Acceptance of Mobile Technology by Older Adults: A Preliminary Study

Sunyoung Kim[1]   **Krzysztof Z. Gajos**[1]   **Michael Muller**[2]   **Barbara J. Grosz**[1]

[1]Harvard University
Cambridge, MA USA
{sunyoungkim,kgajos,grosz}@seas.harvard.edu

[2]IBM Research
Cambridge, MA USA
michael_muller@us.ibm.com

ABSTRACT

Mobile technologies offer the potential for enhanced healthcare, especially by supporting self-management of chronic care. For these technologies to impact chronic care, they need to work for older adults, because the majority of people with chronic conditions are older. A major challenge remains: integrating the appropriate use of such technologies into the lives of older adults. We investigated how older adults would accept mobile technologies by interviewing two groups of older adults (technology adopters and non-adopters who aged 60+) about their experiences and perspectives to mobile technologies. Our preliminary results indicate that there is an additional phase, the *intention to learn*, and three relating factors, *self-efficacy, conversion readiness*, and *peer support*, that significantly influence the acceptance of mobile technologies among the participants, but are not represented in the existing models. With these findings, we propose a tentative theoretical model that extends the existing theories to explain the ways in which our participants came to accept mobile technologies. Future work should investigate the validity of the proposed model by testing our findings against younger people.

Author Keywords

Older adults; mobile technology adoption; healthcare technology; digital health; Aging

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION

With the rapid advancement of information and communication technologies, it has become easier for people to track and monitor health-related measurements using mobile devices. Today, there are a plethora of wearable devices and mobile applications that make it possible to immediately count the calories we have burnt, track the distance we have run, walked or cycled, and monitor the changes in physiological parameters. Such mobile technologies enhance our ability to collect, review, and share data on health concerns and physical conditions with healthcare providers and offer the potential for enhancing self-management of chronic conditions [6]. For these technologies to have impact on the current chronic care management practice, they need to work well for older adults, because the majority of people who suffer from chronic conditions are older.

Nowadays, older adults are increasingly adopting and adapting to information and communication technologies [5]. For example, smartphone ownership among older adults has significantly risen in recent years [3]. However, its adoption levels among older adults in the US still sit at 27% as of 2015, whereas some 85% of Americans aged 18-29 are smartphone owners [31]. This is a striking gap, which we investigate in this paper, beginning with an inquiry among the older adults; subsequent work may extend our analysis to younger comparison group.

Today's generations of older adults have not grown up with information and communications technologies that are widely available these days. Thus, there is "a natural confound of age and experience, since today's older adults are exposed to these technologies at a different point in their lives than today's young adults." [17] And, this problem will probably not go away easily, as new technologies and their interfaces and interaction styles continue to be evolving. Thus, to make new technologies usable and useful for older adults, we need first to fully examine the complex patterns involved in technology acceptance and use among this population.

Technology acceptance has been widely studied, and several models have been proposed and tested [10, 37]. However, the HCI literature lacks a comprehensive explanation of technology acceptance among older adults. As a preliminary step towards understanding this, we investigate how older adults would accept (or reject) mobile technologies—using smartphones and activity-tracking devices as a use case—by seeking answers to the following questions:

- What factors influence older adults' acceptance of mobile technologies, whether positively or negatively?

- Through what process do older adults accept (or reject) mobile technologies?

We conducted semi-structured interviews with 16 older adults (aged 60 or older) who used activity-tracking devices and mobile applications to manage health concerns. Employing the grounded theory method [33], we allowed recurring themes and concepts in relation to technology acceptance behaviors to arise from the data itself. Then, by triangulating our empirical findings with existing theoretical models from the literature, we found out that the existing models of technology adoption require new theory components to be able to describe technology adoption processes of our participants. In particular, we identified an additional phase that is prominent among the participants, *intention to learn*, but did not appear in prior models. Then, we identified three new factors that significantly influence their technology acceptance but which are, again, not represented in the existing models: self-efficacy, conversion readiness, and peer support. In light of our preliminary results, we propose a tentative theoretical model that extends the existing theories to explain the ways in which the participants come to accept (or reject) mobile technologies. To obtain a first comparison dataset, we conducted a second set of interviews with 8 older adults who had not adopted any mobile devices for healthcare to validate and refine our model.

In the next section, we explain existing theories of technology acceptance. Then, we review prior works on empirical studies of technology use among older adults. Next, we describe the details of our data collection and analysis methods. We present a series of key findings from our qualitative studies and comparative analyses. We conclude with discussing a proposed theoretical model, its limitations, and future work.

EXISTING THEORIES OF TECHNOLOGY ACCEPTANCE

This section reviews several well-established theoretical models related to technology acceptance. Most of these models were originally developed to study technologies in organizations. However, their application area has evolved beyond organizational settings to study a wide range of technology-related behaviors. From this literature study, we produce a comprehensive set of factors that existing models determined as important influencers on technology acceptance.

Technology Acceptance Model

Azjen's theory of planned behavior [1, 2] posits that a specific behavior is the result of an intention to carry it out, and that intention is determined by attitudes, norms, and the perception of control over the behavior. Drawing upon this theory of planned behavior, Davis et al. developed the technology acceptance model (TAM) [10]. TAM comprises two primary constructs [10, p. 320]:

- Perceived usefulness: "the degree to which a person believes that using a particular system would enhance his or her job performance".

- Perceived ease of use: "the degree to which a person believes that using a particular system would result in reduced effort" (See Figure 1).
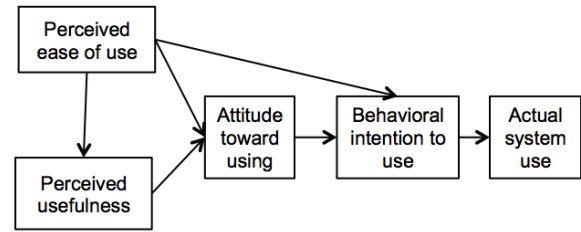
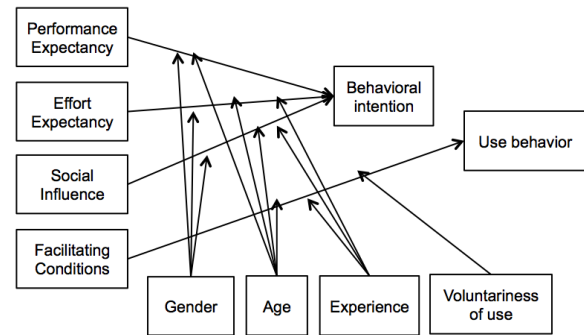

Figure 1. Technology acceptance model

Figure 2. Unified theory of acceptance and use of technology

TAM has been applied to predict the acceptance of many different kinds of technology, including personal digital assistants (PDA) [39], computer interfaces [23], mobile phones [9], the Internet [26], and e-Government Services [27]. While details vary, the authors showed evidence that was consistent with the model, providing convergent evidence that perceived usefulness and perceived ease of use are significant factors in predicting technology acceptance. These studies also identified various personal traits, such as prior experience, personality, and attitudes towards technology, as additional determinants.

Unified Theory of Acceptance and Use of Technology

Extending the original TAM and consolidating the constructs of several other existing models, Venkatesh et al. proposed the Unified Theory of Acceptance and Use of Technology (UTAUT) [37]. UTAUT predicts an individual's behavioral intention to use a system as well as their usage behavior using four key constructs [37, pp. 447–453]:

- Performance expectancy: "the degree to which an individual believes that using the system will help him or her to attain gains in job performance";

- Effort expectancy: "the degree of ease associated with the use of the system;

- Social influence: "the degree to which an individual perceives that important others believe he or she should use the new system";

- Facilitating conditions: "the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (See Figure 2).

In UTAUT, Venkatesh extended TAM by incorporating two constructs not directly related to a system's perceived properties, but derived from external aspects: social influence and facilitating conditions. Additionally, UTAUT posits four mediating factors that moderate the impact of each key construct on usage intention and behavior, namely gender, age, experience, and voluntariness of use. The extent to which each key construct influences the user's intention is determined by these four mediating factors. Several studies have attempted to determine older adults' acceptance of technologies in general, and healthcare-related systems in particular, using the UTAUT framework. (e.g., email [14], a telehealth service [7]).

Seniors' technology acceptance and adoption model

Seniors have historically been late adopters to the world of technology compared to their younger counterparts [24, 40]. As a result, older adults and their adoption of new technologies have been a topic of active research since the advent of consumer technologies (e.g., automated teller machine [32], scanner-equipped grocery stores [41], electronic funds transfer [15]). While numerous studies have adapted prior theoretical models to investigate the relationship between older people and the use of new technology, relatively little effort has so far been made to build a model to predict these behaviors of older populations.

One exception is the senior technology acceptance model (STAM) [28]. Using TAM, UTAUT, and several other works as theoretical underpinning, Renaud and Biljon proposed a model to explain older adults' mobile phone adoption. This model consists of three procedural phases that an older adult goes through to make a decision to accept or reject a new technology: objectification, incorporation and conversion. In the objectification phase, a user forms an intention to use the system based on user context, including social influences and perceived usefulness (similar to TAM and UTAUT). In the incorporation phase, a user explores and experiments with the system, through which users validate their perceptions of the usefulness and the ease of use of the system.

The introduction of the incorporation phase makes a crucial difference between STAM and prior models. In this phase, which links "intention to use" and "actual use", a user acquires a hands-on experience of a technology. This phase takes experimentation and exploration into account as dynamic factors for seniors' acceptance of technology.

In summary

Although many researchers have sought to understand and predict technology acceptance behavior, there has been relatively less effort to build a theoretical model for older adults, with one exception (STAM). From the study of three existing models of technology acceptance (TAM, UTAUT, and STAM), we determined the components that influence technology acceptance of people in general. They are listed in Table 1. These components will be compared with our empirical findings to develop a theoretically and empirically grounded model of technology acceptance for older adults.

PRIOR EMPIRICAL WORK

	Item	TAM	UTAUT	STAM
Phase	Intention to use	Yes	Yes	Yes
	System experimentation	No	No	Yes
	Actual use	Yes	Yes	Yes
Factor	Perceived ease of use	Yes	Yes	Yes
	Perceived usefulness	Yes	Yes	Yes
	Social influence	No	Yes	Yes
	Facilitating conditions	No	Yes	Yes
	User context	No	Yes	Yes

Table 1. Three phases and five factors were identified from the existing three models as the components that influence technology acceptance behavior: TAM[10], UTAUT[37], and STAM[28].

Many studies have empirically investigated technology acceptance practices among older adults. While diverse in detail, most works point out that an individual's personal context [38] and the social context [36] in which the technology is introduced are the primary factors influencing the perception of, experience with, and evaluation of new technological developments among older adults [19]. More holistically, Lee and Coughlin reviewed studies of older adults' technology acceptance and identified ten factors that are critical facilitators or determinants of older adults' acceptance of technology: value, usability, affordability, accessibility, technical support, social support, emotion, independence, experience, and confidence [20].

Another stream of efforts sought to understand physical and cognitive performance of older adults in interacting with mobile technologies. Studies have shown that typical interaction components and techniques of a smartphone often prevent older adults from smooth and instant interactions with it. For example, the small size and the low contrast of buttons on a mobile display has a significant negative influence on interaction performance such as speed and accuracy [18], and decline in motor skills is correlated with time required to complete a task [30]. Based on these findings, studies and commercialized products have proposed tailored interfaces and interaction techniques for older adults. For example, studies suggested a simplified graphical or voice interface for an email interface for senior users [11, 4], and an adaptive touchscreen interface to assist older adults' physical functionalities [18]. Further, several companies have released mobile phones to serve the unique needs of senior citizens (e.g., Jitterbug, Emporia). Incorporating these human factors and practical design suggestions for older adults, Fisk et al. proposed key recommendations for designing mobile devices for this age group [12].

While these empirically-grounded works are critical, our key focus is to build a theoretical model that explains the process through which older adults accept (or reject) mobile technology, which can provide theoretical guidelines when designing a technology, and which may also be able to generate new investigations and experiments.. In what follows, we explain our study methods and findings that result in a theoretical model of mobile technology adoption among older adults.

METHODS

We developed our model of technology acceptance by older adults based on 16 interviews with older people who used mobile technologies for healthcare. We then compared the model that emerged from our data to existing theoretical models, to determine differences and similarities. We subsequently validated our model through a second set of 8 interviews with older people who had never used mobile technologies for healthcare.

Interview I. Adopters: Older adults who use mobile technologies for healthcare

The purpose of the first set of interviews was to uncover the factors that influence older adults' acceptance of mobile devices, either positively or negatively. In particular, we sought to uncover the barriers that older adults encounter when trying to adopt mobile devices and the facilitating factors that help them to overcome such barriers. For this purpose, we recruited participants who were 60 years old or older and used mobile devices to manage some health concerns.

Participants In the recruitment flyer, we described that we are looking for people who are 60 years old or over and using some kind of mobile device or mobile app to track their health or help them stay in shape. We distributed the flyer to six senior centers and community centers that coordinate activities and recreational programs for senior citizens in a Northeastern city in the U.S. We also recruited participants through word-of-mouth and a local Craigslist. In total, we recruited sixteen participants (Mean age = 69, SD = 4.3, see Table 2).

ID	Gender	Age	Tracking device in use	Health concern
A_F1	Female	73	Sun Sprite	Depression
A_F2	Female	71	Calorie King	Diabetes
A_F3	Female	67	Runkeeper	Obesity
A_F4	Female	71	Fitbit	Physical frailty
A_F5	Female	71	Fitbit	Obesity
A_F6	Female	69	ActiveLink	Overweight
A_M1	Male	72	eTools	Heart problems
A_F7	Female	75	Fitbit	Overweight
A_M2	Male	62	eTools	Diabetes
A_F8	Female	69	Calorie count	Arthritis
A_F9	Female	72	Fitbit	Physical frailty
A_M3	Male	63	Fitbit	Arthritis
A_F10	Female	62	eTools	Heart problems
A_M4	Male	71	Pedometer++	Physical frailty
A_M5	Male	72	Bodybugg	Overweight
A_M6	Male	73	Fitbit	Physical frailty

Table 2. Demographics of participants (N=16) in the interview I with their mobile devices in use and major health concerns

Data collection We conducted semistructured interviews to collect qualitative data. Our first interview protocol focused on understanding the experience of adopting mobile devices for healthcare. To explore this space, we constructed a set of open-ended interview questions with four themes: 1) health concerns, 2) a mobile device in use, 3) difficulties in its acceptance, and 4) solutions to such difficulties. In addition, we collected participants age, gender, most recent occupation, housing type as basic demographic information. For each interview, we either visited the place of a participant's preference or invited them to our usability study room. Each interview lasted between one hour and one and a half hours. All interviews were audio-recorded and transcribed. Each participant received 25 dollars as compensation for participation.

Data analysis We inductively analyzed the first-round interview data using thematic analysis based on a grounded theory approach [33]. Grounded theory methods build theory iteratively from the data, using rigorous coding practices. Initial *open codes* are primarily descriptive. These may be combined into more sophisticated *related sets of descriptors*, in which each set is referred to as an *axial code*. Subsequently, axial codes are combined into more theoretically powerful code complexes, called *selective codes*. Our approach included a process of open coding, axial coding, and selective coding.

Open coding In the first step of our data analysis, we identified and coded concepts that were significant in the data as abstract representations of events, objects, happenings, actions, interactions, etc. The example below illustrates one participant's lack of confidence in her ability to use new technology. This response is open-coded descriptively as "Lack of self-efficacy".

" If it doesn't work, you think you've done something wrong with it." (Participant A_F1)

Throughout the open coding process, a total of 46 loosely connected concepts were created, and 1,077 comments were coded.

Axial coding In the second step of our data analysis, we categorized the related concepts created by open coding into higher conceptual phenomena. Phenomena in a grounded theory refer to repeated patterns of events, happenings, actions, and interactions that represent people's responses to problems and situations. For instance, "Barrier to technology acceptance" is a driving factor for the decision to abstain from using mobile technology. "Lack of self-efficacy", for example, is one of open coding concepts categorized to Barrier to technology acceptance.

Selective coding & Model building In the last step, we integrated all concepts and categories identified in axial coding into a single theoretical model through building relationships across phenomena. We employed diagramming among several methods to facilitate selective coding [8].

Comparative analysis with existing models

Again following grounded theory practices from [33], we compared the model that emerged from our data with existing theoretical models of technology acceptance to determine differences and similarities between them. After studying the factors that constitute each existing model, we checked if our model had a component that was equivalent to any of those factors. This comparison allowed us to distinguish the extent to which existing models could explain older adults' behav-

ID	Gender	Age	Health concern
B_F1	Female	65	Heart problems
B_M1	Male	60	Physical frailty
B_F2	Female	61	Diabetes
B_F3	Female	62	Overweight
B_M2	Male	74	Diabetes
B_F4	Female	72	Arthritis
B_F5	Female	71	Overweight
B_F6	Female	63	Physical frailty

Table 3. Demographics of participants (N=8) in the interview II and their major health concerns

iors. Also, we identified the factors that are critical to older adults but did not appear in the existing models. Finally, we applied the existing vocabulary to our model to comply with the conventional terms in the field. Through this step, we completed building our initial model.

Interview II. Non-adopters: Older adults who have never adopted health technology

The purpose of the second interview was to validate and refine our model. Since we built our model from the data of technology-experienced populations, we wanted to validate the model with a different population. For this reason, we targeted those who had never adopted mobile devices for healthcare for the subjects of the second interview.

Participants In the recruitment flyer, we described that we are looking for people who are 60 years old or over and have experiences and thoughts to share about the usefulness of mobile devices - good or bad. Again, our recruitment was made through local senior centers by posting flyers on bulletin boards, as well as through word-of-mouth and a local Craigslist. Through the screening, we confirmed that none of those who responded to participate in the study had used mobile devices for healthcare. In total, we recruited eight participants (Mean age = 66, SD = 5.5, see Table 3).

Data collection We conducted another set of semistructured interviews to validate our model. Our second interview protocol focuses on understanding the experience of using general computing technologies with a particular focus on non-use of mobile technologies for healthcare. To explore these spaces, we constructed a set of open-ended questions with four themes: 1) health concerns, 2) general computing technologies in use, 3) difficulties in their acceptance, and 4) opinions on mobile technologies for healthcare. Besides, we collected participants' age, gender, most recent occupation, housing type as basic demographic information. The logistics of an interview, including its duration, location, and compensation, were identical to the first interview.

Data analysis We analyzed the second-round interview data using inductive and deductive approaches informed by grounded theory and other qualitative analysis methods [33, 22]. That is, we deductively identified themes based on the codes that were identified and the categories that emerged from the first-round interview data analysis, while inductively identifying new themes that did not exist in the first-

round dataset. Because "Intention to learn" and three related constructs (peer support, self-efficacy, conversion readiness) emerged as components that were critical to older adults' technology acceptance but did not present in existing models, these were the focus of the second-round interview validation. Data from the second interviews showed that non-adopters had little or no intention to learn a new technology regardless of its usefulness acknowledge. Nor did they have resources to support learning or access to a new technology. Since the rest of the data conformed to the first-round (adopters) data, we concluded that these learning-related barriers were indeed key reasons for non-adoption of technology. Thus, the remainder of the model did not need revision.

RESULTS

In this section, we first report our primary findings that explain the ways in which older adults' technology acceptance aligns with prior models. We then describe a phase in their process of acceptance that is prominently visible in our data, but is not present in earlier models, and finally identify key factors that influence this new phase.

Behaviors that conform to existing models

We found that existing models partially explain older adults' technology acceptance behaviors. As described by existing models, the intention to use is influenced by several factors including perceived usefulness of a system, perceived ease of use, and a variety of external variables (e.g., social influence, user context, facilitating conditions). All these factors were also present in our dataset. In particular, because we investigated mobile devices for healthcare, perceived usefulness of a system was usually evident when a user had a health concern:

"I lost about 50 pounds last two years on purpose. And, I was looking for ways to continue because I had gotten to a certain weight and I was having trouble getting the last 15 pounds off. That was why I was looking for a step counter to help me get more exercise." (Participant A_F7)

However, older adults did not perceive a system to be useful if they lacked up-to-date information about it. For example, when there are similar devices with different versions or models, older adults have difficulty distinguishing differences among them, which leads them to delay the decision to use one:

"I was looking at it (Fitbit) in a store, as I was curious about it. But, there were all different prices and I did not know what the difference was between different devices in varying degrees of monitoring that go on. I had no idea which one to pick, and so decided not to get it." - (Participant B_F1)

We found that older people usually believed that a new technology would be too difficult for them to interact with, which negatively affected their intention to use a system. Many participants mentioned that they felt technologies to be unnecessarily complex and difficult to use.

"I am not using it (Fitbit) anymore because I had problems with tying it on my phone. I had problems with its website. It just seemed unnecessarily difficult." (Participant A_F1)

While some technologies might indeed be complicated to operate, other technologies are just perceived to be difficult to use by older adults because techniques and vocabulary that older people are accustomed to are not relevant to the current digital circumstance. With lack of knowledge and experience of software conventions or general usage of technology, older people judge that technology is too complex.

"The language that you people use versus people who don't know anything about a computer is one of the big things for me. You know when you call apps but I don't know what it is." (Participant A_F10)

Various user contexts, including prior experience with technology and knowledge, significantly affected how a user perceives usefulness and ease of use of a new technology, which again were represented in the existing models (See Table 1) and confirmed in our analysis.

Before making a decision to accept a technology, an older adult moves to a phase where he or she tries out a system, either by buying it, borrowing it from family or friends, or seeing others using it. In this phase, a potential user tests and confirms perceptions of usefulness and ease of use. According to STAM, a user "formulates the intention to adopt a system based on the simplicity and operability of it." [28]. Our data also indicated that older people decide to accept or reject a new technology after interacting with it.

One participant mentioned that she stopped using an iPhone because it was extremely hard to interact with. She showed how she used to click the touchscreen by tapping on a screen with her fingernail tip in an effort to click as precisely as possible. She did not know that the iPhone's capacitive touch screen responds to contact with the flesh and not to pressure. This failure to succeed was caused by "a system characteristic", especially the lack of transparency of the system to allow a user to easily understand how to operate it. As such, even a very basic interaction technique for experienced users could be a significant obstacle to older people.

"I use a stupid phone. I had an iPhone that was too smart for me. I found it really difficult to use it. If I wanted to turn something on or go to a certain page, I had to tap it over and over and over and over again before I finally got there" (Participant A_F7)

There is often a significant gap between perceived and actual usefulness and ease of use of a technology among older adults. Due to the barriers posed in "the Intention to use" phase, such as lacking the perceptions of usefulness and ease of use, older adults do not even consider exploring a new technology. We found that sometimes simply being put in a situation where the person had to interact with a new technology allowed them to bridge this gap. Providing hands-on experience with a new system can totally reshape initial perceptions of a system:

"I was gonna get a flip phone but the guy [at a smartphone store] said 'We have no deals right now for flip phones, but you can get a free iPhone.' So, even though I really didn't wanna try it, I said I would try it. In fact, it was the best thing

I've ever had because now I can do so much stuff with it. I wish I had caught up to it 10 years ago." (Participant A_M4)

To summarize, existing models of technology acceptance can provide a partial explanation of older adults' behaviors of mobile technology acceptance. However, we also identified critical elements that are not represented in the existing models. Components in red boldface in Figure 3 provide a preview of the new elements we have identified and their relationship to the components proposed in earlier models.

A new phase: intention to learn

We identified an additional phase that is crucial for older adults but was not included in prior models: *Intention to learn a system* (See Figure 3). Many participants were simply not interested in putting efforts to learn a new technology at all.

"It (a smartphone) beeps and buzzes thousand different ways. It's too complicated. I don't want to figure out how it works." (Participant A_M3)

"I think people simply ignore a lot of it (technology). I have a friend who said 'That is not for me. I am too old for that. I have done this way for 60 years. It is too much trouble for me to learn a new way.' " (Participant A_M2)

We found that older people are hesitant to learn a new technology because many of them perceive that a technology might be too difficult for them to learn to use, and some even believe that they are not capable of learning how to use it at all, regardless of its perceived usefulness. Here, a clear distinction arises between "perceived ease of learning" and "perceived ease of use". For example, when an older person observes that a young professional is operating it, he or she might think that the device is easy for that person to use, but they still believe that it is too difficult for them to learn. Because of this, older people often simply give up learning new technology regardless of it being perceived as useful.

"This (installing a mobile app on a smartphone) must be easy for you (the interviewer), but is difficult for me. I won't learn." (Participant B_F5)

The gap between older adults' perceptions of a system's ease of use by others (especially younger adults) and its ease of learning by them reflects age related learning difficulties. Older people have to acquire skills to learn a technology, while the younger population often grow up with the modern technology and thus are accustomed to using it.

"Younger people have often learned how to use a computer at school or at work. This is often not the case for older people, especially those whose occupation did not involve computer use." (Participant B_F4)

Additional influencers

We identified three distinct factors that influence older adults' technology acceptance behaviors, particularly the intention to learn phase, that are not represented in prior models: self-efficacy, conversion readiness, and peer support.

Self-efficacy As described in the previous section, many of our participants were reluctant to learn to use a technology.

We found that lack of perceived capability to learn a technology was the primary negative influencer: older people perceive themselves as not being capable of learning a new technology, and thus refuse to learn it. We classify this attitude as *self-efficacy* (e.g., [25]) and define it as the degree to which a person believes that she or he will be able to operate a technology. When a technology does not operate properly, older people might blame themselves for the problem, instead of systematically searching for a solution, which results in feeling "scared" or "afraid" of using a technology.

"I was probably reasonably terrified of just looking foolish. It is an issue for the elders that if it does not work, you think you have done something wrong with it." (Participant A_F10)

When the participants were asked why they felt afraid of technology, a more specific reason arose: older people have a fear of being publicly embarrassed or made to look foolish by making mistakes, which prevents them from even trying out new technologies. Because older people lack self-efficacy in technology, they cannot distinguish technical glitches or system-oriented problems from making a mistake.

"Unless you drop them out on the floor, that's not gonna happen (break). But it's easy to say that I am afraid of breaking it. But I know I will look foolish. I have gotten past being worried about looking foolish." (Participant A_F1)

Conversion readiness We found that many participants were resistant to converting their current practices to using a new technology because they are satisfied with their familiar ways of doing things without a technology. Because they are satisfied with the current way of doing things, they do not even attempt to find out about the capabilities of new technologies.

"I think it is because I have done the old ways for so long and I am set in my way. Also, I am probably a little bit stubborn because I do not trust the new ways." (Participant B_M2)

In particular, older people refuse to change when they consider their existing skills and expertise as an invaluable part of their identity. This is related to a concern that new technology would replace the expertise that older people acquired during their lifetime. In this process, older people are concerned that their professional skills will be superseded by new technology, and that they have to let go of what they already have. This notion negatively affects their perspectives on new technologies, expressed as a form of refusal or apathy.

"The biggest thing is the refusal of a lot of older people to learn. He (an architect) said that 'I have done this way (hand drawing) for 60 years. It is too much trouble for me to learn a new way (drawing software). It is like you have a million dollars and all of sudden you are saying that it's worthless.' (...) It (adopting a new technology) means that we have to let go of what we have already learned and become a master of it. So, I give up everything and do not learn a new thing. It means that I lose what I already had. It's hard to let go what you knew so well." (Participant A_M3)

Another barrier that prevents older adults from converting to a new technology is that the skillsets and knowledge of operating prior technologies may not transfer easily to new technologies. For example, the design language or interaction techniques used by contemporary technology changes quickly so that even a person who was competent in using a mobile device years ago (e.g., a PDA) might have a hard time translating that knowledge to use of a smartphone. This mismatch in design languages means that each new technology may require learning from scratch, which poses a great challenge to older adults.

"I am so used to computers with a real keyboard with a screen. Probably I would not use it (a smartphone) because I wouldn't be able to use its capabilities." (Participant B_F2)

Peer support We determined that the most critical influencer of technology acceptance among older adults is whether people have someone in their social network who can provide information about and help them in using a new technology. We call this facilitating condition *Peer support* [34]. A peer refers to a person of similar age, social status, and ability as oneself. Older people are less likely to have peers with sufficient technology experiences compared to their younger counterparts.

"I think younger people learn it with your friends, you experiment, and you try it with each other. And, when you're older you really don't have that capability." (Participant B_F6)

Availability of peer support influences both the intention to learn and the system experimentation phases. In the intention to learn phase, simply observing that a peer easily uses a system increases one's self-efficacy, enhancing perceived ease of learning of a technology.

"I just didn't deal with it (texting) because I thought it would be difficult. When they (nieces) first started doing it [texting to me], I thought it was going to be too complicated or something. So I didn't even bother to learn it. Then, I saw a friend of mine was texting in a car and she said, 'This is easy'. She showed me how to do it. It was easy, and then I started. I think I've had some resistance to texting and probably other technologies too." (Participant A_F4)

Thus, a peer turns into a trustworthy personal coach in the system experimentation phase. In many places in the first set of interviews, participants mentioned support from a peer as a critical influencer of the successful acceptance of a technology, whereas those who have never adopted mobile devices did not have any peer resources. Lastly, a trustworthy relationship with a peer makes it safer to disclose one's ignorance and helps one overcome the fear of looking foolish.

"It was nice to have a nice class [at a senior center] and had peers that were really dedicated to it and have fun doing it and chat with each other to help. And then, you make more friends." (Participant A_F2)

"Oftentimes, he (husband) walks me through things on the phone how to do things, as opposed to my daughter, who does things for me in five minutes instead of showing me how to do for half an hour. By doing that, I can understand that, but it's better to have somebody who is patient." (Participant A_F10)

"[Before deciding which phone to buy,] I asked what kinds of phones he (a friend) had used and whether he liked them.
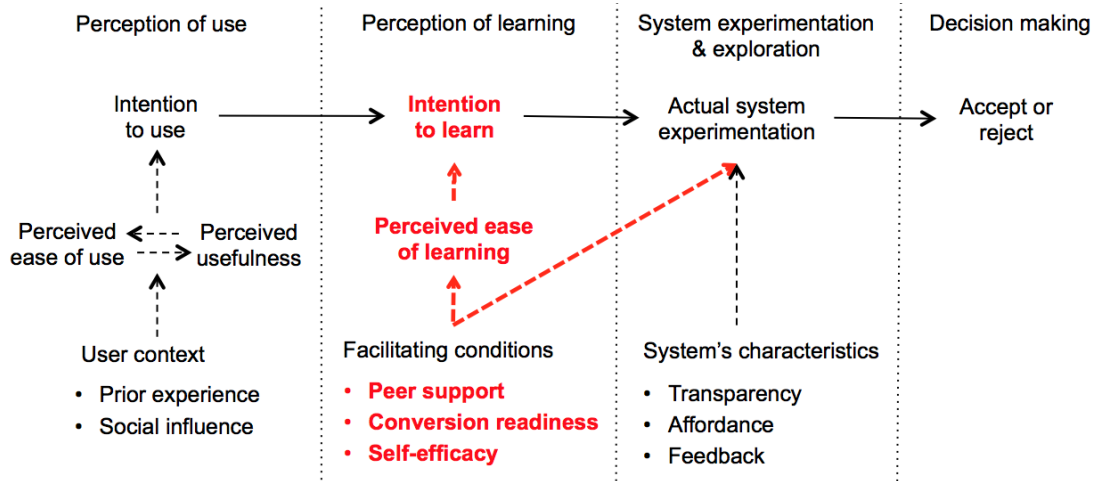
Figure 3. The proposed technology acceptance model for older adults. It explains the process through which older adults would accept a new technology through four phases: perception of use, perception of learning, system experimentation and exploration, and decision making. In particular, we identified that the *perception of learning* phase that is formed by *perceived ease of learning* did not appear in the existing models but critically influences technology acceptance behavior among our participants. We also identified three factors that affect this process including: conversion readiness, self-efficacy, and peer support. Newly identified elements and their relationship to the components were marked in red boldface.

I played with the phones that he mentioned and things like that." (Participant A_M6)

DISCUSSION

Consolidating our preliminary findings with the existing models, we propose an extended technology acceptance model for older adults illustrated in Figure 3. Extending to the predecessor theories, our tentative model introduces the perceived effort of learning a new technology as an obstacle for older adults' technology acceptance, which has not been reported in any studies of younger adults' technology acceptance. Subject to the issues in our Limitations section, below, the model comprises four phases, defined as:

- Perception of using a system - the phase in which a user forms the intention to use a system, influenced by its perceived usefulness and ease of use, which are in turn influenced by various user contexts including:

  - Prior experience: things that a person has done before
  - Social influence: things in relations to other people that a person is influenced by

- Perception of learning a system - the phase in which a user forms the intention to learn a system, influenced by facilitating conditions including:

  - Peer support: people in one's social network who have experience with technology
  - Conversion readiness: the degree to which a person is ready to accept a new thing
  - Self-efficacy: the degree to which a person believes to be capable of accomplishing a task

- System experimentation and exploration - the phase in which a user explores and experiments with a system, influenced by a system's characteristics including:

  - Transparency: the degree to which a user easily understands how to operate a system
  - Affordance: the degree to which a system naturally affords to perform an action
  - Feedback: the degree to which a system responds to user action

- Decision making - the phase in which a user decides whether to accept or reject a system

We found that availability of peer support is a critical key for the participants with little experience with technology to take the first step into the digital world. In our interviews, participants frequently mentioned support from peers in their social network as the most influential external factor of the successful acceptance of technologies. The impact of peer support appears to be due to the nonhierarchical, reciprocal relationship created through the sharing of similar experiences with others undergoing the same tasks and challenges [21]. In addition, learning new knowledge from peers with whom one identifies and shares common experiences enhances one's self-efficacy towards technology. Lastly, a trust relationship with a peer makes it safer to disclose one's ignorance [35, 25] and to overcome the fear of looking foolish.

Furthermore, we found that it was important to find ways to support the participants who did not have tech-savvy peers. Neighborhood groups and community-gathering events could provide venues in which they could access potential peers with similar interests and social status. Altering free classes that market-leading companies (e.g, Apple or Microsoft) provide through their local retail stores specifically for older adults, such as offering classes lectured by peer older adults or peer-collaborative workshops, would be another way to enhance older adults' technology acceptance. By fostering older adults' participation in such events, communities could help technically isolated older adults find potential peer support.

We also found that there is a significant gap between the perceptions of and the actual usefulness and ease of learning of new technologies among our participants: they tend to underestimate the benefits of new technologies and overestimate the required efforts to learn them. These preconceptions are often too strong to overcome easily. We can bridge this gap by providing ways for people to more easily explore a new technology, and by clearly communicating *relevant* benefits to them. Mainstream discourse about modern technologies often emphasizes the needs and values of younger generations (e.g., "hanging out" via video conferencing technologies, becoming a better athlete with the help of activity tracking), while different scenarios (e.g., staying in touch with distant grandchildren, maintaining cardiovascular health) would help older adults more accurately envision how technology could fit into their lives.

Lastly, we saw that our participants become easily frustrated when their existing skills are not applicable to a new technology. This frustration significantly contributes to establishing a negative perspective on new technology, by either perceiving that technology is unnecessarily complex or that the cost of learning exceeds its benefits. In the end, they abstain from converting to a new technology. This problem is further exacerbated by the fact that technology-related skills once acquired quickly become obsolete: a person who invested time and effort into learning how to use mobile devices a decade ago (e.g., stylus-based PDAs) will hardly know how to operate a contemporary smart phone. We might be able to lessen such negative perspective by designing technologies that are more familiar to older people. For example, we could adapt conventional modalities and traditional affordances of non-electronic devices to new designs or use more enduring design languages, instead of making a system full of cutting-edge design vocabulary and technical jargon.

LIMITATIONS AND FUTURE WORK

The principal limitation for our study is the absence of a comparison group of non-elderly users. We note that the research literature, which is based primarily on non-elderly adults (e.g., TAM and UTAUT), has not uncovered the *Intention to Learn* phase that we have described here. Nonetheless, our preliminary results in this paper should be tested against a comparison study of younger people. It may become necessary to repeat the structure of this study with each of several different age-ranges of users, including millennials, baby-boomers, etc.

At a more detailed level, even within the group of older users, the age range of our study participants does not necessarily represent the entire range of older adults, because it does not include those who are aged 80 years or over. Thus, our findings may not reflect the perspectives of the entire older population. Also we only interviewed participants in a metropolitan area with a dense network of public transportation, numerous community and senior centers, and a multitude of stores displaying modern technology. The experiences of our participants may be substantially different from those of older adults living in more isolated settings. Lastly, while our findings are based on only 24 participants, the sample size is commensurate with the Ground Theory approach.

If the model of Figure 3 is supported for any of the age-defined groups, then it will be useful to understand the social relations that are implicated in the *Perception of Learning* stage. We have tentatively proposed that *peers* provide the social support for developing an Intention to Learn. Future research should examine whether family members also play a role, or more diffuse community networks. Is the effect of peers mediated by support and mutual learning (e.g., [29]), or does the peer influence involve a more power-driven dynamic, such as peer-pressure to conform, or fear of being in an out-group? Are the peer influences mediated by the strength of social ties [16]? We may also want to look for different patterns of partial adoption, similar to the report of [13].

CONCLUSION

Emergent mobile technologies offer the potential for enhanced healthcare, particularly by supporting self management of chronic conditions. For these technologies to impact the current chronic care management practice, they need to be suitable for older adults, because the majority of people with chronic conditions are older. What remains as a major challenge is to successfully incorporate the appropriate use of mobile technologies into the lives of older adults. In pursuit of this goal, we sought to understand the process through which older adults accept mobile technologies, and factors that influence the process.

Triangulating the empirical findings from our preliminary results with the existing theoretical models, we proposed an extension of the existing theoretical models that explains the technology acceptance behavior of our participants who were aged 60 or over. Our proposed model incorporates key elements of prior models and introduces novel components that significantly influence the participants' technology acceptance, namely one new phase, *intention to learn*, and three factors, *self-efficacy, conversion readiness* and *peer support*.

Our preliminary findings shed light on the potential to extend the body of knowledge on technology acceptance behaviors among older adults. We identified the characteristics that are unique to our participants who are in the later stage of their lives that did not exist in the existing models. Although, future work is required to investigate the validity of our findings by conducting a comparison study of younger people. We are hopeful that this discovery will be useful to both age-researchers and designers in general, and can motivate future research in designing mobile technologies for self-management of healthcare in older adults in particular.

REFERENCES
1. Icek Ajzen. 1985. *From intentions to actions: A theory of planned behavior*. Springer.

2. Icek Ajzen. 1991. The theory of planned behavior. *Organizational behavior and human decision processes* 50, 2 (1991), 179–211.

3. M Anderson. 2015. The demographics of device ownership. *Pew Research Center: Washington DC* (2015).

4. Robin Brewer, Raymundo Cornejo Garcia, Tedmond Schwaba, Darren Gergle, and Anne Marie Piper. 2016. Exploring Traditional Phones as an E-Mail Interface for Older Adults. *ACM Transactions on Accessible Computing (TACCESS)* 8, 2 (2016), 6.

5. Luca Buccoliero and Elena Bellio. 2014. The adoption of silver e-Health technologies: first hints on technology acceptance factors for elderly in Italy. In *Proceedings of the 8th International Conference on Theory and Practice of Electronic Governance*. ACM, 304–307.

6. Emil Chiauzzi, Carlos Rodarte, and Pronabesh DasMahapatra. 2015. Patient-centered activity monitoring in the self-management of chronic health conditions. *BMC medicine* 13, 1 (2015), 77.

7. Miha Cimperman, Maja Makovec Brenčič, Peter Trkman, and Mateja de Leonni Stanonik. 2013. Older adults' perceptions of home telehealth services. *Telemedicine and e-Health* 19, 10 (2013), 786–790.

8. Adele Clarke. 2005. *Situational analysis: Grounded theory after the postmodern turn*. Sage.

9. Mario Conci, Fabio Pianesi, and Massimo Zancanaro. 2009. Useful, social and enjoyable: Mobile phone adoption by older people. In *Human-Computer Interaction–INTERACT 2009*. Springer, 63–76.

10. Fred D Davis. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly* (1989), 319–340.

11. Anna Dickinson, Alan F Newell, Michael J Smith, and Robin L Hill. 2005. Introducing the Internet to the over-60s: Developing an email system for older novice computer users. *Interacting with Computers* 17, 6 (2005), 621–642.

12. Arthur D Fisk, Wendy A Rogers, Neil Charness, Sara J Czaja, and Joseph Sharit. 2009. *Designing for older adults: Principles and creative human factors approaches*. CRC press.

13. Helene Gelderblom, Tobie van Dyk, and Judy van Biljon. 2010. Mobile phone adoption: Do existing models adequately capture the actual usage of older adults?. In *Proceedings of the 2010 annual research conference of the south african institute of computer scientists and information technologists*. ACM, 67–74.

14. Nancy M Gell, Dori E Rosenberg, George Demiris, Andrea Z LaCroix, and Kushang V Patel. 2013. Patterns of technology use among older adults with and without disabilities. *The Gerontologist* (2013), gnt166.

15. Mary C Gilly and Valarie A Zeithaml. 1985. The elderly consumer and adoption of technologies. *Journal of consumer research* (1985), 353–357.

16. Mark S Granovetter. 1973. The strength of weak ties. *American journal of sociology* (1973), 1360–1380.

17. Vicki L Hanson. 2011. Technology skill and age: what will be the same 20 years from now? *Universal Access in the Information Society* 10, 4 (2011), 443–452.

18. Zhao Xia Jin, Tom Plocher, and Liana Kiff. 2007. Touch screen user interfaces for older adults: button size and spacing. In *Universal acess in human computer interaction. coping with diversity*. Springer, 933–941.

19. Sri Kurniawan. 2008. Older people and mobile phones: A multi-method investigation. *International Journal of Human-Computer Studies* 66, 12 (2008), 889–901.

20. Chaiwoo Lee and Joseph F Coughlin. 2014. PERSPECTIVE: Older Adults' Adoption of Technology: An Integrated Approach to Identifying Determinants and Barriers. *Journal of Product Innovation Management* (2014).

21. Carolyn S Malchodi, Cheryl Oncken, Ellen A Dornelas, Laura Caramanica, Elizabeth Gregonis, and Stephen L Curry. 2003. The effects of peer counseling on smoking cessation and reduction. *Obstetrics & Gynecology* 101, 3 (2003), 504–510.

22. Matthew B Miles and A Michael Huberman. 1994. *Qualitative data analysis: An expanded sourcebook*. Sage.

23. Tracy L Mitzner, Wendy A Rogers, Arthur D Fisk, Walter R Boot, Neil Charness, Sara J Czaja, and Joseph Sharit. 2014. Predicting older adults' perceptions about a computer system designed for seniors. *Universal Access in the Information Society* (2014), 1–10.

24. Michael G Morris and Viswanath Venkatesh. 2000. Age differences in technology adoption decisions: Implications for a changing work force. *Personnel psychology* 53, 2 (2000), 375–403.

25. HH Nap and HP de Greef. 2010. Self-efficacy & stress in senior computer interaction. In *Proceedings of the 28th Annual European Conference on Cognitive Ergonomics*. ACM, 227–230.

26. Björn Niehaves and Ralf Plattfaut. 2014. Internet adoption by the elderly: employing IS technology acceptance theories for understanding the age-related digital divide. *European Journal of Information Systems* 23, 6 (2014), 708–726.

27. Chee Wei Phang, Juliana Sutanto, Atreyi Kankanhalli, Yan Li, Bernard CY Tan, and Hock-Hai Teo. 2006. Senior citizens' acceptance of information systems: A study in the context of e-government services. *Engineering Management, IEEE Transactions on* 53, 4 (2006), 555–569.

28. Karen Renaud and Judy Van Biljon. 2008. Predicting technology acceptance and adoption by the elderly: a qualitative study. In *Proceedings of the 2008 annual research conference of the South African Institute of Computer Scientists and Information Technologists on IT research in developing countries: riding the wave of technology*. ACM, 210–219.

29. Toni Robertson, Tuck W Leong, Jeannette Durick, and Treffyn Koreshoff. 2014. Mutual learning as a resource for research design. In *Proceedings of the 13th Participatory Design Conference: Short Papers, Industry Cases, Workshop Descriptions, Doctoral Consortium papers, and Keynote abstracts-Volume 2*. ACM, 25–28.

30. Mary E Sesto, Curtis B Irwin, Karen B Chen, Amrish O Chourasia, and Douglas A Wiegmann. 2012. Effect of touch screen button size and spacing on touch characteristics of users with and without disabilities. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 54, 3 (2012), 425–436.

31. Aaron Smith. 2015. US smartphone use in 2015. http://www.pewinternet.org/2015/04/01/chapter-one-a-portrait-of-smartphone-ownership/, *Pew Research Center* (2015), 18–29.

32. Janan Al-Awar Smither and Curt C Braun. 1994. Technology and older adults: Factors affecting the adoption of automatic teller machines. *The Journal of General Psychology* 121, 4 (1994), 381–389.

33. Anselm Strauss and Juliet Corbin. 1994. Grounded theory methodology. *Handbook of qualitative research* (1994), 273–285.

34. Hironobu Takagi, Akihiro Kosugi, Tatsuya Ishihara, and Kentarou Fukuda. 2014. Remote IT education for senior citizens. In *Proceedings of the 11th Web for All Conference*. ACM, 41.

35. Keith J Topping. 2005. Trends in peer learning. *Educational psychology* 25, 6 (2005), 631–645.

36. Phil Turner, Susan Turner, and Guy Van de Walle. 2007. How older people account for their experiences with interactive technology. *Behaviour & Information Technology* 26, 4 (2007), 287–296.

37. Viswanath Venkatesh, Michael G Morris, Gordon B Davis, and Fred D Davis. 2003. User acceptance of information technology: Toward a unified view. *MIS quarterly* (2003), 425–478.

38. Kerryellen G Vroman, Sajay Arthanat, and Catherine Lysack. 2015. "Who over 65 is online?" Older adults' dispositions toward information communication technology. *Computers in Human Behavior* 43 (2015), 156–166.

39. Wiktoria Wilkowska and Martina Ziefle. 2009. *Which factors form older adults' acceptance of mobile information and communication technologies?* Springer.

40. Yurong Yao and Lisa Murphy. 2007. Remote electronic voting systems: an exploration of voters' perceptions and intention to use. *European Journal of Information Systems* 16, 2 (2007), 106–120.

41. Valarie A Zeithaml and William L Fuerst. 1983. Age differences in response to grocery store price information. *Journal of consumer affairs* 17, 2 (1983), 402–420.