to make about the tips and information on liquid intake feature?

<u>Seeing the congratulation message upon reaching your fruit and vegetables daily target</u>

For Question 44 – 48 please refer the image below.



44. Did you get a congratulations message upon reaching your daily target?

Never Very Frequently

45. If you answered ‘Never’ in Q44, please state your reason.

46. If you did get the congratulations message,

   a. Did seeing a congratulations message upon reaching your target raise your awareness about eating fruits and vegetables?

Not at all A great deal

b. Did seeing a congratulation message upon reaching your target motivate you to have more servings of fruits and vegetables?

Not at all A great deal

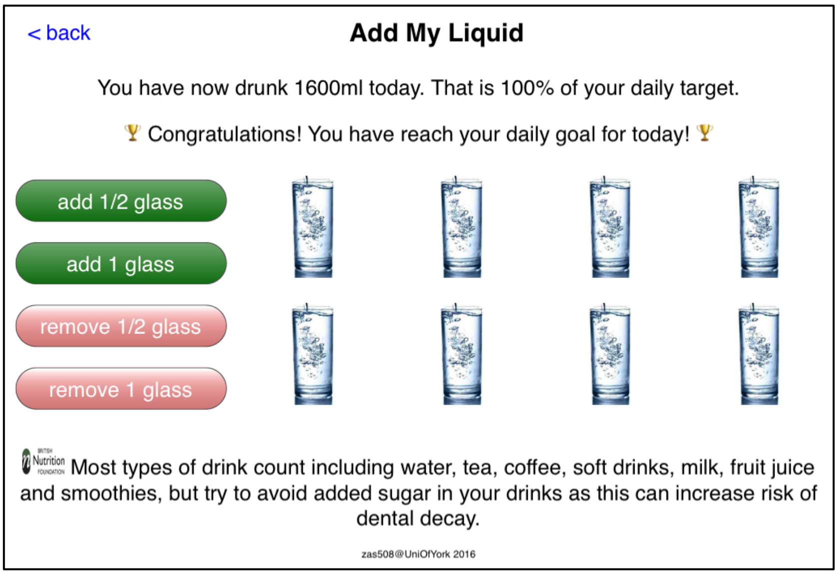
47. How useful was this feature?

Not at all useful Very Useful

48. Do you have any comments about this feature?

<u>Seeing the congratulation message upon reaching your liquid daily target</u>

For Question 49 – 53 please refer the image below.



49. Did you get a congratulations message upon reaching your daily target?

Never Very Frequently

50. If you answered ‘Never’ in Q49, please state your reason.

51. If you did get the congratulations message,

a. Did seeing a congratulations message upon reaching your target raise your awareness about drinking more liquid?

Not at all A great deal

b. Did seeing a congratulations message upon reaching your target motivate you to drink more liquid?

Not at all A great deal

52. How useful was this feature?

Not at all useful Very Useful

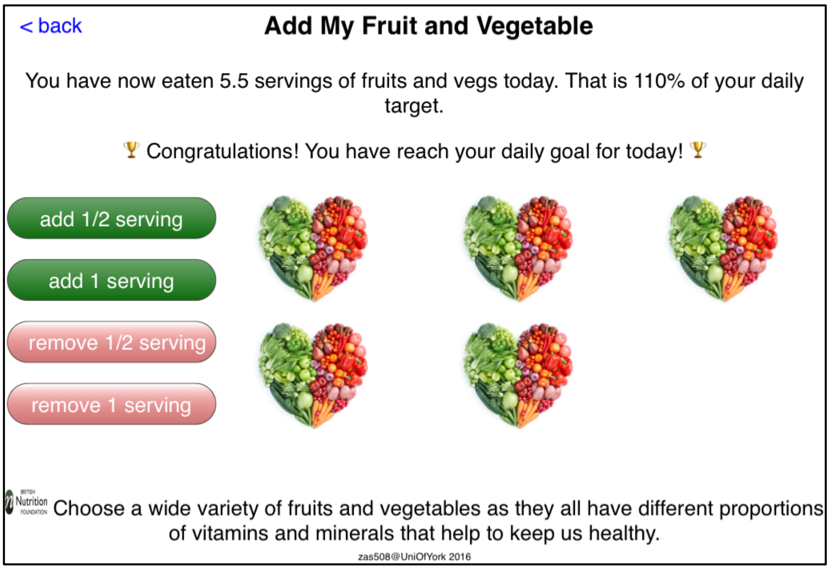
53. Do you have any comments about this feature?

____

____

Reading tips while updating your fruit and vegetables intake

For Question 54 – 58 please refer the image below.



54. Did you read the tips at the bottom of the page while updating your fruit and vegetables intakes?

Never Very Frequently

55. If you answered 'Never' in Q54, please state your reason.

____

____

56. If you did read the tips,

a. Did having a different tip each time you updated your fruit and vegetables intake raise your awareness about eating fruit and vegetables?

Not at all A great deal

b. Did having a different tip each time you updated your fruit and vegetables intake motivate you to eat more fruit and vegetables?

Not at all A great deal

57. How useful was this feature?

Not at all useful Very Useful

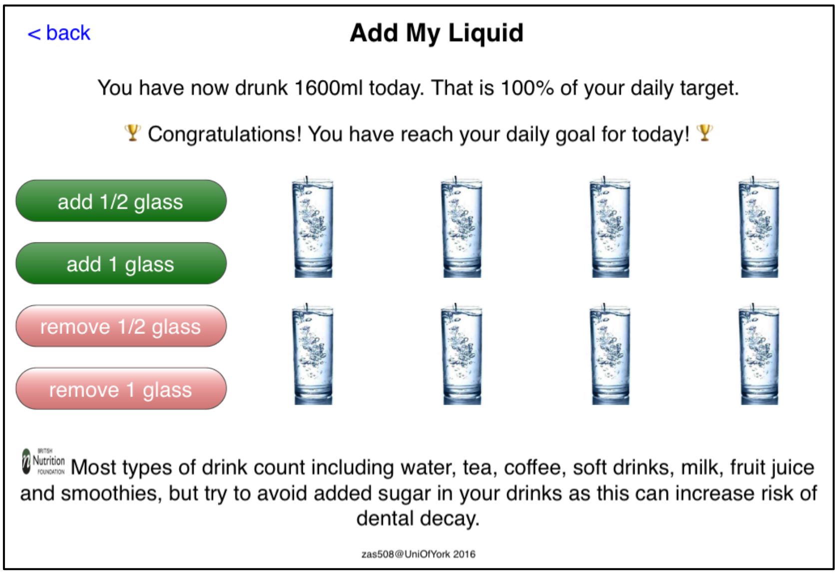
58. Do you have any comments about this feature?

____

____

Reading tips while updating your liquid intake

For Question 59 – 63 please refer the image below.



59. Did you read the tips at the bottom of the page while updating your liquid intakes?

Never Very Frequently

60. If you answered ‘Never’ in Q59, please state your reason.

____

____

61. If you did read the tips,

a. Did having a different tip each time you updated your liquid intake raise your awareness about drinking more liquid?

Not at all A great deal

b. Did having a different tip each time you updated your liquid intake motivate you to drink more liquid?

Not at all A great deal

62. How useful was this feature?

Not at all useful	Very Useful

63. Do you have any comments about this feature?

____

____

Reading the User Instruction for My Healthy Living App

64. Did you read the User Instruction?

Never | Very Frequently

65. If you answered 'Never' in Q63, please state your reason.

____

____

66. If you did read the User Instruction, how useful was it?

Not at all useful | Very Useful

67. Do you have any comments about the User Instruction?

____

____

Part C: General questions on My Healthy Living App

68. Overall using My Healthy Living App made me more aware of the amount of fruits and vegetables I was eating during the study.

Strongly disagree | Strongly agree

69. Overall using My Healthy Living App motivated me to eat more servings of fruits and vegetables during the study.

Strongly disagree Strongly agree

70. I think I ate more servings of fruits and vegetables during the study than before.

Strongly disagree Strongly agree

71. What do you find was the most motivating aspect of My Healthy Living App to encourage you to have more servings of fruit and vegetables? Please select all that apply.

	adding ½ serving
	adding 1 serving
	removing ½ serving
	removing 1 serving
	reading tips while updating the fruit and vegetables intake
	seeing a congratulations message upon reaching the daily target
	viewing a coloured list of the overall fruit and vegetable intakes
	viewing a coloured chart of the last seven fruit and vegetable intakes
	reading tips on healthy living
	Others: ___________________________________

72. Overall using My Healthy Living App made me more aware of the amount of liquid I was drinking during the study.

Strongly disagree Strongly agree

73. Overall using My Healthy Living App motivated me to drink more liquid during the study.

Strongly disagree Strongly agree

74. I think I drank more liquid during the study than before.

Strongly disagree Strongly agree

75. What do you find was the most motivating aspect of My Healthy Living App to encourage you to drink more liquid? Please select all that apply.

	adding ½ glass (cup / pint)
	adding 1 glass (cup)
	removing ½ glass (cup / pint)
	removing 1 glass (cup)
	changing the liquid measurement options
	reading tips while updating the liquid intake
	seeing a congratulations message upon reaching the daily target
	viewing a coloured list of the overall liquid intakes
	viewing a coloured chart of the last seven liquid intakes
	reading tips on healthy living
	Others: ____________________________________

76. I think that I would like to use My Healthy Living App frequently in the future.

Strongly disagree Strongly agree

77. I found My Healthy Living App unnecessarily complex.

Strongly disagree Strongly agree

78. I thought My Healthy Living App was easy to use.

Strongly disagree Strongly agree

79. I think that I would need assistance to be able to use My Healthy Living App.

Strongly disagree Strongly agree

80. I found the various features in My Healthy Living App were well integrated.

Strongly disagree Strongly agree

81. I thought there was too much inconsistency in My Healthy Living App.

Strongly disagree Strongly agree

82. I would imagine that most people would learn to use My Healthy Living App very quickly.

Strongly disagree Strongly agree

83. I found My Healthy Living App very cumbersome / awkward to use.

Strongly disagree Strongly agree

84. I felt very confident using My Healthy Living App.

Strongly disagree Strongly agree

85. I needed to learn a lot of things before I could get going with My Healthy Living App.

Strongly disagree Strongly agree

Participant ID:

Part D: Your experience with mobile devices

For each question below, please write an 'X' to indicate your response.

Using a mobile device (e.g. smartphones, tablet computers) I can:

		Never tried	Not at all	Not very easy	Somewhat easily	Very easily
86.	Navigate onscreen menus using the touchscreen					
87.	Use the onscreen keyboard to type					
88.	Send emails					
89.	Send pictures by emails					
90.	Transfer information (files such as music, pictures, documents) on my mobile device to my computer					
91.	Transfer information (files such as music, pictures, documents) on my computer to my mobile device					
92.	Find information about my hobbies and interests on the Internet					
93.	Find health information on the Internet					
94.	Enter events and appointments into a calendar					
95.	Check the date and time of upcoming and prior appointments					
96.	Use the device's online					

	"store" to find games and other forms of entertainment (e.g. using Apple App Store or Google Play Store)					
97.	Listen to music					
98.	Set up a password to lock / unlock the device					
99.	Erase all Internet browsing history and temporary files					
100.	Update games and other applications					
101.	Delete games and other applications					

102. Any other comments you would like to make about My Healthy Living App or being in this study?

____

____

____

Thank you.

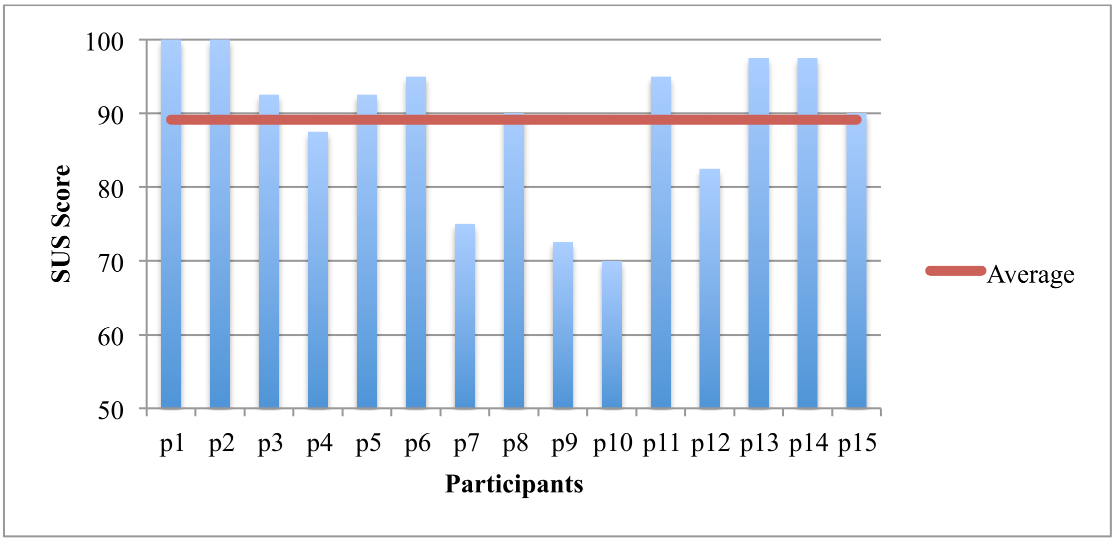
Appendix 31: Post Study Interview Questions (Study 6)

1. What do you like about My Healthy Living App?
2. What do you not like about My Healthy Living App?
3. What was easy to use or understand about My Healthy Living App?
4. What was difficult to use or understand about My Healthy Living App?
5. What general comments do you have about My Healthy Living App in its current form?
6. If you had full control of designing My Healthy Living App, what would you change?

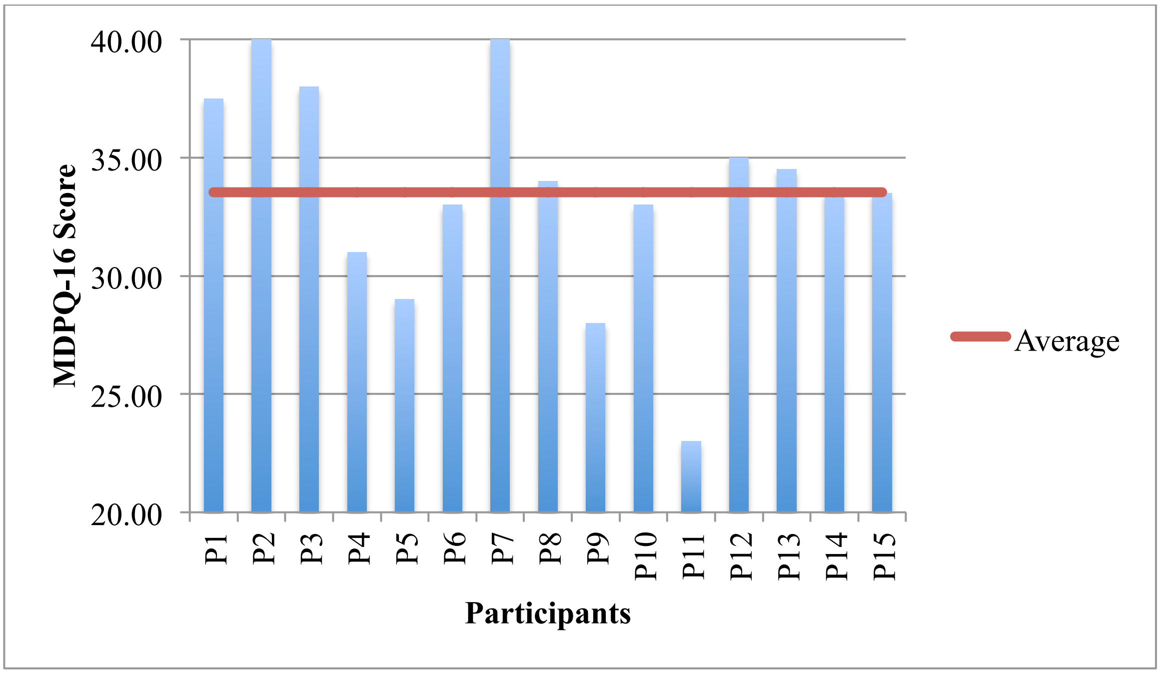
Appendix 32: List of Participants (Study 6)

Participant No	Gender	Age
P1	M	76
P2	M	67
P3	F	68
P4	F	78
P5	M	72
P6	M	71
P7	F	66
P8	F	66
P9	F	70
P10	F	68
P11	M	77
P12	M	70
P13	F	69
P14	F	66
P15	F	66

Appendix 33: Participants' SUS Score, and the overall average SUS score (Study 6)



Appendix 34: Participants' MDPQ-16 Score, and the overall average MDPQ-16 score (Study 6)



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