What Health Topics Older Adults Want To Track: A Participatory Design Study

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ABSTRACT
Older adults are increasingly savvy consumers of smartphone-based health solutions and information. These technologies may enable older adults to age-in-place more successfully. However, many app creators fail to do needs assessments of their end-users. To rectify this issue, we involved older adults (aged 65+) in the beginning stages of designing a mobile health and wellness application. We conducted a participatory design study, where 5 groups of older adults created 5 designs. Four groups identified at least 1 health metric not currently offered in either the iPhone app store or the Google Play store. At the end of the sessions we administered a questionnaire to determine what health topics participants would like to track via smartphone or tablet. The designs included 13 health topics that were not on the questionnaire. Seventeen of eighteen participants expressed interest in tracking health metrics using a smartphone/tablet despite having little experience with these devices. This shows that older adults have unique ideas that are not being considered by current technology designers. We conclude with recommendations for future development, and propose continuing to involve to older adults in participatory design.

Categories and Subject Descriptors
H.5.2. [**Information Interfaces and Presentation (e.g. HCI)**]: User Interfaces – user centered design.

General Terms
Design, Human Factors.

Keywords
Older adults; participatory design; health; smartphone applications; mHealth

1. INTRODUCTION
An age-wave is upon us. According to the US Census, the population of people over 65 is projected to double by 2030, going from 12% to 20% of the population [13]. In addition, older adults are increasingly consumers of technology. A 2010 Pew Internet Research survey shows that 47% of older adults (aged 50-64) used social media, a sharp increase from 25% in 2009 [25]. In a survey conducted of 36 countries in 2011, 61% of older adults had access to a mobile device [36]. According to a Pew Internet Research survey in February 2012, 31% of older adults (aged 50-64) owned a smartphone, a statistically significant jump up from 22% in 2011 [30]. As of January 2013, 71% of older adults (aged 50-64) who use the Internet, sought health information online [9]. Seeing as these trends will probably continue as more technology-savvy baby boomers reach retirement age, it seems vital that older adults be involved in mobile application development, specifically related to health.

mHealth is an area of research and product development focused on the development of mobile applications to support healthy living, either from a personal perspective, or a healthcare industry perspective. A report on mHealth and older adults talks about a "viscous cycle" of technology development – one that excludes older adults and results in lower adoption rates and higher rates of cognitive decline [16]. If we continue our current trajectory, we will perpetuate this viscous cycle. According to the model, the viscous cycle will lead to a higher cost for our society, as older adults would not age-in-place successfully. They also speak of a "virtuous cycle" where older adults are involved in technology development, and specifically mHealth applications. They claim that this virtuous cycle will not only improve how the needs and desires of consumers are met, but encourage participation of older adults, and thereby reduce the amount or speed of their cognitive decline. This is supported by a study which found that computer use is associated with lower rates of cognitive decline (in their words, "use it so you won't lose it") [31].

To help implement the "virtuous cycle", Davidson and Jensen showed that even without software development experience, older adults are able to provide meaningful contributions to smartphone application design [7]. This is important because it significantly broadens the pool of potential design partners, making these types of design activities more viable in a real-world setting. Ultimately it is life experience and an understanding of the needs of this population that is more important than an intimate understanding of the underlying technologies.

As researchers, we should enable the desires of older adults to be heard, to further support this "virtuous cycle". The work presented here is based on the same research study reported in a previous publication which analyzed the creativity of the designs [7]. Our novel contribution of this publication is to provide researchers and developers with a set of possible directions for mHealth designs specifically targeted for *personal use* by older adults. Many mHealth developers focus on how to increase connectivity between doctors, health insurance companies, and patients [16].

Rather than a *patient*-centric approach, we take a *user*-centric approach. With our results, we are aiding the design of health-related applications that focus on what the *user* wants, instead of focusing solely what the doctor and/or medical insurance industry wants.

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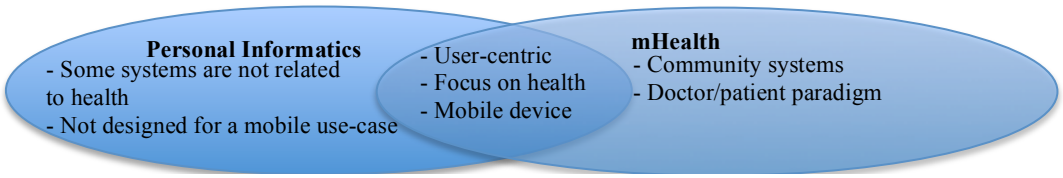

Figure 1. Venn diagram showing the overlap and difference between personal informatics and mHealth.

Our research questions are as follows:

RQ1. What health topics do older adults want to track?

RQ2. Are current mHealth tools tailored to meet the needs of older adults?

We answer these research questions through a two-step process:

1. A participatory design study with 18 older adults (65+) with no programming experience that involved an interview, group sketching session, and a questionnaire.
2. A comparison of the health topics in our study to what is available in the current smartphone app market.

The rest of the paper is organized as follows: first we review related work in mHealth (both from an industry and an academic standpoint), and personal informatics. Then we review our methodology, followed by our results. We conclude with a discussion of shortcomings and future work.

2. RELATED WORK

For our discussion about designs for a mobile health and wellness application, there are three main areas of research that are relevant: technology design with older adults, mHealth, and personal informatics. We start with a brief mention of technology design with older adults then move onto a discussion of industry reports related to mHealth. Finally, we provide a brief overview of the breadth of work being done in these two areas, and where they overlap (see Figure 1).

2.1 Technology Design with Older Adults

There are a handful of research teams who have conducted participatory design activities with older adults [1,21,24,26,32,33]. None of these teams have worked with older adults to design a health and wellness mobile application. For a more in-depth literature review of this area, see our previously published work [7].

2.2 mHealth Reports

A recent report published by the mHealth Alliance and funded by Pfizer speaks about mHealth specifically related to older adults [16]. In addition to proposing two models of development, one that is beneficial to older adults and one that is not, they provide recommendations for mHealth developers to follow. Their results are much more broad and medical-industry-focused than our work, but are nonetheless relevant. They claim that primary outcomes of mHealth should include data quality, lifestyle modification, and collecting data separated by age and gender. Their recommended secondary outcomes of mHealth applications are that they should focus on compliance, cost-effectiveness, and biomarker readings.

In addition to this recent report, the March 2013 monthly "Health Information Technology" report by Circle Square claims that mHealth is in a new stage of growth, with over 97,000 mHealth apps on the market [18]. They also claim that a "major driver [of mHealth market's growth] is the growing penetration of smartphones" [18]. Both of these reports explain how mHealth can be used to change behaviors and/or enhance patient compliance [16,18]. In our study, we did not emphasize behavioral change, rather we focused on "tracking your health". Regardless, these two reports show that mHealth is a current issue that is receiving growing attention from industry.

2.3 mHealth and Personal Informatics

Figure 1 shows a Venn diagram comparing the fields of mHealth and personal informatics. The overlap between mHealth and personal informatics is the area that is most relevant to the study presented in this paper. We focused on understanding what users wanted, and asked our focus groups to draw designs for a mobile health application that they would personally want to use to track a health topic of their choosing, regardless of whether this was something they believed or knew already existed on the market or not. Our work is situated in the overlap between personal informatics and mHealth

To provide the reader with a better understanding of the breadth of work in the area of personal informatics and mHealth, we provide a review of selected systems in this area.

2.3.1 Mobile Personal Informatics Systems

Most personal informatics systems have one or more of the following purposes: self-diagnosis, awareness of routines/self-reflection [20], and/or behavioral change. Li et al. describe these purposes as a "stage-based model": preparation, collection, integration, reflection, and action [19]. The systems mentioned in this brief review cover some of the stages, however, not all systems have a goal of "action".

The systems described in the paragraphs below live in the middle of the Venn diagram (Figure 1), as they are user-centric, related to health, and are available on a mobile device.

One of the few personal informatics/mHealth studies specifically related to older adults, is a self-diagnosis application that aids in diagnosing vision problems [2]. The other applications discussed in this section did not have an explicit emphasis on older adults.

Sleep tracking is an area of significant interest to the mHealh community. One example of an application in this area is ShutEye, an application that encourages healthy sleep patterns, and therefore seeks behavioral change [4]. Gartenberg et al. also conducted a study related to an application that enabled users to track their sleep patterns, but does not explicitly seek behavioral change [12]. Similar to sleep trackers, Ahtinen et al. mention an application entitled SelfRelax, which provides a way for people to relax (by playing background sounds, for example) [3].

Diet is another area of great interest to researchers creating mobile applications. Freyne et al. ran a clinical trial of applications that support dietary change [11]. SapoFitness is another application that seeks behavioral change by changing one's diet [29].

Exercise is a third area that has been explored in the overlap of mHealth and personal informatics. Ubifit garden encourages users to get more exercise [6]. In a similar vein, WalkMinder seeks to create behavioral change by interrupting users after long periods of no movement, and encourages them to take a walk [14]. As part of a comparative usability study, Ahtinen et al. mention Wellness Diary and Mobile Coach, which are two applications aimed at tracking exercise routines [3].

Not only are there applications about general health and well being, there are also applications that relate to specific conditions.

For example, Kanstrup et al. discuss a design for an mHealth application that aids in diabetes management [15]. This is related to personal informatics because it enables users to track their personal information for their needs. It also has the goal of adherence and improvement of a routine for treating diabetes.

Xue et al. discuss the design of a mobile health application for women in Singapore [35]. The specifically focused on women's health needs, and it was an application geared toward awareness, rather than behavioral change.

2.3.2 mHealth

It is important to note that not all mHealth systems fall within the same purposes listed above (self-diagnosis, etc.). Some mHealth systems are designed to act on a community level. These systems would fall under the right side of the Venn diagram in Figure 1. For example, Littman-Quinn et al. discuss the adoption of an mHealth system deployed in Botswana [22]. The system's aim was to provide medical assistance to those with HIV/AIDS in the area. Similarly, Purkayastha et al. discuss the deployment of a system in Malawi [28]. They provide insights on how to do mHealth deployments in the future. One of their insights is to be respectful of the local needs of the community.

In addition to the community level deployment, some mHealth applications do not follow a user-centric paradigm when designing or deploying solutions. Rather, they follow a doctor/patient paradigm, where the focus of the application is for communicating data to and from a healthcare professional. One such application was geared toward rehabilitation through exercise, and where doctors would provide electronic feedback about the patient's exercises [5]. The doctor/patient paradigm is also apparent in eEmergency systems, where the goal is to provide immediate healthcare [17].

Researchers in mHealth and personal informatics have covered a lot of ground in recent years. One major difference between our work and previous work is our methodology. Many of the mHealth and personal informatics systems have a solution to a supposed problem, they create the solution, then test it with users (usually through a field/clinical trial) [3,4,5,6,11,12,14]. We decided to take a step back. Instead of asking participants to work with us to create a specific app (for example, an exercise tracking app), we asked older adults what they wanted. We asked them to work as a group to sketch an application to track health topics. They were free to choose *which* health topics. In this way, we were assessing the needs of our local community, as recommended by Purkayastha et al. [28] prior to developing a system. Another difference between most of the cited systems and our work is that many of them do not focus on the needs of older adults. Our work is specifically geared to older adults (in this case, aged 65 and older).

3. METHODOLOGY

3.1 Participants

We recruited people with no prior programming or software development experience to get an "end user" perspective of health applications as most smartphone owners are end users. We did not want experience with software development to potentially hinder or interfere with the creativity of the product ideation process, as software developers might be more familiar with the limitations of the system, and thus "locked in" to a set of biases and preconceptions.

Table 1. Participant Demographics

Gender	Age	Occupation Pre-Retirement	Education
Group 5			
M	65	Police Officer	Associate's
M	67	Electrical Contractor	Some college
F	71	Small Business Owner	Bachelor's
F	68	Executive Director of Credit Counseling	Master's
Group 4			
F	85	Accountant	Some college
M	66	Chemist	Master's
F	82	Homemaker	Master's
Group 3			
F	65	Human Metrology Researcher	High School
F	72	Counselor	Some college
M	72	Detective	Bachelor's
F	72	Homemaker	Some college
Group 2			
M	71	Office Manager	Bachelor's
F	73	Director of County Health	Master's
M	71	Professor	PhD
Group 1			
F	67	University Staff	Some college
F	65	Accountant	Bachelor's
F	83	Advertising Coordinator	Some college
M	88	Petroleum Engineer	Master's

Eighteen participants were aged 65 years and older (median age 71), 12 of them were women. They were volunteer participants with a wide range of professional backgrounds (see Table 1).

We administered a self-reported health scale adapted from Winter et al. [34]. The participants were healthy overall. They provided self-rated health scores (0=terrible, poor, fair, good, 4= excellent), and had an average of 3.5, which would fall between good and excellent. Our results were similar to Winter et al., with no participants choosing the lowest measure of health.

Seventeen participants owned a cell phone, 4 of those smartphones. Three of the smartphone owners had applications on their phone related to healthcare. Seven participants tracked health metrics (either on paper, computer, or phone). Even though our sample size is small, the fact that 75% of smartphone owners used their phone for health-related apps indicates that older adults should be involved in the design process.

We recruited participants from the LIFE Registry [38], a registry of Oregon residents aged 50 and older who given their permission to be contacted about research studies. We also recruited participants by hanging flyers in senior centers and assisted living centers, and through participant word-of-mouth.

They were paid $20-$50 (depending on travelling distance) for their participation. The entire study session lasted approximately 2.5 hours. It was conducted on the university campus. We did 5 group sessions of 3-4 participants each.

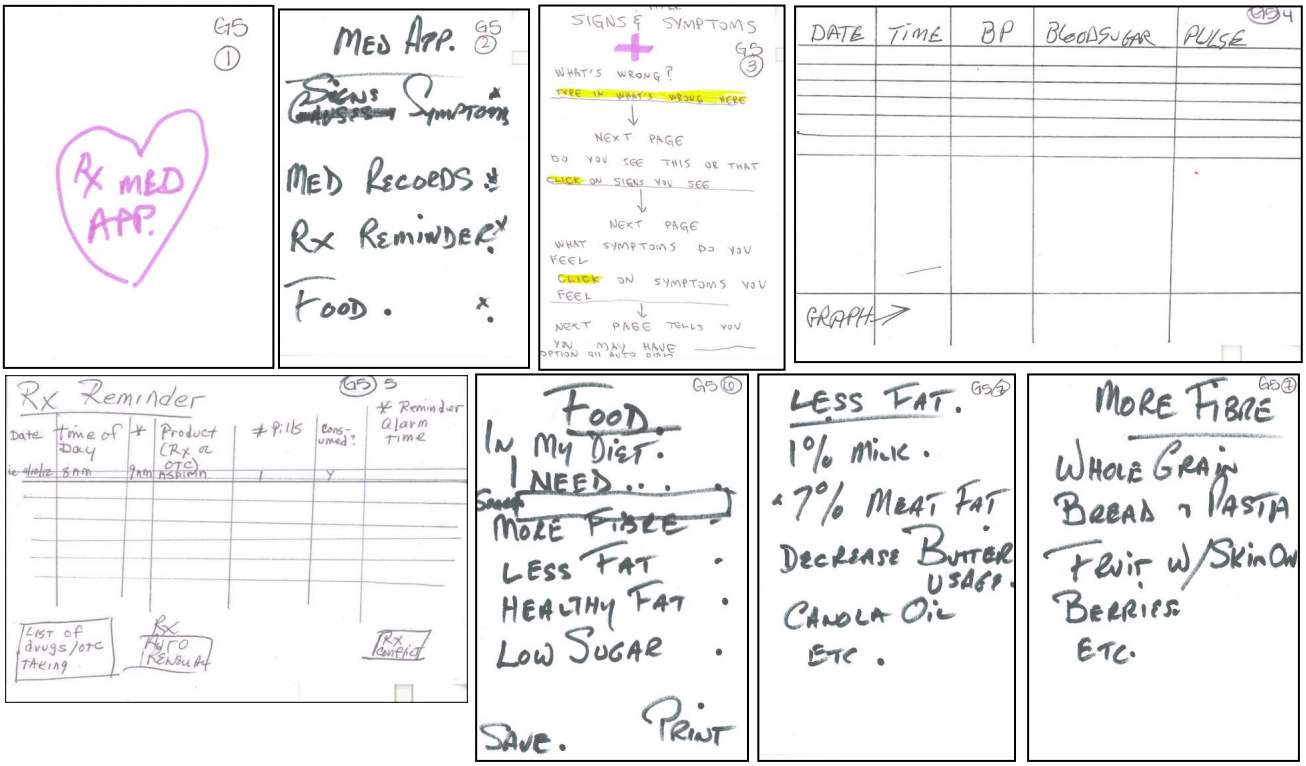

Figure 2. Example Design called RxMedApp. It allows you to track symptoms, track health metrics, track prescriptions, and provides suggestions on health eating.

3.2 Interviews

After brief introductions with the group, we individually interviewed each participant. Our goal was to learn about their backgrounds and experience with technology, specifically related to smartphones and health. We asked about 13 questions, and each semi-structured interview took 10-20 minutes.

3.3 Participatory Designs

After the interviews, we conducted participatory design sessions. Three of the groups critiqued existing health-related iPhone applications before sketching an idea for application. The other two groups sketched an idea for an application then critiqued existing applications. Each group sketched 1 design, as a group. The critique session lasted for 10-20 minutes, and the sketching session lasted for 30 minutes. During the sketching session, the researcher took a "hands-off" approach, and allowed the groups to work as independently as possible. The instructions prior to the sketching session emphasized creativity and creating an idea for an application that they (the participants) would actually *want* to use.

3.4 Questionnaires

3.4.1 Online activities questionnaire

Prior to the design session, we administered an Online Activities Questionnaire. We were aiming to learn how older adults use the Internet. The survey contained 24 items (such as "look for health/medical information online"), and each item was followed with "yes", "no", "maybe", and a space for written comments.

3.4.2 Health topics questionnaire

After the design session, we administered a questionnaire to see what kinds of health topics older adults would want to track using a smartphone application. We iterated on the topics to be included with a group of graduate HCI researchers and gerontology researchers. There were 14 items (i.e. "cholesterol"). Each item was followed by "yes", "no", and a space for comments.

4. RESULTS

4.1 SAMPLE DESIGN

To help readers understand the context of the results, we provide a sample design (see Figure 2). This design was found to be the most creative (from a panel of 7 domain experts using a modified Creativity Product Semantic Scale [23]), and was created by a group where participants had no prior smartphone experience, and who did not critique existing applications before their design session [7]. To see the backgrounds of the participants, see Table 1 - Group 5. The design is entitled "RxMedApp". First, it allows the user to determine ailments by walking through a "signs and symptoms" checklist. It also allows users to record and graph health records. There is functionality to allow users to record prescription information. It includes a method for auto-renew of a prospection, and a method to automatically determine if there was a conflict in prescriptions. Finally, it provides suggestions for users on how to change their diets based on their needs. For example, the user could choose "less fat" from a pull-down menu, and it would give the user suggestions on how to ingest less fat. The design team included a way for the user to print these suggestions.

As with each of the 5 designs from the participatory design study, we extracted health topics that were represented in the design. This design touched on the following health concepts:

- Blood pressure
- Blood sugar
- Prescription auto-renew
- Prescription conflict reminder

- Prescription reminder
- Pulse
- Suggestions for eating healthier based on what the user wants to change in their diet
- Symptom tracking

Many of the other designs were less complicated than this example. It was one of three designs that included a way to graphically represent health information. Next, we report responses from an online activities questionnaire, to show that our participants use the Internet to find health information online.

To answer RQ1, *"What health topics do older adults want to track?"*, we present responses from the online activity questionnaires, a list of health topics that were in the designs, and results from a questionnaire about what health topics they would want to track using a smartphone.

4.2 Online activity questionnaires

Prior to the design sessions, we asked older adults to respond to questionnaires about what activities they participated in online. The questionnaire included the same metrics as a Pew Internet Research Survey about older adults and internet use habits [10]. Only 1 of 18 participants did not use the Internet at all. Table 2 shows that many older adults use the Internet to find health information. There were 2 metrics related to finding health metrics online (see grey shaded areas in Table 2), and the vast majority of participants reported that they looked for health information online (83.33%). Our result was similar to the 2012 Pew Internet Research survey that found that 71% of older adults look for health information online [9]. The slightly higher percentage may be because our participants self-selected to be in this research study related to health software. Regardless, these results indicate that the idea of using and promoting these types of applications may be natural and desirable for this population.

4.3 What health topics were in designs?

Table 3 shows 22 health topics that were targeted in the designs generated by our focus groups. Additionally, we counted how many health topics appeared in multiple designs. Out of the 22 health topics in the designs, only 4 appeared in more than 1 design, and no health topic appeared in more than 2 designs. This shows that our participants provided a diverse range of ideas. Some of the health topics were very specific, and related to a participants' personal needs. This aligns well with a Pew Internet Research Survey that found that 43% of health topics searched for online by older adults were regarding a specific disease or medical problem [9]. Other designs were much more generic and focused on broader wellness issues. Also, the designs showed health topics that were different than the health topics in the questionnaire. The participants thought of 13 health topics that appeared in their designs but were not listed in the questionnaire.

4.4 What health topics would they like to track according to the questionnaires?

While Table 3 shows an analysis of designs compared with the app store, Table 4 shows the health topics that our participants would like to track with a smartphone application. These were results from a 14-item questionnaire. One participant of 18 did not want to track *anything* regarding health topics. This was the same participant who did not use the Internet. The most popular health topic was "health appointments" with a total of 15 participants. Surprisingly, health appointments were not in any of the designs. This suggests that we should not only include older adults in participatory design, but we should also administer questionnaires and interviews, to get a broader understanding of their needs and desires in relation to technology design.

Table 2. Online Activity Questionnaire.

Online Activity	Rank	Yes %	Yes Count/ Total
send or read e-mail	1	94.44	17/18
use a search engine to find information	1	94.44	17/18
look for information on a hobby or interest	1	94.44	17/18
look for information from a government website	1	94.44	17/18
buy a product	1	94.44	17/18
research a product or service before buying it	2	90.00	9/10
go to web sites that provide information or support for a specific medical condition or personal situation	3	88.89	16/18
get news	3	88.89	16/18
look for political news or information	3	88.89	16/18
look for health or medical information	4	83.33	15/18
buy or make a reservation for travel	4	83.33	15/18
get financial information	5	77.78	14/18
check the weather	5	77.78	14/18
download other files such as games, videos, or pictures	6	72.22	13/18
bank online	6	72.22	13/18
surf the web for fun	7	64.71	11/17
check sports scores or information	8	55.56	10/18
play a game	9	38.89	7/18
research your family's history or geneology	9	38.89	7/18
make a phone call online	10	33.33	6/18
send instant messages	11	27.78	5/18
buy or sell stocks, bonds, or mutual funds	12	23.53	4/17
participate in an online auction	13	22.22	4/18
look for religious or spiritual information	14	16.67	3/18

4.5 Market Analysis

To answer RQ2, *"Are current mHealth tools tailored to meet the needs of our older adult participants?",* we examined the current offerings in the iTunes App store and the Android App store and compared what we found to the list of health topics identified by our participants. We chose to examine those two app stores because according to the International Data Corporation, iPhones and Android phones represented 87.6% of the smartphone market in 2012 [37]. We did a keyword search for each topic, and manually searched through titles and descriptions of the resulting applications.

Table 3. A comparison of health topics to the iPhone store and the Android app store. There were 5 health topics in the designs that were not in either of the app stores.

Health Topics in Designs	iPhone App?	Android App?
rest tracking	✖	✖
social interaction tracking	✖	✖
suggestions for eating healthier based on what you want to change in your diet	✖	✖
suggestions for local stress relief activities	✖	✖
hematocrit	✖	✖
urine protein	✔	✖
urine sugar	✔	✖
urine wbc	✔	✖
balance assessment	✔	✔
blood pressure	✔	✔
blood sugar	✔	✔
cholesterol	✔	✔
diet tracking	✔	✔
exercise tracking	✔	✔
prescription auto-renew	✔	✔
prescription conflict determiner	✔	✔
prescription reminder	✔	✔
proper posture	✔	✔
pulse	✔	✔
symptom tracking (diagnosis / 911)	✔	✔
weight	✔	✔

We found that most of the health topics were covered by apps in either store. However, there are still gaps between what the market offers and what older adults want to track. We found 5 topics that were not present in either app store (see Table 3). One of these was very trivial (recoding hematocrit), so we will leave it out of this discussion.

4.5.1 Restful Tracking

One health topic that researchers and designers could focus on moving forward is expanding what is offered in terms of tracking rest. There are many apps that allow you to track sleep patterns, but to our knowledge, no apps allow you track a variety of restful activities. One group was interested in tracking sleep and other restful activities like meditation, yoga, or gardening.

4.5.2 Social Interaction Tracking

Another aspect of a design that was not represented in the app stores, was social interaction tracking. Positive social interactions are vital for older adults, as it is correlated with a positive well-being [8]. This topic appeared in one design, where they wanted a way to log their social activities. This would be beneficial to older adults, to learn about their social tendencies. Tuan et al. created a way for older adults to track social goals and moods using an online form [27]. They also included an interactive visualization to allow users to explore their data. However, this application was for research purposes and was not designed for use on a smartphone. We would recommend using the health topic of social interaction tracking (perhaps without goals as a constraint) to complement the existing research in the field, and create an application that could be available in app stores.

Table 4. Responses from "What health topics would you track using a smartphone?" questionnaire.

Questionnaire Health Topic	Yes Count (n=18)	Yes %	In their designs?
health appointments	15	93.75	✖
cholesterol	11	78.57	✔
weight	12	66.67	✔
heart rate	11	61.11	✔
blood pressure	10	55.56	✔
pedometer	10	55.56	✖
exercise diary	9	50.00	✔
injury log	8	50.00	✖
food diary	7	38.89	✔
pill reminder	6	33.33	✔
mood diary	5	31.25	✖
social interactions	5	31.25	✔
calorie counter	5	27.78	✖
stressful events diary	4	25.00	✖

4.5.3 Local Stress Relief Activities

Another idea for an application was to have a database of suggestions for activities to do in your local community that could relieve stress. Some of these activities included "gardening", "volunteering for a pet walking service", and "social drinking". Currently, there are no apps on the market of this nature. Many apps related to stress relief focus on meditation techniques[3].

4.5.4 Healthy Eating Suggestions

As part of one of the designs (discussed in Section 4.1), the participants wanted a way to receive advice on how to change their diet based on their desires. There are applications that exist that focus on "low carb" eating[4] or "the Mediterranean diet"[5], but no apps allow you to choose your *outcome* out of a *list* of outcomes (i.e. "less fat", "more fiber", etc.), and give you tips on how to achieve that outcome. From these results, there are many

[3] https://play.google.com/store/apps/details?id=com.bestappsforphone.relaxmeditationtechniques3, https://play.google.com/store/apps/details?id=net.feathertech.meditationtechniques, https://play.google.com/store/apps/details?id=com.meditationoasis.rest

[4] https://play.google.com/store/apps/details?id=com.atkins.android.carbcounter

[5] https://play.google.com/store/apps/details?id=com.andromo.dev117641.app119156

directions that application designers could take to develop apps that better suit older adults' desires.

Interestingly, the first 3 health topics (restful activity tracking, social interaction tracking, and local stress relief activities) show that our participants had a definition of health that went beyond *clinical health*, and included aspects of the mind, body, *and* soul. It was surprising to the panelists who were grading the designs for creativity, that there was such a breadth of topics covered in the designs, with everything from very specific health metrics (such as hematocrit and blood pressure) to very broad health-related topics (such as suggestions for local stress relief activities). These topics showed that our participants had an interest in some hard-to-measure health topics, which are more subjective than blood pressure, for example. This provides an opportunity for researchers to collaborate from different disciplines (gerontology, sociology, psychology, and computer science) to help tackle the difficult issue of tracking subjective measures in a meaningful, relevant way.

5. DISCUSSION

As with any empirical work, there are some limitations to our study. First and foremost, because we were interested in qualitatively analyzing the data and gathering rich data from design sessions, we had a small sample size. This may contribute to lowering our external validity, and our results may not generalize to a different population.

That said, the take-home message of involving older adults in the design process, and using results from studies like these to shape future technology design and creation still holds. We strongly encourage future researchers to not only include older adults in actively designing applications, but also be sure to administer questionnaires and interviews. Simply put – the more data, the better. Each method has its strengths, and as we found in our study, these methods complement each other. We should keep in mind that this is a dynamic process. The next generation of older adults will be different and have different needs than the current generation of older adults, so we should continually conduct studies of this nature.

By conducting this participatory design study, we were able to identify gaps in the current market, and we also learned health topics that older adults find important. We propose that this method be applied to future research in the development of mHealth systems, to accurately assess the needs of the community of interest. This methodology will allow us to uphold the "virtuous cycle" of technology development, where we purposefully include older adults. Researchers can take this idea of a "virtuous cycle" further by conducting more longitudinal studies on mHealth system development that includes older adults from the beginning stages of design to deployment and use.

6. CONCLUSION

People are living longer, and baby boomers are reaching retirement. Because of the increase in technology adoption by older adults and because they look for health information online, it is important to include them in the technology design process. Our novel contribution was to provide researchers and designers with directions for mobile health-related applications. To answer our first research question, *"What health metrics do older adults want to track?",* we suggest looking into these four areas: Social Interaction Tracking, Rest Tracking, Suggestions for Local Stress Relief Activities, and Suggestions for eating healthier based on what you want in your diet.

These health topics were identified during participatory design sessions with older adults, and as of the writing of this paper, there are no apps in either the Android app or iPhone app store that cover these areas. This helps to answer our second research question, which was *"Are current mHealth tools tailored to meet the needs of our older adult participants?"* While the majority of the health topics that were found in participants' designs were in either app store, there were 5 topics that were not present.

We suggest continuing to involve older adults throughout the technology design process. As a next step, we plan to involve older adults directly in the development of free/open source software, as another way to continue the "virtuous cycle" mentioned earlier. By involving older adults in our rapidly changing technology process and keeping their needs and desires at the forefront of technology innovation, we may enable older adults to age-in-place more successfully, and may help to delay the onset of cognitive decline.

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REFERENCES

1. Abeele, V.A. and Rompaey, V. Introducing human-centered research to game design: designing game concepts for and with senior citizens. *Extended abstracts on Human factors in computing systems*, ACM (2006), 1469–1474.
2. Ahmad, D., Komninos, A., and Baillie, L. Future mobile health systems: designing personal mobile applications to assist self diagnosis. *Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction - Volume 2*, British Computer Society (2008), 39–42.
3. Ahtinen, A., Mattila, E., Vaatanen, A., et al. User experiences of mobile wellness applications in health promotion: User study of Wellness Diary, Mobile Coach and SelfRelax. *3rd International Conference on Pervasive Computing Technologies for Healthcare, 2009. PervasiveHealth 2009*, (2009), 1–8.
4. Bauer, J., Consolvo, S., Greenstein, B., et al. ShutEye: encouraging awareness of healthy sleep recommendations with a mobile, peripheral display. *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems*, ACM (2012), 1401–1410.
5. Caulfield, B., Blood, J., Smyth, B., and Kelly, D. Rehabilitation exercise feedback on Android platform. *Proceedings of the 2nd Conference on Wireless Health*, ACM (2011), 18:1–18:2.
6. Consolvo, S., McDonald, D.W., Toscos, T., et al. Activity sensing in the wild: a field trial of ubifit garden. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM (2008), 1797–1806.
7. Davidson, J. and Jensen, C. Participatory Design with Older Adults: An Analysis of Creativity of the Design of Mobile Healthcare Applications. *9th ACM Conference on Creativity and Cognition*, ACM (2013).
8. Finch, J.F., Okun, M.A., Barrera Jr., M., Zautra, A.J., and Reich, J.W. Positive and negative social ties among older adults: Measurement models and the prediction of psychological distress and well-being. *American Journal of Community Psychology 17*, 5 (1989), 585–605.

9. Fox, S. and Duggan, M. *Health Online 2013*. Pew Research Center's Internet & American Life Project, Washington, DC, USA, 2013.
10. Fox, S. *Pew Internet & American Life Project: Older Americans and the Internet*. Pew, 2004.
11. Freyne, J., Brindal, E., Hendrie, G., Berkovsky, S., and Coombe, M. Mobile applications to support dietary change: highlighting the importance of evaluation context. *CHI '12 Extended Abstracts on Human Factors in Computing Systems*, ACM (2012), 1781–1786.
12. Gartenberg, D., Thornton, R., Masood, M., Pfannenstiel, D., Taylor, D., and Parasuraman, R. Collecting health-related data on the smart phone: mental models, cost of collection, and perceived benefit of feedback. *Personal Ubiquitous Comput. 17*, 3 (2013), 561–570.
13. He, W., Sengupta, M., Velkoff, V., and DeBarros, K. *65+ in the United States: 2005*. U.S. Census Bureau, United States, 2005.
14. Hirano, S.H., Farrell, R.G., Danis, C.M., and Kellogg, W.A. WalkMinder: encouraging an active lifestyle using mobile phone interruptions. *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, ACM (2013), 1431–1436.
15. Kanstrup, A.M., Bertelsen, P., Glasemann, M., and Boye, N. Design for more: an ambient perspective on diabetes. *Proceedings of the Tenth Anniversary Conference on Participatory Design 2008*, Indiana University (2008), 118–127.
16. Kwan, A. *Using Mobile Health Technologies for Healthier Aging*. Pfizer, mHealth Alliance, United Nations Foundation, 2012.
17. Kyriacou, E.C., Pattichis, C.S., and Pattichis, M.S. An overview of recent health care support systems for eEmergency and mHealth applications. *Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2009. EMBC 2009*, (2009), 1246–1249.
18. Lake, M. *HIT Trends*. Circle Square Inc., 2013.
19. Li, I., Dey, A., and Forlizzi, J. A stage-based model of personal informatics systems. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM (2010), 557–566.
20. Li, I., Dey, A.K., and Forlizzi, J. Understanding my data, myself: supporting self-reflection with ubicomp technologies. *Proceedings of the 13th international conference on Ubiquitous computing*, ACM (2011), 405–414.
21. Lindsay, S., Jackson, D., Schofield, G., and Olivier, P. Engaging older people using participatory design. *Proceedings of the 2012 ACM annual conferenceo n Human Factors in Computing Systems*, ACM (2012), 1199–1208.
22. Littman-Quinn, R., Chandra, A., Schwartz, A., et al. mHealth applications for telemedicine and public health intervention in Botswana. *IST-Africa Conference Proceedings, 2011*, (2011), 1–11.
23. Lobert, B.M. and Dologite, D.G. Measuring creativity of information system ideas: an exploratory investigation. *Proceedings of the Twenty-Seventh Hawaii International Conference on System Sciences, 1994*, (1994), 392 –402.
24. Lorenz, A., Mielke, D., Opperman, R., and Zahl, L. Personalized mobile health monitoring for elderly. *Proceedings of the 9th international conference on Human computer interaction with mobile devices and services*, ACM (2007), 297–304.
25. Madden, M. *Pew Internet & American Life Project: "Older Adults and Social Media"*. Pew, 2010.
26. Massimi, M., Baecker, R.M., and Wu, M. Using participatory activities with seniors to critique, build, and evaluate mobile phones. *Proceedings of the 9th international ACM SIGACCESS conference on Computers and accessibility*, ACM (2007), 155–162.
27. Pham, T., Mejia, S., Metoyer, R., and Hooker, K. The effects of visualization feedback on promoting health goal progress in older adults. *Eurovis - Short Papers*, M. Meyer, T. Weinkauf (Eds.) (2012), 91–95.
28. Purkayastha, S., Manda, T.D., and Sanner, T.A. A Post-development Perspective on mHealth – An Implementation Initiative in Malawi. *2013 46th Hawaii International Conference on System Sciences (HICSS)*, (2013), 4217–4225.
29. Silva, B.M., Lopes, I.M., Rodrigues, J.J.P.C., and Ray, P. SapoFitness: A mobile health application for dietary evaluation. *2011 13th IEEE International Conference on e-Health Networking Applications and Services (Healthcom)*, (2011), 375–380.
30. Smith, A. *46% of American adults are smartphone owners*. Pew Research Center's Internet & American Life Project, Washington, DC, USA, 2012.
31. Tun, P.A. and Lachman, M.E. The Association Between Computer Use and Cognition Across Adulthood: Use It So You Won't Lose It? *Psychology and Aging 25*, 3 (2010), 560–568.
32. Uzor, S., Baillie, L., and Skelton, D. Senior designers: empowering seniors to design enjoyable falls rehabilitation tools. *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems*, ACM (2012), 1179–1188.
33. Vines, J., Blythe, M., Dunphy, P., et al. Cheque mates: participatory design of digital payments with eighty somethings. *Proceedings of the 2012 ACM annual conferenceo n Human Factors in Computing Systems*, ACM (2012), 1189–1198.
34. Winter, L., Lawton, M.P., Langston, C.A., Ruckdeschel, K., and Sando, R. Symptoms, Affects, and Self-Rated Health Evidence for a Subjective Trajectory of Health. *Journal of Aging and Health 19*, 3 (2007), 453–469.
35. Xue, L., Yen, C.C., Chang, L., et al. Mobile phone-based health application for women: a Singapore study. *Proceedings of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies*, ACM (2011), 73:1–73:5.
36. *Ageing in the Twenty-First Century: A Celebration and A Challenge*. UNFPA and HelpAge International, New York and London, 2012.
37. *IDC - Press Release*. International Data Corporation, Framingham, MA, 2013.
38. LIFE Registry. http://health.oregonstate.edu/healthy-aging/life-registry.