A Longitudinal Evaluation of the Acceptability and Impact of a Diet Diary App for Older Adults with Age-Related Macular Degeneration

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ABSTRACT
Ongoing advances in technology are increasing the scope for enhancing and supporting older adults' daily living. The digital divide between older and younger adults raises concerns, however, about the suitability of technological solutions for older adults, especially for those with impairments. Taking older adults with Age-Related Macular Degeneration (AMD) as a case study, we used user-centred and participatory design approaches to develop an assistive mobile app for self-monitoring their intake of food [12,13]. In this paper we report on findings of a longitudinal field evaluation of our app that was conducted to investigate how it was received and adopted by older adults with AMD and its impact on their lives. Demonstrating the benefit of applying inclusive design methods for technology for older adults, our findings reveal how the use of the app raises participants' awareness and facilitates self-monitoring of diet, encourages positive (diet) behaviour change, and encourages learning.

Author Keywords
Age-related macular degeneration (AMD); older adults; assistive technology; mobile apps; diet diary, health behaviour change; user-centred design (UCD).

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
With more than 500 million people around the world with some form of recognised disability associated with a mental, physical or sensory deficiency [22], there is considerable scope for IT-based assistive technologies to enhance the

independence and quality of life for many. To achieve this potential, however, requires researchers to invest time and effort in familiarising themselves with the domain, needs and specific capabilities of target users with given disabilities – a challenging task [25].

Figure 1. Example of how an image might be viewed through an eye affected by AMD at various stages of the disease [generated using www.inclusivedesigntoolkit.com].

With around 285 million people worldwide and almost 2 million people in the UK living with sight loss [23], visual impairment is one of the most serious age-related health concerns among older adults. The most common cause of sight loss in the UK is Age-Related Macular Degeneration (AMD); it impacts nearly one in ten of those over 80, and accounts for 16,000 blind/partial sight registrations per year [23].

As a progressive, degenerative disease of the eye it severely affects the macula, located at the centre of the retina, which is vital for clear central vision. As highlighted by Figure 1, AMD presents a significant challenge in terms of user interface (UI) design for technology – a challenge which is further complicated by the degenerative nature of the disease.

AMD significantly limits the independence of elderly patients as a result of the increased challenges associated

with completion of daily activities and reduces their quality of life [18]. There is now evidence of a link between dietary factors, AMD risk and AMD progression [1]. Unfortunately, however, risk factors such as diet are not easily measured in routine clinical practice [6] and little guidance – and certainly not guidance that is customised to the individual – is currently available to people with AMD in terms of dietary adjustments that might positively impact the risk or rate of progression of the disease.

Grounded in these issues, our aim was to develop an assistive mobile app – a bespoke diet diary – for accurately and conveniently recording diet information and automatically providing customised dietary recommendations to empower aging persons with AMD to make informed dietary choices that could lead to retardation of the progression of the disease. We adopted user-centred and participatory design approaches to the design and development of the diet diary and would refer interested readers to [12,13] for more detail in this regard. In this paper, we detail the research design and methods used, and report on findings from, the *evaluation* phase of our project that was conducted in two separate stages to collect empirical data to support investigation of the usability, acceptability and initial impact indicators of the prototype app.

BACKGROUND

Traditionally, many researchers have subscribed to the belief that older adults may feel sceptical about the need to use or benefits derived from using computers [24] or too old to learn to use computers [28], and have questioned the impact of computer use on older adults' wellbeing [9]. The generalised misconceptions that older adults are not willing to or capable of learning to use technology is problematic, particularly since recent evidence suggests that there has been a growth in the number of older adults using computing devices. The number of older adults aged 65 years and over (and it is estimated 1 in every 10 people aged 65+ has some degree of AMD) using smartphones in 2014 increased to 20% compared to only 12% in 2012, and more than 40% of older adults now use various devices to go online compared to only about 30% in 2012 [20].

Contrary to popular belief, a recent study examining the experiences and attitudes of older adults towards technology has found that older adults are highly motivated to learn (or continue to learn) to use technology, but consideration of their lifestyles and the role of proposed technology is crucial to the successful design of such technology [5].

Another study challenging some of the dominant stereotypes associated with older adults' use of and, more importantly, attitudes toward technology, recognised older adults' positive attitudes toward technology use, and suggested their perceived advantages of technology use includes "*supporting activities*" (e.g., health monitoring), "*adding convenience*" (e.g., when technology reduces effort), and "*having useful features*" (e.g., enlarged UI components) [19].

A recent comprehensive review of theoretical frameworks for the adoption of technology for older adults identified two fundamental components of the use (or abandonment) of technology by this user group: (1) the intention to use technology as underpinned by users' attitudes and perceptions; and (2) the usability of technology in terms of its design [2].

Designing IT specifically for people with AMD, however, is a relatively under-researched area and individuals with AMD have not traditionally been directly involved in the design of technology to support their needs and abilities, despite its potential to have a positive impact on their quality of life [4]. They *have* been the focus of a study into handheld GUI-based computer interaction for older adults with AMD which identified that severity of the disease, design efforts and strategies, and contrast sensitivity were important indicators for successful iconic search using, and manipulation of, handheld computers by this user group [16]. Beyond this, however, research into designing technology to match the abilities of this user group had been (prior to our work reported below) limited to a more general focus on desktop computers for the visually impaired rather than (mobile) assistive technologies for persons with AMD.

Besides their challenges with focus-intensive tasks (as a consequence of the degeneration in central vision), individuals with AMD are also likely to suffer from other sensory and motor impairments (as a consequence of aging) and, as such, find interaction with technology (and possibly participation in research studies overall) rather challenging. We have addressed these 'challenges' head on in our pursuit of technology to mitigate AMD risk and retard degeneration in older adults with the disease.

THE DIET DIARY APP

The app was developed for the Android platform in part because of its flexibility across a range of devices and manufacturers, supporting greater ultimate choice in device size and price, etc. A novel user interface (UI) was designed using a participatory design approach involving older adults with AMD: this is outlined in brief below and documented in more detail in Hakobyan et al. 2014 and Hakobyan et al. 2015[12,14]. The development of a computational engine (back-end) for the app included the creation of a simple food and associated nutritional ontology together with the daily nutritional recommended intake based on nutritional information sourced from the Macular Society [26], and the development of a rule engine that combines information from the ontology with data from user profiles and captured dietary data (i.e., daily food entries) to generate individualised dietary recommendations.

Figure 2 shows the main screen of the app from which users can record their dietary intake, record personal preferences, monitor progress, and record personal notes. They also have an option to set-up the app to suit their needs.
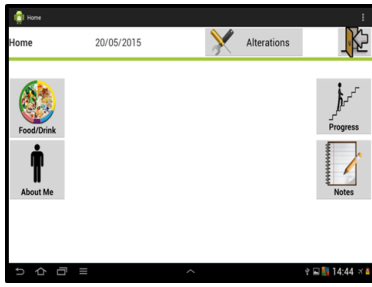
**Figure 2. Main Menu screen within the prototype app.**

Upon creating an account, users are presented with the option of conducting a simple vision test using an Amsler Grid (a test used for detecting macular degeneration[1]) for the purpose of personalising/configuring the layout of the UI based on measured visual acuity. Our diet diary can be further personalised by enabling users to individually tailor the app appearance in terms of background colour and font size to best serve their needs and maximise app accessibility.

Users record (see Figure 3) their daily intake of food as meals, snacks and drinks, and also have an option to record intake of vitamins (such information also being taken into account when providing customised dietary recommendations). Users select a food to enter by accessing the appropriate main food group and then selecting the required, specific food from that group; the same concept also applies for entering drinks, snacks, and vitamin supplements (for examples, see Figures 4 and 5).
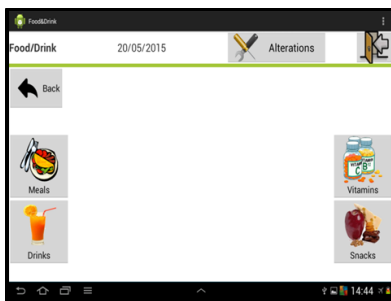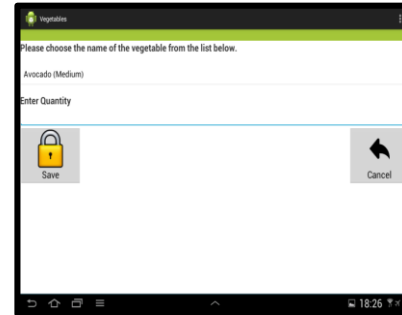

Figure 3. 'Food & Drink' screen.

It is important to note that, for the purpose of developing our simple prototype application, the type and number of food groups was set up to ensure the selection process remained very simple and to require users to focus on detail (as opposed to higher-level food group selection) only where necessary to support the AMD-related dietary recommendations sourced from the Macular Society. This is important, given that a recent study – reviewing the challenges people experience with food journals – found the difficulty of entering food items can negatively alter users' behaviour and result in abandonment of a technology/food journal altogether [8,29].
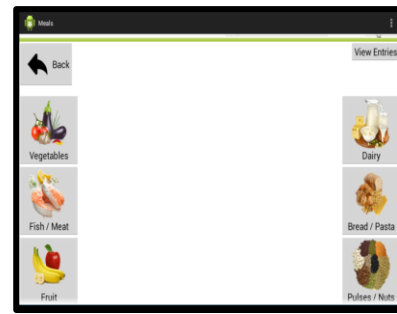
Figure 4. 'Meals' screen to select appropriate food group.

Figure 5. Example of how a type of vegetable would be selected from the 'Vegetables' screen; the same process would be followed for other food/drink types.
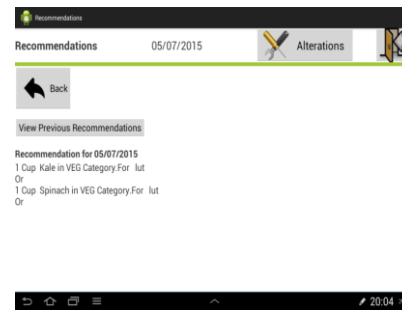
Figure 6. 'Recommendations' screen for accessing daily recommendations.

To facilitate the personalisation and customisation of the dietary advice and recommendations, users record information about their medical condition, disliked foods (in order to avoid inappropriate or unwelcome recommendations and hence maximise compliance), level of exercise and number of cigarettes smoked daily (both of which are taken into account when providing customised dietary recommendations).

Additionally, users have a 'Progress' option (see Figure 2) for viewing their progress made in terms of adherence to dietary recommendations, and for accessing their recommendations (see Figure 6) (customised daily dietary advice is automatically provided to users).

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[1] http://www.armd.org.uk/amsler.htm, accessed 1 May 2016.

For more detail about the initial and design phases of our research, and the development of the diet diary app we would direct interested readers to [12-14].

EVALUATION METHODS

This section details the research design and methods used as part of a usability evaluation study that was conducted in two separate phases to collect empirical data to support investigation of the usability, acceptability and initial impact indicators of the prototype app.

Preliminary Evaluation Study

The main purpose of our preliminary evaluation study activity was to introduce our diet diary app to representative target end users (i.e., older adults with AMD) in order to elicit their initial reactions to it and to invite potential participants to participate in a longitudinal evaluation study that was to follow.

In total, 9 participants (see Table 1 for participants' characteristics) were enrolled in the study with a gender split of 6 women and 3 men; participants' ages ranged from 65-89 (mean age 77). Three of the 9 participants were existing participants form the participatory design phases of our research; they had been part of the project right from the onset and were keen to "*test their designs*" (note the ownership inference which demonstrates the value in participatory design of such technologies).

ID	Age	Gender	Experience with Computers	AMD Severity	Number of Years Since Diagnosed
P1	74	Female	Some	Unknown	3
P2	87	Female	None	Wet one eye, dry other eye	10
P3	89	Female	Some	Dry one eye	8
P4	72	Male	Moderate	Wet both eyes	4
P5	65	Female	Moderate	Dry one eye	2
P6	73	Male	Some	Wet one eye	4
P7	78	Male	None	Wet one eye, dry other eye	12
P8	72	Female	None	Dry both eyes	14
P9	81	Female	Some	Dry one eye	3

Table 1. Overview of study participants' characteristics (participants from previous design phases are highlighted in blue).

Given the potential issues of vulnerability associated with participants' capacity to read documentation associated with the study, in all phases of our study we have paid particular attention to valid mechanisms for fully informing them about the study and obtaining their consent to participate. To this end, all documentation (including consent forms) has been produced in various font sizes and distributed in advance of each phase of the study so that participants could turn to family/support workers to help them read the material and give them a chance to ask any questions before consenting to participate; in addition, we provided detailed verbal explanation when handing out such documentation.

To commence their participation in the study, each participant was visited individually to provide him/her with a mobile device running our diet diary app and instruct him/her on the use of both the device and app (this initial visit typically lasted 1-2 hours). We set up the device (participants had an opportunity to select from three different tablet sizes – 5", 7" and 10") and the app for each participant; this included creating a user account and setting up the customisation to ensure the app was optimised to its 'user'. Each participant was then given time to 'play' with the app and ask questions to ensure they were comfortable with it.

Participants were asked to use the app as part of their daily routine for the subsequent 7 days to both provide initial feedback to the researcher and to help them decide if they would like to continue into the longitudinal study. It is important to note that participants were not requested to use any particular feature(s) of the app for any specific period of time; they were merely asked to use the app as it suited them in order to see how well it fit within their daily routine and to determine what features they gravitated naturally towards using; participants were given the lead researcher's contact details should they encounter any difficulties, have questions, or want to withdraw from the study and advised that they could contact her at any time, regardless of the issue.

Findings

It is important to note that the week-long initiation phase was primarily intended as an assessment of the feasibility of conducting a longer trial and as an extended recruitment phase for the longer trial period rather than the source of substantial research results in its own right. That said, there were some interesting observations from this phase which are summarised below.

During the course of the preliminary phase there was unfortunately some unavoidable (and anticipated) participant attrition, amounting to three participants in total. One participant (P9) was hospitalised and could not, therefore, continue with the study. Another participant (P7) engaged with the week-long study but declined further involvement on the basis that he was intrinsically averse to food and technology in general. The final participant (P8) who had to withdraw from the study provided some important insight into, and further awareness of, the needs of people with worst case AMD who have to rely on magnifiers for reading. During the end-point visit, the participant explained that she was incapable of using the device because a new magnifier she was prescribed to use was interacting with the device and "*changing*" the screens, making it rather troublesome to use the application. It turned out that this was because she had to

hold the magnifier very close on the screen to read through it, and this was triggering input to the device, ultimately resulting in screen changes.

Of the remaining 6 participants who all agreed to continue into the longitudinal study, two reported very little (but understandable) engagement with the application – one participant's (P1) health had deteriorated and she was hospitalised for a few days during the study week and the other participant (P5) had suffered the loss of a family member and so had stopped using the application while she was away from home. Both participants, however, were enthusiastic and indeed hopeful about the prospect of using the application for a longer period.

The remaining 4 participants had each used the application for 5.5 days on average. One participant (P3) reported no issues with the tablet; she was thankful for the opportunity and eager to continue with the study. The other 3 participants (P2,P4,P6) reported similar positive experiences, but had contacted the researcher during the initial days of the study to request help with the device/application.

Interestingly, most of the problems that participants were encountering were not application related, but were due to hardware issues. One participant (P2), for instance, was encountering difficulties with the on/off button on the tablet; after every use she was finding it challenging to locate the button on the side, and then she was pressing it with such force that the tablet was turning off entirely, thus causing unnecessary distress when she had to switch the tablet back on (fully rather than just awakening it from sleep) and log back into her account. The issue was clarified to the participant during the visit, where she also had the opportunity to try turning the device on and off with the researcher present.

None of the participants used the device for anything other than the application, except for one participant (P3) who unintentionally "*opened Google*" when trying to launch the application. All participants used the application to merely record their intake of food and did not make much use of its other available functions (e.g., checking recommendations or taking notes). This was primarily for the reason that most participants assumed "*experimenting*" with the device/app did not include using any other function than recording food.

Encouragingly, while our PD participants were yearning to use the application right from the onset of this study, some of the newly recruited participants were sceptical about the use of technology and the prospect of changing (or monitoring) their diet. By the end of this week-long study, however, all continuing participants reported promising positive changes in their attitudes towards our application to monitor their diet and technology in general.

Longitudinal Field Evaluation Studies
Having used the preliminary study to determine the feasibility of a longer-term evaluation, a longitudinal evaluation study was established to explore the following research questions: 1) Will people use the diary over time?; 2) How do they use the diary?; and 3) Are there indications that users improve dietary behaviours in line with advice and recommendations provided by the app?

In total, 6 participants (participants P1-P6 in Table 1) were re-enrolled into the second phase of the study with a gender split of 4 women and 2 men; participants' ages ranged from 65-89 (mean age 77). Two of the ongoing participants (P3 and P5) were from previous design phases of the research and, where applicable, the results from those participants are highlighted in the following discussion in order to illustrate any influence of increased stakeholdership of the app. Participants were invited to use the app as part of their daily routine (and not only in their homes) for the subsequent 6 weeks. Each participant was provided with the same (as for the previous week-long study) mobile device running our diet diary app, and was re-instructed on the use of the app. For this 6-week study, participants were encouraged to use the app in as realistic a manner as possible; they were also encouraged to explore all the functions of the app and, in particular, the recommendations. The device and app were again set up for participants, who then kept the device for the entire duration of the study. We also created 'user manuals' for participants to use if required. Consent was obtained as per previous phases of the research.

At baseline, and at every 7-10 days (subject to participants' availability), participants were informally interviewed to assess their ongoing experiences with the app. Basic auto-logged data was also downloaded from the participants' devices by the researcher during these visits; logged data included their food recordings and dietary recommendations they had received from the app. Time, location and duration of meetings (typically lasting one hour) were agreed with participants on a person-by-person basis; participants were encouraged to have a family member/friend present at meetings if they wished. While no financial compensation was offered for their participation in the study, the researcher gave participants a small bunch of flowers as a token of appreciation during most visits.

Data was collected via several instruments, including weekly discussions with participants, auto-logged use of the app, and a final interview. No hypotheses were formulated before the evaluation – this being an exploratory study to discover (a) how this particular mobile technology is adopted and (b) the outcomes of using it for older adults with AMD.
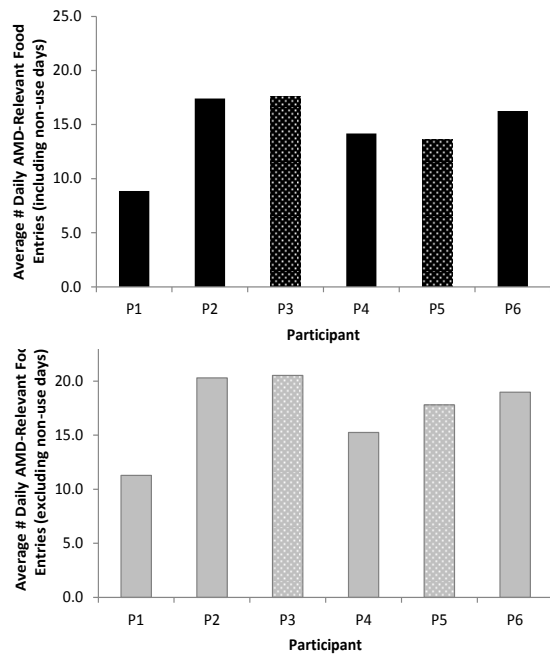
FINDINGS
It is important to note that findings (from the 6 week longitudinal study) reported in this section are exploratory and should not be interpreted as predictive or generalisable in the statistical sense; these results are indicative in nature. All qualitative data collected was subjected to thematic analysis [3] to enable us to identify patterns across the dataset and afford a representation of participants' experiences of using the diet diary app.
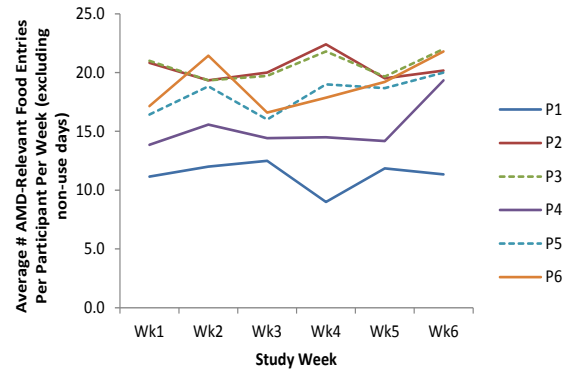
App Usage

On average, as shown in Figure 7, participants recorded 14.6 AMD-relevant food entries per day (including days with no recordings) or 17.4 AMD-relevant food entries per day (excluding days with no recordings).

Encouragingly, the average number of days where no food entries were recorded at all was 6.7 per participant: reasons for no food entries varied, with participants mentioning feeling unwell, being away from home (e.g., hospital stay or visiting a relative), remembering very late in the day or forgetting altogether as their main reasons for not recording their dietary intake on a given day.

Figure 8. Average number of AMD-relevant food entries recorded over the course of the 6 weeks according to participant (participants from previous design phases are shown using a dotted line).
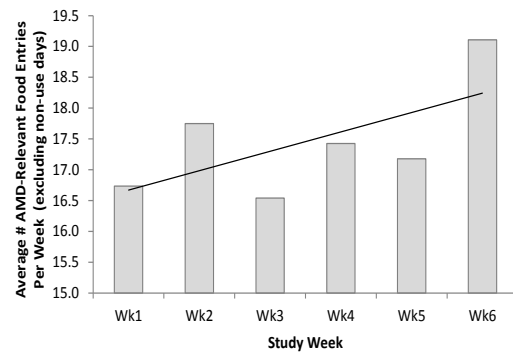

Figure 7. Average number of daily AMD-relevant food entries including (top) and excluding (bottom) non-use days (participants from previous design phases are shown in dotted fill).

Participants' individual use patterns (see Figure 8) showed that participants P1 and P2 largely maintained their entry rate across the duration of the study (allowing for fluctuations along the way), with participants P3-P6 (of which two were our PD participants) increasing their average number of food entries from week 1 to week 6 of the study. None of the participants dropped their entry rate overall, which is a promising indicator of continued use. In fact, as illustrated in Figure 9, results would suggest that, when considering the participants as a group there seemed to be an increase in the number of AMD-relevant food entries from week 1 to week 6 – *potentially* indicating effective adherence to dietary recommendations.
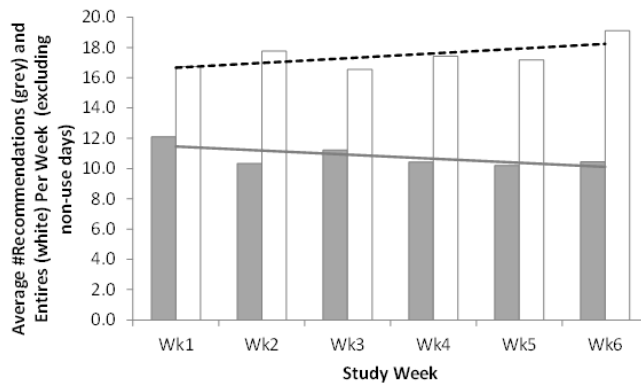

Figure 9. Average number of AMD-relevant food entries recorded over the course of the 6 weeks across all participants, showing linear trend line.

It was, however, not possible to record and therefore determine participants' *specific* observance of the system's dietary recommendations: i.e., we cannot tell if a dietary intake was a direct consequence of recommendations from the system or something participants would have otherwise consumed anyway. That said, if we consider the number of recommendations from the system as a proxy for participants' attempt to improve their diet (i.e., fewer recommendations representing stronger conformance with AMD dietary guidelines) then we can identify *indicators* of the potential positive impact of the recommendations.

Figure 10 shows the average number of recommendations made across all participants from week 1 to week 6 of the study: the overlaid trend line *suggests* a possible reduction over time of the average number of recommendations, accounting for days of non-use.
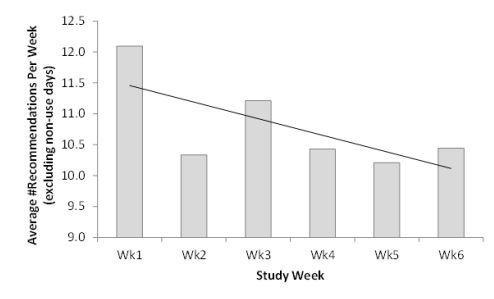
Figure 10. Average number of recommendations made over the course of the 6 weeks across all participants, showing linear trend line.

Figure 11. Average number of recommendations (grey) made over the course of the 6 weeks compared to average number of AMD-relevant food entries (white) across all participants, showing linear trend lines for each.

If we then compare (see Figure 11) the average number of recommendations to average number of AMD-relevant food entries (excluding non-use days) per week, we can see divergent trend lines – increasing AMD-relevant food entries against decreasing recommendations. This might *suggest* (given the lack of statistical analysis, we make no stronger a claim at this time) an overall move towards not just more detailed food recording, but also more appropriate diet (such that fewer recommendations are required). The qualitative feedback from participants (see later) would seem to support this proxy-based assessment.

Perceived Ease of Use
Participants' main qualifier in terms of the app's usability and acceptability was that the app was "*easy to use*", as exemplified in the following quote:

"It was just easy to use, very pleased. Thumbs up" (P2).

Feedback from all participants indicated they found the app less confusing to use than they anticipated would be the case. One participant mentioned keeping a paper diary of his intake of food for other health conditions, and said that using the app for recording intake of food was "*encouraging*" and "*much easier to use*". He also explained:

"I don't have to write things down and it records it straight away – Brilliant" (P4).

Interestingly, another participant also compared the app to a paper diary and indicated that ease of use and efficiency are the main advantages of using the diet diary app over the paper diary, explaining:

"It's certainly easier then writing on a paper. If you'd asked me to write it down, my diet, every day, I might get really bored doing it every day, but this one took only a few minutes to do it, so easy to use. I did forget the other night, but as far as time is concerned it's very easy to use I didn't find it tiresome or anything like that" (P3).

In addition to ease of use, participants also recognised comfort and portability as further advantages of the app, as explained below:

"I just see it as an application that is trying to make an improvement in how people generally think about food, and anything to do with health, and move towards making it easier and easier to deal with. […] The app is quite easy and takes a very short time: I mean you can even do it sitting in front of the TV" (P5).

Participants also commented that it was reassuring and encouraging to know that they could use "*trial and error*" to learn how to use the app by being able to handle errors, with one participant explaining:

"No, I just found it quite easy. When I did something I could take it back, especially when you showed me the bits and bobs, it was really easy" (P1).

Perceived Usefulness
Our thematic analysis uncovered four sub-themes pertaining to the perceived usefulness of the diet diary app as recognised by our participants, all of which are discussed in the following subsections: (1) the app raises awareness and facilitates self-monitoring of diet; (2) it encourages positive (diet) behaviour change; (3) it encourages learning; and (4) could *potentially* support memory.

Increases Awareness & Encourages Self-Monitoring of Diet
Findings from our study revealed that one of the main advantages of the app was its capacity to empower participants to self-monitor their health and thus improve their health and independence. This is particularly important, as studies examining the experience of living with AMD have found that many older adults find it troublesome and upsetting to rely on others (i.e., family members) for help and fear that this potential dependence can lead to unsatisfying consequences [29]. All our participants indicated that the app would heighten their confidence and hopefulness in taking charge of their own health, and thus improve their emotional wellbeing: low mood and a lack of positive outlook are also reported as recurrent consequences of AMD [27], and have been shown to be significantly associated with poor appetite in older adults [10]. As one participant explained:

"It [the app] *would give you some hope, whereas with this* [shows doctor's appointment note] *you would just get medically messed with…whereas with this* [the app] *you would have some hope of directing your own health. It's a self-help. It would only do good and make you feel emotionally really good"* (P1).

A less frequent but noteworthy sub-theme was the importance of raising participants' awareness about their intake of food and motivating them to take better care of themselves as a result. As one participant explained:

"You are trying to help yourself. It raises your awareness about what you take. It's an eye-opener so [friend] *and I could use this"* (P4).

Another participant was surprised to learn how much food he was consuming on a daily basis:

"It was fine, it was interesting. I was surprised I could use it; one thing I was surprised is when I looked at the list of food entered at the end of the day I was quite surprised at how much I had eaten. When you look at the list you think did I consume all this?" (P6).

All participants agreed this increased awareness of their nutritional intake was one of the most positive impacts of use of the app. Most commented that, by just recording their intake of food and then checking their 'history' of items recorded, the app made them realise how little (or unhealthily) they were eating. It was this self-monitoring of their diet that required them to evaluate and rethink their intake of food, as exemplified in the following quote:

"I eat well now and its only when I scribbled down for this thing [the app] *I realised I was eating hardly anything.* […] *I was looking at what I had* […] *I hardly had any fruit* […] *so I need to do something, haven't I?"* (P2).

Participants also reported that as a result of their increased awareness, they felt more determined to monitor and improve their health. As one participant noted:

"I am also determined to eat well to look after myself, so if I eat well and look after myself I can do it, wouldn't it be marvellous" (P3).

Positive Behaviour Change
One of the most encouraging realisations to emerge from our findings was our participants' observed positive change in their health behaviour. All participants described positive behaviour changes to various degrees (from drinking more water to generally improving their diet). They reported that their increased awareness (as discussed in the above subsection) of their intake of food motivated them to reconsider and re-evaluate their diet, and led to positive changes in their eating habits. For some, this awareness afforded an explanation for other health concerns and, therefore, offered a prevailing motivating trigger to change (and improve) their diet overall. For instance, one participant explained:

"You know what's really interesting, since I have been checking my history [app entries] *I did not realise how little I was eating, so no wonder I am so weak. So I am determined to improve my diet"* (P1).

For some participants the use of the app led to minor changes. As one participant noted:

"I have started drinking more water because of this [the app]*"* (P4).

Other participants, however, affected more substantial changes to their eating habits. For instance, one participant explained:

"Funnily enough I looked, I don't [eat] *enough fruits so when I saw grapes on my recommendation list, I started eating grapes and I shall continue doing so"*(P6).

Interestingly, some participants have also delved into the nutritional values of the suggested recommendations. This supports claims that older adults are more likely to perceive self-monitoring technologies useful and thus adhere to recommendations when the use of such technologies can improve their healthcare knowledge [11]: in our case, this involved understanding why a particular item of food is being recommended. As one participant explained:

"Now, the other day I did not realise I did not have zinc, I used to eat bananas but then stopped, so that was a great thing to discover that I do not eat enough zinc" (P5).

The qualitative findings reported here and in the above subsection suggest that the app was successful in promoting enhanced (eating-related) health behaviour and various degrees of adherence to dietary recommendations. This was primarily because the app successfully increased participants' awareness about their eating behaviour, encouraged self-monitoring of their intake of food, and improved their healthcare knowledge. As one participant explained:

"The benefit I found was it made me sit down and list everything I was eating and drinking so it reminded me if I did not eat or drink enough, though drinking primarily. So it concentrated my mind on what I was eating or drinking because we never do enough, so it's a discipline of doing it […] *so this* [the app] *is great"* (P2).

Increases Motivation to Learn
A further important finding of our study was the increase in our participants' motivation and determination to learn as a result of the confidence gained from using the app. Challenging recent suggestions that low healthcare knowledge amongst participants hinders the acceptance of self-monitoring technologies [21], findings of our study suggest that older adults are more than willing to invest time and effort on learning about both about their condition and the proposed technology as long as the benefits of such investment are appreciated. Most of our participants reported a keen interest in learning to use the diet diary app (and

mobile technology in general), provided they could appreciate the need for such technology, the relevance of it to their lifestyles, and benefits gained from using technology. As one participant explained:

"Because of this I am back to reading heavy stuff, so thank God for it. I am pleased about that and also I rung about joining the computer club I told you […] *I really should be learning shouldn't I"* (P1).

In fact, some participants suggested the opportunity (and challenge) of learning new things is an important advantage of using technology: it was perceived as a means for keeping mentally agile. As one participant explained:

"It's up to you, it's up to you, the choice is yours. You can go out or stay at home and keep twiddling my thumbs […] *you need something to register, to keep your brain cells busy"* (P6).

Further, the experience seemed to enhance our participants' (at least self-perceived) social status and changed their outlook on life. Participants reported feeling honoured to be part of the project, and took pride in sharing their experience with friends and family members. Most participants were surprised by their own learning capabilities. As one participant explained:

"People say 'and this lady left school at 14 you know', so I have to self-educate, I can't believe I am saying this" (P3).

Other participants have also reported strong desire to learn to use computers, and to take full advantage of the "*internet*" and their mobile phones. In fact, two participants (P1,P4) reported making enquires at local libraries and clubs for courses on using technology.

One participant hoped that learning to use technology could improve her independence, as she had to rely on her hairdresser for most technology associated tasks (e.g., booking flights). She explained:

"It's like a God send, absolutely brilliant. When I see my hairdresser she booked everything for me. Yes it's the fact that I feel inadequate without technology, so maybe I can do all these things" (P1).

All participants acknowledged that some effort was required from them to learn how to use the diet diary to start with, but they also recognised the sense of accomplishment and enjoyment felt when challenges and fears were conquered, as highlighted in the following quote:

"Oh the first couple of days to get [started I was] *struggling but* [now] *no difficulties at all, soon I could get myself out of troubles, and that was a great feeling, indeed"* (P2).

Overall, our participants were surprised to learn and enjoy something they previously did not understand. Importantly, participants also learned a great deal about healthy lifestyle and their own eating habits.

Potential to Support Memory

It should be emphasised that we were in no way formally assessing or measuring the impact of our app on participants' memory (this not being the focus of our study) but, that said, it is worth noting that an unexpected and very encouraging finding of our study was that the use of the diet diary app appeared to *support* participants' memory (an area with which many older adults require assistance [17]) or at least their perception of their own memory. Participants felt that this was primarily because they were required to follow a planned and structured routine to record their intake of food and that this could *potentially support* their memory. One participant explained:

"I think you have to have a routine with it, especially if you make your mind up teatime–ish. But I have to tell you it makes wonders to your memory" (P3).

The fact that the app required participants to reflect on and remember their intake of food has also likely contributed to their *perception* of support for memory. As one participant noted:

"if I was really well I could remember all the things I had. It wasn't difficult to remember what I ate because it made me think, yes, it made me think I could. At times I would not do it quick and it irritated me – I wanted something simple on my mind, but when my memory clicked I did master it, I thoroughly enjoyed it" (P1).

Similarly, participants who used the 'Notes' option found it particularly helpful to record notes and appointments to support their memory (and were not constrained to notes about just diet – hence were purposing the app beyond our expectations). As one participant noted:

"I have all my appointments here, its brilliant, look I have your appointment here and my doctor's one. All the things that I have to remember goes here" (P5).

Finally, all participants reported taking advantage of the prospect of viewing (and thus recalling) their daily intake of food: all acknowledged it supported them in monitoring their diet, planning ahead, structuring and "*organising*" their "*actions*", all of which have contributed to their perception that the app potentially supported memory-related tasks.

CONCLUSIONS

This paper has discussed a study that was conducted as part of the final evaluation phases of our user-centred research to assess the usability, acceptability and initial impact indicators of the prototype app. The findings indicate that perceived ease of use and perceived usefulness play a considerable role in participants' acceptance and use of the diet diary app. Specifically, analysis of the study transcripts revealed four sub-themes pertaining to the perceived usefulness of the diet diary app as recognised by our participants: (1) the app raises awareness and facilitates self-monitoring of diet; (2) it encourages positive (diet) behaviour change; (3) it encourages learning; and (4) although not

formally tested, participants perceived use of the app as *supporting* their memory. Participants, who were from previous design phases of the research, also felt a sense of pride and ownership of the final prototype design being evaluated (but did not exhibit behaviours atypical of the other participants). In addition to the perceived usefulness of the diet diary app and its ease of use, we identified other factors influencing and contributing to older adults' experience of using our technology. These factors include participants' determination and motivation, pride in taking part in the study, and showing interest in others; discussion of these is outside the scope of this paper.

All participants recognised potential benefits of use of technology (or at least assistive technology). Participants noted "*keeping in touch*", "*changing outlook of life*", "*keeping brain active*", "*staying in touch with the younger generation*", "*improving independence and quality of life*", and "*making life easier*" as some of the main advantages of (assistive) technology use. As already noted, in terms of following dietary recommendations, reassuringly all our participants expressed interest in changing (or monitoring at the very least) their diet to various degrees. They acknowledged how recording their intake of food has encouraged them to reassess their diet. This also highlights the positive impact that actual use of technology can have on participants.

There is very little documented evidence of longitudinal field evaluations of mobile assistive technologies such as ours, and as such we report on our efforts and findings to encourage more of this work which illustrates the rich data returned from close examination of technologies in real world use by older adults. That said, we acknowledge that health behaviour such as healthy eating is only beneficial when maintained over a prolonged period of time [7]. We also support calls for pilot or feasibility studies to be replicated with larger samples to generate more generalisable results and stronger base of evidence for effectiveness of mobile phones for health interventions [15].

Thus to further substantiate our claims of positive behaviour change and demonstrate the sustainability of such change over time, extended research is necessary. Within the scope of the current project, a 6 week usability-focused evaluation of the system was conducted with a limited number of users. We propose to expand our evaluation efforts to include much longer longitudinal field evaluations, wherein a larger number of users would use the device for an extended period of time in order to fully assess the long-term acceptability to and impact of the system on persons with AMD. Such a study would lead to deeper appreciation of issues such as: 1) the extent to which the diary encourages *sustained* positive behaviour change over time; 2) the extent to which use of the diary leads to quality of life improvements over time; and 3) closer examination of the characteristics of users who follow advice and recommendations versus those who do not. Nevertheless, we hope that our findings thus far illustrate

that, by designing an app with and for older adults to support specific functions identified by them to be of value to their independence and wellbeing and that are delivered in a way that heightens ease of use for such users, it is possible to deliver mobile assistive technology that inspires positive behaviour change (in this case in the form of adherence to dietary recommendations) in older adults.

ACKNOWLEDGMENTS

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