Exploring Traditional Phones as an E-Mail Interface for Older Adults

ROBIN BREWER, RAYMUNDO CORNEJO GARCIA, TEDMOND SCHWABA, DARREN GERGLE, and ANNE MARIE PIPER, Northwestern University

6

This article explores the design and development of voice interfaces via traditional telephones as a way of supporting asynchronous online communication for older adults. E-mail is the primary form of online communication for older adults. However, e-mail communication currently requires access to and the ability to use an Internet-connected computer or device, which may be problematic due to barriers of physical access, expense, insufficient computer skill, or other accessibility issues. To address this, the present work leverages the pervasive hardware of traditional phones and familiar nonvisual models of phone-based interaction to create a new e-mail interface for older adults. We examine the potential of e-mail interaction via traditional phones through long-term field observations, prototype testing, and a four-week field-based user study. Our findings indicate that a simple voice e-mail interface accessed through traditional phones is usable for older adults and is a useful way for offline older adults to interact with an e-mail account. The ease of use and convenience of a phone-based interface are important given the "work" of keeping in touch over e-mail, and this approach has the potential to open up new avenues of online access for older adults who are still offline or who have late-life disabilities that make using traditional graphical e-mail systems difficult. This project contributes new insights regarding the ways in which voice interfaces can support asynchronous online communication for older adults and provides design guidance for the development of subsequent voice interfaces.

Categories and Subject Descriptors: H.5.m. [**Information Interfaces and Presentation**]: Misc

General Terms: Design, Human Factors

Additional Key Words and Phrases: Older adults, e-mail, communication, telephones

ACM Reference Format:
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 Trans. Access. Comput. 8, 2, Article 6 (January 2016), 20 pages.
DOI: http://dx.doi.org/10.1145/2839303

1. INTRODUCTION

Staying connected in late life can improve physical and mental health [Ferlander 2007; Lubben and Gironda 2003], and seniors who use the Internet for communication are less likely to feel depressed, socially isolated, and lonely [Cotten et al. 2012; Sum et al. 2008]. However, a staggering 41% of older adults are still offline [Smith 2014], and these seniors tend to be older and have disabilities or chronic health conditions that make it difficult to physically access or use a computer. For other older adults who are active online, disabilities such as macular degeneration, advanced osteoarthritis, and severe

This work is supported by the National Science Foundation under grant number IIS-1533340.
Authors' addresses: R. Brewer, R. C. Garcia, T. Schwaba, D. Gergle, and A. M. Piper, Department of Communication Studies, Northwestern University, Evanston, Illinois, 60208; emails: rnbrewer@u.northwestern.edu, rcornejoga@conacyt.mx, tedmondschwaba2014@u.northwestern.edu, dgergle@northwestern.edu, ampiper@northwestern.edu.

DOI: http://dx.doi.org/10.1145/2839303

tremors can make using computers and smartphones increasingly difficult, although some techniques may help mitigate this (e.g., Hourcade et al. [2010]). Furthermore, short-term disability from an injury or illness can make older adults nonambulatory and unable to physically access e-mail due to pain and exhaustion. These issues can make it difficult for older adults to stay digitally connected at precisely the time when their social support network is most needed for better health and well-being. New tools are needed to address these challenges and help older adults stay connected in the later stages of life.

This article examines the potential for traditional phones, a familiar interface for older adults, to support late-life online communication. For our research, we refer to older adults as being over the age of 65 years because this is common in research [World Health Organization 2015]; however, some prior work may define an older adult as being over the age of 60 years. Our work is grounded in long-term field observations that, over the course of a year, allowed us to identify challenges around e-mail communication for older adults. We observed that many older adults experience difficulty using and maintaining e-mail even when simplified graphical e-mail interfaces are available. Moreover, e-mail access is affected by health, mobility, and cost. Traditional phones, however, are pervasive among older adults, with few owning smartphones [Smith 2014]. Also, many older adults value the affective and emotional qualities of voice communication via phones [Dickinson and Hill 2007; Lindley et al. 2009; Hope et al. 2014]. Building on our field work, we investigate the potential for landline and feature phones to support e-mail communication for older adults, and, in doing so, we address several important questions: Which older adults might benefit from this approach and under what circumstances? How should voice interfaces be designed to facilitate online communication for older users? Is a voice-based e-mail interface usable and useful for seniors, including those without prior e-mail experience?

Driven by earlier interviews and observations, we developed V-Mail, a voice-based e-mail system for older adults. On the surface, V-Mail resembles a voicemail system and, through this, provides older adults with a familiar model for interaction. However, V-Mail is much more than voicemail because it allows older adults to navigate and interact in real-time with an existing e-mail account by sending, reading, replying to, and printing e-mail messages through keypad and spoken input. While older adults interact through their phone, their family members and friends interact through traditional graphical e-mail interfaces, sending and receiving e-mail messages on their computers, tablets, or smartphones.

Our work provides new understandings of how to design voice interfaces for older adults and contributes to a growing literature on new technologies for late-life social connectedness [Hope et al. 2014; Lindley et al. 2009; Moffatt et al. 2012; Sundar et al. 2011]. Although several voice-based e-mail systems have been developed [Resnick 1992; Schmandt 1993], prior work has not considered older adults as a potential user group nor understood how voice interfaces may increase online access for this population. We found that e-mail communication through traditional phones is useful for and usable by older adults who were previously not online but also benefits those who are already active online and do not own a computer. The ease of use and convenience of V-Mail was an important benefit, particularly with respect to the "work" of keeping in touch over e-mail [Lindley et al. 2009; Hollinworth and Hwang 2011; Hope et al. 2014]. Although our system demonstrates benefits by leveraging the familiarity of traditional phones, in doing so, it also introduces new tensions based on the established social practices of phone communication. We report on these tensions and then conclude with a discussion of the design of voice interfaces for older adults and the broader implications of this approach.

2. RELATED WORK

2.1. Designing E-Mail Systems for Older Adults

Prior work has focused on improving graphical e-mail interfaces to support the needs of older people. Hanson [2009] offers general guidelines for supporting older users online and suggests that small font, low color contrast, multiple windows and views, and unclear terminology can be disorienting to older adults. Similarly, Sayago and Blat [2010] investigate email practices of seniors and suggest that terminology should be based on metaphors that older populations understand. Dickinson and colleagues [2005] created a simplified graphical e-mail interface for seniors and indicate that e-mail menus with deep navigation structures are not ideal and can lead to confusion in users. The PRISM project[1] provides yet another example of a simplified graphical system for older adults and includes an e-mail component. In our field work, older adults used TouchTown,[2] a commercial system designed for seniors with two e-mail programs that feature basic graphical interfaces. Although these systems are useful for older adults, they presume physical access to a computer and are not widely available (e.g., TouchTown is only available to seniors who live in communities that have purchased this software). Moreover, in our field research, we observed that even these simplified systems can be difficult for some older adults to use, particularly individuals with vision loss, motor impairments, and people recovering from illness or injury (e.g., a fall).

2.2. Voice-User Interfaces

Our work requires designing for people with limited online access and experience with traditional computers. We draw design inspiration from people designing for the developing world, which has shown phone-based voice interfaces to be useful for users who have limited online experience or minimal access to desktop or laptop computers (e.g., Patel et al. [2009] and Sambasivan et al. [2011]). Moreover, while older adults are adopting cell phones, only 18% currently own smartphones [Smith 2014]. Instead, older adults are familiar and comfortable with using landline and non-smart cellular telephones, particularly those seniors in the United States who are still offline [Smith 2014].

Limited work has focused on how voice interaction supports older users [Lines and Hone 2002; Wolters et al. 2009a, 2009b], and the literature on best practices of synthetic voices for older adults is somewhat inconclusive. One study found a preference for male voices among older adults [Lines and Hone 2002], yet a larger study with younger adults suggests a self-similarity bias (i.e., women prefer female voices) [Lee et al. 2000; Nass and Brave 2005]. Understanding how to design the voice for voice-user interfaces is critical because people automatically assign social characteristics (e.g., emotion, trust, competence) to voices that resemble human speech [Nass and Brave 2005]. Beyond preference, factors such as gender, pitch, and playback rate may also affect how well older users understand voice output. Our work evaluates these factors with older adults and integrates the results into our final design.

The concept of voice-based access to e-mail is not new (e.g., Baptista et al. [2009], Resnick [1992], and Schmandt [1993]), but prior systems are aimed at more technical, experienced users and have yet to be examined with older adults. These systems integrate multiple services, a two-step authentication process, and use predefined synthetic audio properties, all of which increase the complexity of interaction. Furthermore, prior work has shown that older adults do not typically interact with speech interfaces in a way that these systems can understand [Wolters et al. 2009a], thus motivating the

[1]http://centeronaging.med.miami.edu/prism.
[2]http://www.touchtown.us.

use of keypad input rather than spoken commands. Our research moves toward a more complete understanding of how to design voice interfaces for older adults and builds on this prior work by examining interface usability, characteristics of synthetic speech, and the usefulness and appeal of this approach for older adults.

2.3. Supporting Late-Life Social Communication

The present work aims to understand new techniques to help older adults participate more fully in online communication with their social support networks. While intergenerational communication is often asymmetrical, in which older adults put forth more effort to initiate and maintain communication, mutual reciprocity is desired [Cornwell and Waite 2009]. Lack of reciprocity can have a negative effect on seniors, but, at the same time, older adults are cautious about being a burden on their relatives and interrupting their schedules [Lindley et al. 2008]. Prior systems (e.g., Tlatoque [Cornejo et al. 2013], Wayve [Lindley 2012]) examine how new tools for asynchronous online communication affect issues of asymmetry and reciprocity involving older adults. The development of V-Mail provides a platform through which we can examine these issues with respect to e-mail. Collectively, these systems integrate the communication interfaces and practices of different user groups into a common platform for interaction. Leveraging familiar interfaces and practices in design is important because fear of failure, low self-efficacy, and perceived lack of usefulness or ease-of-use can negatively impact older adults' interest levels in using technology [Braun 2013]. As we find in our work on V-Mail, blending traditional telephones with e-mail is a useful interface for design, yet this introduces complexities around expectations for interaction with the interface and one's contacts.

In summary, simplified graphical e-mail systems are useful but still present challenges for certain older adults and require physical access to a computer. Voice interfaces, although beneficial to people with limited computer access or experience, have yet to be studied in detail for older adults and are promising for online communication. This article brings together these areas to explore a new approach to supporting e-mail communication for older adults.

3. UNDERSTANDING E-MAIL USE AND CHALLENGES

To understand the practices and challenges of e-mail use for older adults, we conducted participant observations over the course of one year in the computer rooms of a senior living community and in-depth interviews with seven older adults.

3.1. Method

Two members of the research team conducted 1–2 hours of participant observation per week in the computer rooms of a senior care facility for approximately one year. Through observation, we regularly worked alongside more than 15 older adults (most were aged 75–100) and helped them with computer problems. The most frequent help topic involved e-mail, and, as such, we were able to observe a myriad of challenges with learning and sustaining e-mail communication. To complement the breadth of observations, we conducted semi-structured interviews with eight participants: seven older adults (age 81–93; $M = 87$; 5 female) and the daughter (age 62) of one participant. Participants had a range of computer and e-mail experience, including three people who had never used e-mail, two with occasional use, and three who used e-mail daily. We recruited participants from the same community in which we conducted observations, focusing on residents in assisted living who are no longer able to live independently. Although these individuals live with others in the community, many are separated from their immediate family members and closest friends, which was discussed during the interviews. All interviews were conducted in participants' homes or in a communal

living room. Interviews focused on technology usage and patterns of offline and online communication.

Data analysis followed a constructivist grounded theory approach [Charmaz 2000], which allows the process of data analysis to emerge through interactions during fieldwork, with the data, and between members of the research team. All interviews were audio recorded and transcribed for analysis. The research team took photographs of communication devices that participants brought into discussion and analyzed this data alongside interview transcripts. Multiple researchers iteratively reviewed, coded, analyzed, and discussed the data. Analysis focused on constant comparison of data through a process of relating the codes and emerging concepts to one another. Through this, we further refined our emerging understanding of the lived experience of e-mail communication among our participants, resulting in the five themes below.

3.2. Findings

Our analysis of observation and interview data revealed five high-level themes regarding the challenges of accessing, using, and maintaining e-mail communication.

The work of maintaining e-mail and staying connected. Prior studies describe the "work" of keeping in touch for older adults [Lindley et al. 2009; Hollinworth and Hwang 2011; Hope et al. 2014], and we observed this in the field. For many of our informants, receiving 10–15 e-mails a week (excluding spam) was described as "a lot to manage." Older adults at our field site scheduled help sessions to learn to use e-mail and visited the computer room multiple times per week to maintain e-mail correspondence.

Simplified e-mail clients still present challenges. The majority of seniors we worked with accessed e-mail through AOL or TouchTown on a traditional desktop computer, although some owned laptops or tablet computers where they accessed e-mail. We observed that screen-based e-mail, even the simplified interface of TouchTown, presented challenges for some seniors. Older adults had difficulty setting up a new e-mail account, entering password credentials, managing pop-up ads, understanding changes to the interface layout, and printing attachments [Dickinson et al. 2005; Hanson 2009; Norval et al. 2014]. For some, poor vision presented accessibility problems that required specialized adaptations. Three interview participants noted their declining vision in context of being able to read e-mails. One woman said, *"I have macular degeneration so I'm going blind very slowly but at one point the screen I had was very difficult for me to read."* Another older adult at our field site described that advanced macular degeneration makes her unable to use e-mail entirely; instead, she communicates by phone.

E-mail access is affected by health, mobility, and cost. We observed an important trend in e-mail usage. We noted various weeks when our regular visitors to the computer room were absent; when they returned, we would often learn that they were ill or had been injured. Yet, being disconnected due to health and mobility may be precisely when they need social support that e-mail can provide the most. For many seniors in assisted living communities such as the one in which we worked, the only e-mail access available is through community computer rooms. A similar trend can be observed with seniors living in their own homes, particularly lower income groups, who use communal resources through libraries [Zickuhr et al. 2013]. As shown previously [Aging in Place Technology Watch 2011], our informants also described the cost of paying for wireless service and maintaining a personal computer as barriers. We worked with a number of older adults who own iPads but note challenges around learning to use and maintain these devices. Some brought in unopened iPads, after receiving the devices months ago, so that we could help them learn to use them.

Preference for phone over e-mail communication. Much work examines the communication practices of older adults, including the importance of phone calls and e-mail [Dickinson et al. 2005; Hope et al. 2014; Lindley et al. 2009]. It is worth noting that all but one interviewee preferred to talk by phone rather than e-mailing or writing letters. Others described the benefits of using a phone for reasons other than social communication. One participant explained, *"I do usually all my ordering by phone, not by computer. Because I know how to do that (laughs)"* (age 82, F). As this participant described, in some situations, a phone-based interaction model is easier to navigate than one on a graphical computer interface. In addition to the established social practices of phone communication, physical access to phones is pervasive for older adults. One participant said, *"But you see, living here... I'm always somewhere where there is a phone"* (age 85, F). Hence, solutions that leverage the familiar model of phone-based interaction and the pervasiveness of commodity phone hardware have the potential to open up new directions for design.

Staying connected with those who are offline. Although many of our informants used e-mail, they described the challenges of keeping in touch with their contacts who are not online. As shown in prior work (e.g., Hope et al. [2014] and Lindley et al. [2009]), many interview and observation participants relied on paper-based communication to stay in touch, and this was particularly important for social groups in which some members did not use e-mail. We also observed the social practices related to e-mail, such as printing out multiple copies of a forwarded e-mail or an e-mail attachment to distribute to social contacts who do not use computers. One participant (82, F) described a unique group letter-writing tradition she and her friends developed:

> "A lot of them don't want to have anything to do with the computer so we write one letter and put it in the envelope with the 15 other letters with the other people and we send it... I get the packet of letters...I read it and I take my old letter out and write a recent letter, what I've been doing."

This illustrates how older adults may adapt and go to great lengths to maintain communication with contacts who do not use computers, further suggesting the utility of new systems that connect offline and online practices. E-mail through traditional phones could potentially bridge these communication practices by enabling groups of computer and non-computer using older adults stay connected online.

3.3. Design Considerations for Phone-Based Interfaces

As the concept of a voice-based e-mail interface emerged, we used the in-depth interviews to understand older adults' concerns regarding phone-based communication systems. From these data, we derived an initial set of considerations to inform subsequent system design:

Leverage the familiarity of traditional phones. Landline phones are a familiar interface for older adults, and many seniors still use physical answering machines, which may serve as another useful metaphor for design. All participants stated that they were comfortable using their answering machines. Seniors were also familiar with playing and deleting messages in this context. The simple voice-based menu of answering machines is effective for older adults and can inform development of similar auditory messaging systems.

Emphasize recognition rather than recall. We observed that older adults had difficulty recalling the steps needed to access e-mail on a computer and wanted to write the process down step-by-step. From the interviews, participants described great difficulty with customer service numbers, which tend to have more open-ended speech entry

and rely on recall. Participants expressed frustration with not knowing how to phrase the question to the voice system. Additionally, older adults may not interact with speech recognition systems in a way that these systems can easily understand [Wolters et al. 2009a] and are likely to have greater success with keypad input that relies on recognition and selection of a few finite commands [Patel et al. 2009].

Focus on audio quality, not simply amplification. A major concern for participants was the quality of their hearing. Even with hearing aids, some noises can become amplified and very difficult to understand. Therefore, they wanted a system that is not only loud enough and speaks at a comfortable speed, but also has high-quality audio that would be compatible with their hearing aids. To achieve this, a more detailed understanding of voice variables (e.g., gender, pitch, and speaking rate) is needed to inform the design of voice interfaces for older adults, especially given the inherently lossy audio quality of phone communication.

Consider the cost of phone-based services. Cost was also a concern for older adults. Typical of most senior communities, in-home Internet access was an additional cost. We observed many people coming to the computer room because they could not afford or did not want to purchase in-home Internet. Also, at this particular community, residents are charged for calls outside of an approximate five-mile radius. Therefore, they must consider whom they call on the phone and how often. One participant said she would use a new phone-based service *"...if they don't charge me for it. Have you seen the kind of bills we have from the phone company?"* (82, F). Phone-based systems must fit within the cost structure of telephone services for communities and private residences [Resnick 1992], incorporating toll-free calling for older adults who prefer to use landline phones (e.g., due to cost of mobile services).

4. INITIAL VOICE INTERFACE PROTOTYPE

Guided by these design considerations, we created a first version prototype of a phone-based e-mail system to test (i) the usability of a basic voice UI and (ii) to understand the properties of a synthetic voice best suited for older users.

4.1. Prototype Design

The prototype was developed using Twilio,[3] a web service for prototyping voice-user interfaces, Twilio's TwiML markup language for controlling the flow of phone calls, and PHP. Users access the system by calling a toll-free number on a landline or cellular telephone.

4.1.1. Menu Structure. We examined various models of voice menu design and structure. Related work indicates that older adults prefer a chauffeur-like interface that guides them through the menu [Nass and Brave 2005]. We designed a minimalistic interface that facilitates such an experience, drawing on interaction models of answering machines and voicemail. After calling the system, users are greeted and told how many messages they have. For the purposes of prototype testing, we created a variety of e-mail messages and added them to the system. Users first have the option of listening to messages or sending a new message. After listening to a message, users are provided with the option to reply, print, or delete the message. The menu responds to input through the phone keypad, as suggested by prior work [Patel et al. 2009] and our field research. The user speaks into the phone to record a new message or reply to a message. We phrased all menu items as *option* then *user action* (e.g. 'To listen to your messages, press 1') to enable users to first hear their desired option, then attend to the

[3]https://www.twilio.com/.

action required to select that item. Prototype testing examined how well older adults were able navigate the menu structure.

4.1.2. Voice Design. To select the qualities of the voice for the interface, we carefully considered related literature and comparable existing systems. One study with older adults shows a preference toward male voices [Lines and Hone 2002], although other extensive work [Nass and Brave 2005] indicates that people prefer accents, gender, and voice personalities similar to their own, which is described as *similarity attraction*. Because females tend to live longer than males, a female voice may be perceived, in the aggregate, as more likeable when deployed among a female-skewed cohort of older adults. However, other work indicates that older adults have difficulty comprehending higher pitched voices and rapid speech [Fisk et al. 2009]. For the initial voice menu prototype, we used prerecorded audio with a slow, low-pitch, female voice based on several other works [Fisk et al. 2009; Lee et al. 2000; Nass and Brave 2005]. Given the conflicting recommendations (e.g., Nass and Brave [2005] and Lines and Hone [2002]), we also conducted an experiment to understand how these variables affect understanding and preference.

4.2. Prototype Testing Method

Prototype testing evaluated menu usability, voice understandability and preference, and desired features for a full system. We tested the prototype with 16 older adults (aged 76–94; mean age = 87; 11 female) who reside in assisted and independent living communities. The age and gender distribution is similar to that of the observations and interviews. Of these participants, 14 reported familiarity with computers and e-mail. The study was conducted in participants' homes, where they interacted with the prototype through their landline or cellular telephone. We verified that all participants were able to hear content delivered through their personal phone.

First, participants were asked to call the system. Voice menu options were played over the user's phone, and they were able to interact with the menu by pressing phone keypad buttons. We instructed participants to perform three tasks: listen to a message, print a message, and send a message. Participants received printed instruction prompts that described each task, including instructions for dialing the phone number to access the system. We used a Wizard-of-Oz technique to simulate printing and sending messages. No time constraints were imposed, and participants could make multiple attempts to complete the tasks if needed.

Second, we were motivated by the somewhat contradictory findings in prior work regarding important voice characteristics in interfaces for older adults. A 2 x 2 x 2 within-subjects design was used in which participants responded to message prompts that varied by gender (male or female), pitch (normal or 10% lower), and speed (real-time or 10% slower). We used Oddcast[4] to create the gendered text-to-speech stimuli and Audacity to manipulate pitch[5] and speed.[6] Baseline pitch and speed were based on Oddcast's default settings. Participants listened to four unique message prompts (e.g., "To listen to your messages press 1"), repeated eight times for the different combinations of gender, pitch, and speed (total of 32 statements per participant). Message prompt order assignment was counterbalanced using a Latin-square design to minimize the potential for order effects. For consistency among participants and to promote generality of our findings, messages presented during this part of the experiment were

[4]http://oddcast.com/.

[5]Pitch is a perceptual property closely related to the frequency of the audio. We decreased the frequency of each audio message by 10% using Audacity's Change Pitch effect to obtain a lower pitch.

[6]Normal speed was approximately 900 characters per minute.

played over high-quality speakers from a researcher's laptop. However, we note that the sound quality may be different when played over commodity phone hardware, and we examine this through the subsequent field deployment (Section 5). We individually assessed both preference and understandability for each message prompt using a 3-point Likert-style scale (1 = not at all and 3 = very much). We originally used a 5-point scale in pilot testing, but older adults reported confusion with the number of responses.

Third, participants verbally completed a questionnaire in which they were asked to assess whether a variety of features should be included in a phone-based e-mail system, such as previewing and revising a message before sending. Participants responded "Yes," "No," or "Maybe."

4.3. Prototype Testing Results

4.3.1. Usability. The first step in using the prototype was to dial the phone number to access the root phone menu. Participants had a 96% (46/48) success rate in dialing the phone number, with issues of not pressing 9 to dial out or hanging up accidentally resulting in failed attempts. The majority of participants navigated the simplistic phone menu, accomplishing the specified tasks (listening to, printing, and sending a message). Twelve of the 16 participants were able to complete all three tasks on the first attempt. Two participants were unsuccessful in all three tasks due to their use of caption phones because there were conflicts between the text displayed on the caption phone and the timing of keypad input. One challenge we observed is that study participants did not know when to hang up or end their interaction with the system. Another insight is that the quality of the voice for the prototype may be too realistic and conversation-like: Participants responded to the voice on the phone, greeting it with "hello" after it greeted them [Nass and Brave 2005]. The naturalness of the synthetic voice also confused some users who initially thought the messages were recorded voicemails rather than text-to-speech messages.

4.3.2. Voice Gender, Pitch, and Speed. To understand voice characteristics, we used a mixed-model analysis with the Restricted Maximum Likelihood (REML) estimation method to predict user preference and understandability ratings [Littell et al. 1996]. Voice gender, voice speed, voice pitch, and participant gender were included as factors in the model. Two-way interactions for the experimental conditions were included in the analysis, and participant gender was included as a control variable. Participants were modeled as a random effect because each participant rated multiple message prompts across the three experimental factors, and observations were not independent.

The results revealed a significant effect of the voice characteristic of gender on the participant's reported preference ($F(1,14.01) = 10.40$, $p = .006$), where male voices ($M = 2.74$, $SE = .123$) were preferred over the female voices ($M = 2.23$, $SE = .123$). The voice characteristic of pitch also influenced the participant's reported preference ($F(1,14.72) = 7.78$, $p = .014$), where a lower pitch ($M = 2.57$, $SE = .099$) was preferred to the normal pitch ($M = 2.40$, $SE = .099$). We note that these effects were found even with a predominantly female sample and that it confirms earlier work [Lines and Hone 2002]. We did not detect a significant preference for the voice characteristic of speed ($F(1,15.01) = 1.45$, $p = .247$).

We also examined how the voice characteristics influenced the participant's reported ability to understand the statements. There was a significant effect of the voice characteristic of gender on understandability ($F(1,13.99) = 14.07$, $p = .002$), where the participants reported understanding male voices ($M = 2.86$, $SE = .096$) better than female voices ($M = 2.47$, $SE = .097$). Although not significant, there appeared to be a trend for the voice characteristic of speed on understandability ($F(1,14.97) = 3.75$,

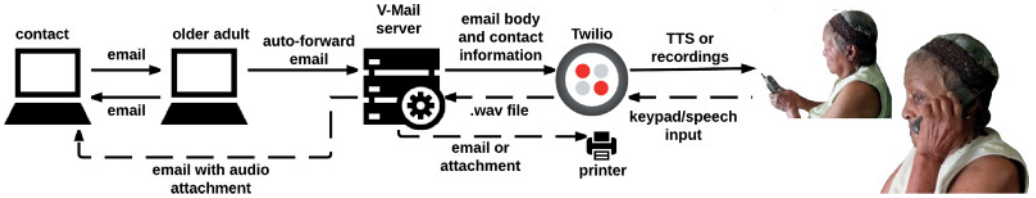

Fig. 1. Depicts how messages are received (solid line) and sent (dashed line) by older adults using V-Mail. Older adults interact through keypad input on their landline or cellular telephones. They can send a message by speaking directly into the phone, which transmits to the recipients e-mail account.

$p = .072$), where commands spoken at a normal pace (M = 2.71, $SE = .084$) were understood better than commands spoken at a slower pace (M = 2.62, $SE = .084$).

Finally, we examined whether a self-similarity bias [Lee et al. 2000; Nass and Brave 2005] was present in our data by examining the extent to which the preferences for a voice gender aligned with participant gender. We did not find evidence of a similarity bias on preference ($F(1,14.01) = 1.44$, $p = .25$), and analysis of similarity bias on understandability trended in the expected direction ($F(1,13.99) = 3.30$, $p = .09$), where the findings suggesting that there may be a preference for a male voice over a female voice was stronger for male participants than it was for female participants.

These findings suggest that future systems for older adults should use a male, low-pitch voice but that slowing down the rate of speech may not improve preference or understanding. After evaluating the voice manipulations, we asked participants to describe why they liked particular voices. Participants described liking the male voices because they were *"clear and commanding"* (89+, M) and *"distinct"* and *"understandable"* (88, F) or liking low-pitch female voices, which one participant described as sounding like *"Diane Sawyer"* (89, F). Of the few participants who liked the female voices, reasons why included that they were *"softer"* and *"not as harsh"* (86, F).

4.3.3. Desired V-Mail Features. Nearly all participants (15 of 16) wanted the ability to send messages in addition to receiving them, indicating the importance of reciprocal communication [Lindley et al. 2008]. Similarly, 13 of 16 participants wanted to listen to messages before sending them, having the chance to craft a voice message and reflect on it before sending. Nearly all (15/16) wanted a printed instruction guide to accompany their interaction over the phone. They also wanted the ability to print messages (11/16) and attachments (12/16), and we have seen many examples of the challenges of printing attachments in our field work. One participant said, *"I do a lot of printing just to keep a record of it"* (89, F).

5. V-MAIL: VOICE-BASED E-MAIL FOR OLDER ADULTS

Based on results from our formative field research and prototype testing, we created and evaluated a full version of the voice-based e-mail system, which we call V-Mail.

5.1. System Design

We designed V-Mail (Figure 1) to integrate with existing e-mail accounts, in which users configure the account to forward certain messages to the V-Mail server. For example, a family member or friend sends an e-mail to a V-Mail user by sending the message to a traditional e-mail account (e.g., GMail, AOL). Messages from specified contacts are forwarded to the V-Mail server, which manages each older adult's list of contacts, read and unread e-mail messages, and attachments in a MySQL database. This database uses Python to interact with Twilio when an older adult calls the system.

V-Mail users dial the system phone number to initiate Twilio's IVR system and access e-mail on a landline and/or mobile phone. A user's phone number(s) acts as the password to authenticate and enable access to the appropriate e-mail account from the V-Mail server. After dialing the number, a user hears the status of her e-mail inbox (e.g., "You have two new e-mail messages") and then is prompted with *menu options* on how to proceed. Menu options were prerecorded messages played in a male synthetic voice from Oddcast with pitch adjusted to 10% lower than the default Oddcast voice, per findings from earlier prototype testing. Using Twilio's embedded text-to-speech software, *e-mail content* is played by phone in a male synthetic voice. Although the UI appears much like a voicemail system, it allows full integration with a graphical e-mail account through which seniors can listen to, send, and print e-mail messages and image attachments by interacting through touch-tone input. To print a message, users are prompted to press a button on their phone, and the message is routed to an HP ePrint printer associated with their account. Low-cost ePrinters are an effective way of managing content without the need for a print server.

When an older adult wants to send a new message through V-Mail, she calls the system and selects a person from her contact list, pressing a number on the keypad that corresponds to the e-mail address of that contact (e.g., "For Alice, press 1"). The user speaks into the phone receiver to record an e-mail message and is then prompted to re-record or send the message. When an older adult sends a message, Twilio captures the voice recording of the message and stores it as a .wav file in the server's database. The server then sends an e-mail to the contact with the .wav file of the older adult, speaking her response as an audio attachment, although a text transcription can also be provided. Messages sent from V-Mail arrive in the recipient's e-mail inbox on his computer.

5.2. Field-Based User Testing Method

Evaluating new communication systems such as V-Mail requires usage to be both contextualized and to extend beyond an isolated instance of interaction. To achieve this, we evaluated the usability, appeal, and broader implications of V-Mail through a four-week field-based user study with 14 older adults (aged 77–96, $M = 83$, 10 females) and 53 of their social contacts (on average, four contacts per older adult). Although we aimed to recruit older adults who did not previously use e-mail, we allowed all interested older adults at our field site to participate in the testing. As such, we attracted many seniors who were already online and using e-mail. The age and gender distribution of participants in the field study is similar to these involved in the first two phases of this project, and again we recruited participants from the same retirement community in which we conducted our formative research and prototype testing. Of the older adults, nine owned a computer and 12 had their own e-mail account before using V-Mail. Older adults were able to use an existing e-mail account or have a new e-mail account set up for the study. Only one older adult participated in the earlier prototype testing because she was not an e-mail user and was eager to try out the full system. We provided participants with access to V-Mail on their landline and/or mobile phone. We simply asked that they try out V-Mail with their social contacts at their convenience, maintaining flexibility for those who traveled or fell ill during the study period.

In contrast to a lab-based study, our aim was to assess the usability and appeal of V-Mail in the context of older adults' current communication routines, devices, and actual social networks. The research team introduced older adults to V-Mail, answering questions as they used the system for the first time, and provided them with an instruction guide. The instruction guide (Figure 2) was designed to be accessible to older adults who may have minor vision impairments (e.g., black text on yellow paper in Arial, size 16 font [Fisk et al. 2009]). It included a diagram of a phone with keypad

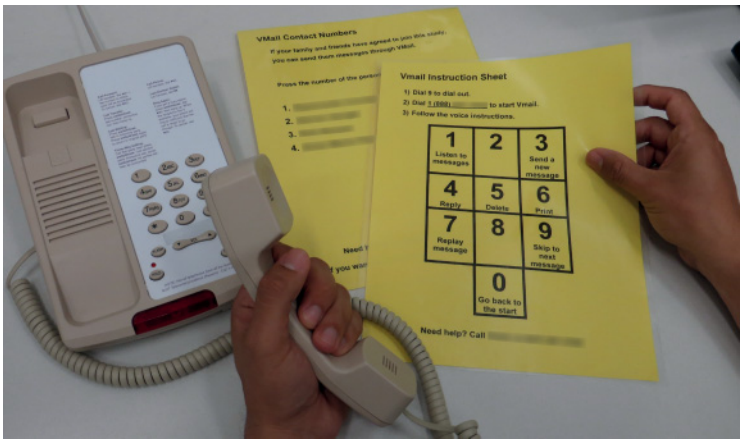

Fig. 2. Instruction guide given to participants.

numbers corresponding to V-Mail options and a list of their personal contacts accessible via V-Mail. We provided instructions to older adults' social contacts by e-mail, including an overview of V-Mail features (e.g., printing photo attachments) and system limitations. One constraint at this stage is that social contacts must consent to the study and be added to the system manually by the research team, thus limiting the people older adults could contact using V-Mail to those who agreed to participate.

Researchers took notes and/or audio recorded interactions with older adults during the initial training, a one-week phone check-in, an in-person interview after week two, and a final in-person interview after week four. We also solicited feedback from social contacts via e-mail after each week. All interviews with older adults were transcribed and iteratively coded for themes alongside data from social contacts, following constructionist grounded theory techniques similar to those used in earlier phases of this project [Charmaz 2000]. Through iterative coding, we examined how they became accustomed to using V-Mail, how it aligned with their existing offline and online communication routines, and any challenges they encountered. Relationships between these data were then used to identify higher level themes, which are organized in later sections. Excluding message content, all interactions with the system were logged and analyzed.

5.3. Results from Field-Based User Testing

We highlight findings regarding usability, perceived usefulness of this approach, and the affordances and challenges of blending phone and e-mail communication practices.

5.3.1. Usability and Initial Usage. We provide initial usage data for the purposes of understanding the user experience because adoption and sustained use will need to be measured with a separate, extended field study. Over the four-week testing period, 14 older adults sent 91 messages (68 new messages and 22 replies; average message length = 22 seconds) and received 64 messages, of which 48 were listened to. After the initial first-time use, all but two older adults (who were frequent computer users) continued to use V-Mail to listen to or send new messages.

As earlier testing suggested, the printed instruction sheet accompanying V-Mail was useful for participants, particularly when learning to use the system and for remembering the V-Mail phone number. One participant (81, F) said, *"It's useful although the guy, the message tells you what to do. But it's just good to have it..."* Each system command is associated with a single button on the phone keypad (e.g., 1 was always

play messages) and illustrated on the instruction sheet; however, in the submenu for listening to messages, we needed to overload the send button with an additional option to re-record the message in case an older adult wanted to modify the original message. This button overload confused several participants; otherwise, the one-to-one mapping between buttons and commands was well-received. Another point of confusion with recording and sending messages stems from prior use of voicemail. Through observations of first-time system use, we noted that five older adults recorded a message and did not press the '#' key, which is required to send the message in V-Mail. These older adults recorded their message and hung up, assuming it sent as with typical voicemail systems.

Several older adults commented that the volume of the e-mail content was not loud enough, particularly in contrast to predefined menu options, with one participant who said, *"...the volume is not high enough. The rest of the message I can hear very clearly"* (84, F). V-Mail interweaves audio recordings for the menu options and e-mail content, and the presentation of these audio files needs to be adjusted so that the volume is uniformly loud. Aside from this, participants responded favorably to the characteristics of the male, low-pitch synthetic voice. Participants commented, *"The speech is fine and the speed is fine, yes but it's going to be louder..."* (84, F), and one liked that the voice was *"clear sounding and a good pronunciation"* (85, M). Interestingly, a participant perceived the synthetic voice for the menu options as sounding like that of her contacts, saying it *"sounds like them talking to me. The computer voice sounds a lot like [Jeff]"* (81, F), similar to what we observed in prototype testing.

Printing was perceived as an important feature in prototype testing, and, for the deployment, we installed two V-Mail-enabled printers in common shared locations at this retirement community because of the existing Internet access in these rooms. However, only two participants printed messages. When asked about this feature in the final interview, several still said they did not know of this capability, even though it was explained at multiple points throughout the study. We presume that distanced printer access was the actual cause of the lack of printing. Just as accessing a computer down the hall presents challenges for some older adults, so does accessing a shared printer. In future deployments, we will examine whether access to a printer in one's home benefits usage. Regarding this, one participant (81, F) said, *"...if it [would] work in my printer here [in my home], yeah."*

5.3.2. Perceived Usefulness. One motivation for introducing V-Mail is to understand whether a voice interface over a traditional phone is a useful alternative for online communication for older adults who currently do not or rarely use computers. While we were only able to recruit two individuals who previously did not use e-mail or a computer and one who did not own a computer nor use e-mail often, these participants and their social contacts provide insights into the potential of this approach. We examine these three participants to understand how V-Mail supports non- and novice e-mail users as well as the reactions to V-Mail by existing e-mail users.

Non- and Novice E-mail Users: One participant (82, F) who did not previously have an e-mail account relied on another resident at the community, who is an e-mail user, to be her intermediary and relay information received by e-mail. This participant learned to use V-Mail and was an active user over the four-week study, printing three messages, sending four messages, and listening to five messages. After the first week, she expressed both comments of perceived usefulness and confusion in using V-Mail, stating *"I think [it is useful]... as soon as I understand it completely it will be very useful."* Her son mentioned that she used V-Mail to print e-mails as a way to remember information and take notes. This participant stated that she would continue to use V-Mail after the study if more of her friends were added to the system because she has

established communication routines with family and is seeking a better way to keep in touch with friends, particularly those using e-mail.

The other participant (88, F) who did not previously use e-mail nor a computer fell ill a few times during the four-week study. Although she did not print messages or listen to messages, she sent four new messages with V-Mail. Moreover, she requested to continue using V-Mail beyond the study period because she saw it as a way to keep in touch with her family members who are all heavy e-mail users. We note that she has Internet access in her apartment and owns an iPad but stated that she does not know how to use it. Her family members were active in the study and coordinated in-person "practice" sessions with her. She commented that V-Mail was "easy to use" and "simple" for sending e-mail messages. She saw V-Mail as being useful for short messages, such as coordinating meeting times, but also for keeping in touch with family members who infrequently answer their cell phones, appreciating the asynchronous nature of e-mail.

Similarly, older adults' social contacts involved in the study explained the benefits of V-Mail for offline older adults. One contact noted the value of V-Mail *"...for an elderly person not on the Internet, I do see the upside benefit."* Another stated, *"This is a great app for senior citizens. My mother-in-law would never touch a computer but this would have worked well for her. I think it is essential to transmit pictures and e-mail messages as it is presently set up to do."*

Another participant (81, F) was a novice e-mail user who just began using e-mail before the study, and she used V-Mail frequently. She initially had difficulty understanding how messages were received, asking, *"Do they hear my voice?"* Although she did not print messages, she soon became one of the most active users, sending 20 messages and listening to 16 messages in four weeks. She stated that she wanted to continue using V-Mail because it is a cost-effective way to communicate with long-distance friends who tend to have long phone conversations. She also desired a notification feature where V-Mail called her when a new e-mail message was received, rather than calling each day to check for new messages.

Existing E-Mail Users: For older adults who already use e-mail, V-Mail offers convenience, simplicity, and increased situational access to e-mail. One participant explained, *"It is right here. I do not have go downstairs or upstairs [to the computer room], the convenience of it"* (81, F). Another participant, who also checks e-mail on her iPad said, *"Well actually it's easier on the phone ... because all you gotta do is dial that number"* (81, F). Another participant said *"I do think it is particularly interesting for older people,"* and then continued to note that it enabled new communication for people who are offline, *"Well, simple because it is a way of ... getting a message and also getting something for someone who might otherwise not hear from you"* (84, F). Given the "work" required to keep in touch by e-mail [Lindley et al. 2009; Hollinworth and Hwang 2011; Hope et al. 2014], V-Mail enables sending spontaneous e-mail messages without accessing a computer. One participant (85, M) explained:

> "One thing of course [is] that we could use this if we were traveling ... If you are away from your computer obviously or you don't want to go through the bother of opening up your computer, turning it on, and putting in your password... You can use it spontaneously, if you suddenly have something 'hey we want to tell you so and such a thing.' Then that's easier to do right then while you are thinking about it. Just grab the phone."

Similarly, one older adult mentioned the utility of V-Mail when she was ill. One participant explained, *"I didn't feel good last week... I was just really tired"* and that V-Mail made it easier because *"I don't have to go downstairs"* (81, F). Another perceived benefit of V-Mail was for coordinating and communicating with offline peers, which

was noted early on by Resnick [1992] but is still a challenge today for older adults. An active computer and e-mail user said, *"If that [V-Mail] were my method for contacting my neighbors here, that would be good..."* (81, F). Providing e-mail access to her offline contacts through V-Mail would help her coordinate events: *"If everybody [here] had been hooked up, that would have been good but see they weren't... And they could have replied on here. I had to call them all about the open house."*

In contrast to these participants, a few participants did not see any benefit in V-Mail over ordinary e-mail. These individuals either did not have any challenges accessing e-mail or had already established sufficient communication routines with their contacts. One participant who is a frequent e-mail user said of his contacts, *"neither them or I are finding this easier than the ordinary e-mail"* (89+, M). Another user said she still checks e-mail on her computer every day and does not find much value in this approach (84, F).

5.3.3. Social and Conceptual Implications of V-Mail. Drawing on the richness of voice and importance of phone communication for older adults [Dickinson and Hill 2007], we are interested in understanding how these perspectives affected interaction with V-Mail, both socially and conceptually. Older adults and their social contacts appreciated the e-mails with voice attachments and e-mails being read aloud. One contact said, *"It is most enjoyable to hear the voices of [Allen] and [Rebecca]..."* Another participant (81, F) said, *"it just seems more personal... than sending a regular email [on the computer]"* (81, F). Several participants explained the benefits of conveying a message through speech. One participant (81, F) said, *"I think you can communicate a little better because you're talking rather than typing out an email. And I think you can explain things better."* Another person (84, F) commented, *"I think it would be easier because I could just chat with her in a sense, telling her what I want to tell her without having to type it all out..."*

As prior research shows, one advantage of composing e-mails on a computer is the ability to reflect on a message before, and even after, sending it [Dickinson and Hill 2007]. One participant (85, M) mentioned the flexibility of sending messages by phone, but noted a tradeoff with the reflection afforded by composing on a computer:

> "I like writing and composing, and e-mail gives me a chance to write friends and others and compose things just the way I want, which of course is one thing you don't do with voice...there are times where it's easier to speak than to write... I guess my main use of the computer is being used on conversations where I can re-edit and look."

V-Mail allows users to replay and re-record messages before sending, yet only three participants used this feature. Furthermore, several participants mentioned that the system was best for sending short messages, such as *"Well, 'hey we forgot to get in touch with you on your birthday,'"* and for *"a quick question someone wants to ask"* (85, M).

Although V-Mail leverages the familiarity of traditional phones, the model of phone-based communication led to some confusion about the asynchronous nature of V-Mail, where participants wondered whether their contact would need to be immediately available to respond. Older adults would often end their e-mail messages with *"call me back later"* or ask the researcher *"What if they don't pick up?"* Although the familiar physical interface of a phone was useful in scaffolding interaction with the system, the social practices of phone-based communication (e.g., expecting communication to be reciprocated through the same medium it was sent, hanging up the phone after recording a voicemail, hearing human speech) influenced and sometimes complicated the experience. For example, the synthetic voice was too realistic for some older adults, resulting in confusion when they perceived it to be their contact's actual voice. These

results open up a broader discussion of how to design effective voice interfaces for older adults, particularly when voice systems support online interaction for individuals who are otherwise offline.

6. DISCUSSION

This research contributes new insights into the design and utility of voice interfaces for older adults, including implications for creating more accessible interfaces, increasing online access, and challenges and limitations of this approach.

6.1. Designing Voice Interfaces for Older Adults

Results from our iterative design and evaluation of V-Mail provide recommendations for the development of similar voice-based systems for older adults. We summarize these recommendations below:

—Use a male, low-pitched synthetic voice, confirming Lines and Hone [2002].
—A natural sounding voice is desirable but may cause initial confusion.
—Support keypad input rather than relying on speech recognition for input, also informed by Patel et al. [2009] and Wolters et al. [2009a].
—Present two to three menu options at a time, with items structured as *option description* then *keypad number*.
—Map menu options to a single keypad value throughout the system, even within submenus, because overloading keys with different commands confused users (i.e., overloading in Usability and Initial Usage section of field testing).
—Have menu options represented on a printed guide.

Although we used these design recommendations within an e-mail client, they could be applied to better support older adults using smartphones with speech interfaces as well as screen readers for older people with vision loss, which we discuss next.

6.2. For Whom and When Is Voice-Based Online Access Appropriate?

Much research focuses on improving interface accessibility for older adults, yet considering new avenues for increasing online access is equally important. Smartphone and tablet computers can improve access to online communication for many older adults, but adoption among the oldest old is low, with less than 10% of seniors age 80+ owning these devices [Smith 2014]. We see V-Mail as a niche approach that may work well for select groups of older adults, primarily individuals who are not current e-mail users due to disability and/or do not have regular access to an online computer.

For many older adults, regular access to an online computer is still a pressing concern due to physical proximity, income, or disability [Smith 2014; Zickuhr et al. 2013; Aging in Place Technology Watch 2011]. V-Mail provides Internet access by phone at a relatively low cost in comparison to the monthly cost of Internet service and maintaining a home computer (e.g., each phone call to V-Mail costs approximately three cents). Such low-cost online access may be important to some groups of older adults, similar to its impact in the developing world [Patel et al. 2009; Sambasivan et al. 2011]. Similarly, phone-based services may be important to older adults who are physically unable to access a computer. One informant from our field work who was unable to participate in user testing indicated that severe mobility challenges prevent her from using the computer, although she would like to. She said that e-mail over a telephone *"would be a miracle"* given the barriers she faces in physically accessing and using a computer. Although most study participants made minimal use of V-Mail during the deployment, primarily because these individuals could access e-mail through other means, the system provided a new way of accessing e-mail for those who were still offline due to cost reasons, mobility limitations, or challenges learning to use computers.

Our data suggest that another user group who may benefit from V-Mail's approach is older adults with vision impairments who are either offline or are experiencing increasing difficulty with graphical or visual e-mail clients. Although we do not report system usage with older adults with vision impairments, study participants noted that V-Mail may be particularly relevant to these individuals. One older adult mentioned her neighbor who is *"100 years old and very active... Her eyesight is going and she thought this would be a great idea, because she likes to keep in touch and they both use email over the years but she can't type anymore or read the messages too well"* (84, F). Another participant mentioned that he does not need V-Mail now but will in a few years, highlighting both the changing abilities in older adulthood and need for technologies to help people maintain online communication in the later stages of life.

For seniors who are already active online, V-Mail may not be an optimal solution. However, our data suggest that V-Mail may, in some cases, help increase situational access when one is traveling or ill and unable to access a regular computer. In this way, V-Mail could potentially fill gaps in one's communication practices rather than be the primary way of accessing e-mail. Additionally, some participants noted that the ease of checking e-mail without needing to open up a computer or visit a shared computer room was an advantage of V-Mail. For older adults without smart mobile devices, such lightweight alternatives may be important for more spontaneous access to e-mail, which could help alleviate some of the "work" of keeping in touch described by older adults who are active on e-mail [Lindley et al. 2009; Hollinworth and Hwang 2011; Hope et al. 2014].

6.3. Supporting Networks with Offline and Online Members

Throughout our data collection period, we observed older adults making great efforts to connect with their offline peers, and, in parallel, we learned of many older adults who wanted to use e-mail but were unable to due to various reasons. For social groups in which some members are still offline, phone-based systems may address important communication and coordination needs. Active e-mail users in our study suggested V-Mail as a way of coordinating events with their peers who do not use e-mail on a regular computer. In turn, others without e-mail were excluded from social events only publicized online, such as one participant who was left out of book club notifications by not using e-mail. Understanding how new technologies can foster late-life social connectedness is a difficult challenge, largely because of the perpetual changes in this demographic. While the current oldest generation is less likely to be online [Smith 2014], future generations will be more connected. However, a topic of much debate (e.g., Hanson [2009]) is whether future generations will be able to stay connected in the later stages of life due to age-related disability. In our research, we have observed this "drop off" in how older adults access computers and go online due to late-life disability, and, as such, we see voice interfaces as providing new opportunities for those who were once active online but face challenges in sustaining computer use due to age-related impairments.

6.4. Challenges and Limitations of Voice-Based Online Communication

Although the present work provides an exploration into the design of voice-based online communication for older adults, it also reveals several social and technical challenges with this approach. We note that one limitation of our field study is that participants made minimal use of the system. We believe there was limited use of V-Mail during the field trial because the older adults who self-selected to participate were primarily already computer owners and e-mail users. Our findings showed that participants who did not own a computer were more active with the system and thought the system was

more useful for their own communication needs. Future deployments of V-Mail will focus on seniors who do not have regular computer or Internet access.

Nonetheless, the present study highlights several social challenges inherent in blending these modes of communication. As we observed, some older adults were confused about the asynchronous nature of V-Mail, expecting the system to have the synchronous nature of phone communication. The development and early field evaluation of V-Mail raises questions of how blending voice-based interaction via phones with asynchronous online communication (e.g., e-mail) may affect older adults' adoption of various communications technologies and their use over time. Computer anxiety and self-efficacy strongly impact older adult's usage of technology [Czaja et al. 2006], yet the key predictors to technology acceptance is ease of use and usefulness [Mitzner et al. 2010]. This prior work shows that older adults already see the value and usefulness of e-mail for communication [Mitzner et al. 2010], and V-Mail may enable adoption of e-mail for individuals without the access or ability to use modern graphical displays. Further, this approach may alter expected patterns of technology adoption, as suggested by the Technology Acceptance Model [Davis et al. 1989], and change the ways in which both telephone calls and graphical e-mail accounts are used. For example, longer-term usage of V-Mail could lead to distinct e-mail practices based on the affordances of voice input via phones, such as sending longer messages because older adults no longer need to type out a message or using the system to convey affect not possible in text-only e-mails (e.g., singing the birthday song). In contrast, using the system over time could lead to more conversational and informal e-mails from older adults' social contacts due to the affordances of having the text-to-speech message played over the older adults' phone.

Although the basic V-Mail system is useful as a proof-of-concept, there are broader technical considerations of this approach. For example, with V-Mail, traditional phones function as an auxiliary interface for e-mail, which requires such systems to work in conjunction with a traditional e-mail account. Our system forwards messages from an existing e-mail account to the voice-based system to allow delivery of a subset of content marked as important by the user, which helps alleviate spam, but may in the long-run introduce challenges with feature support between these interfaces. Handling e-mails with heavy graphical content, HTML forms, or attachments will pose other challenges, and one approach is to identify these messages and provide audio instructions for that type of content (e.g., print this message). Extending our initial system, other features such as sending e-mails to multiple recipients and entering new e-mail addresses over the phone, must be examined. Furthermore, the security and privacy of similar online systems for seniors is a known concern [Garg et al. 2012], and V-Mail could be improved by integrating existing techniques (e.g., two-step authentication with a PIN).

Another limitation of voice-based interaction for older adults is that it relies on hearing ability, and hearing loss is pervasive in older adulthood. We anticipated that normal late-life hearing loss would present a more substantial problem for older adult participants than it did, and hearing loss was not raised as a significant issue in the early prototype usability testing or field study. Although the volume of audio playback in our particular system must be adjusted, we learned that the quality of the synthesized speech was clear and understandable for most participants using their personal telephones. Moreover, older adults are already using adaptive techniques with phones to maintain this critical communication channel (e.g., Bluetooth hearing aids, caption phones), and it is important to integrate and ensure compatibility with these assistive devices.

7. CONCLUSION

E-mail is the most common form of online communication for older adults. As such, much work focuses on designing simplified graphical interfaces to support the needs

of older adults. However, our analysis indicates that age-related disability, limited access to computers, and cost structures still present challenges for many seniors in accessing and maintaining e-mail usage. Grounded in extensive field work, this article examines the design, usability, and appeal of a voice-based interface for e-mail that uses traditional phones. Results from a four-week field study of the developed voice-based e-mail system indicate that this approach has the potential to help older adults maintain e-mail communication in the later stages of life and presents new opportunities for interaction among networks of seniors who are offline. Additionally, we provide concrete and empirically driven recommendations for designing voice interfaces for older adults, hoping to inform and encourage subsequent work that explores the possibilities of using the pervasive and familiar interface of phones to foster new forms of online communication for older adults.

REFERENCES

Aging in Place Technology Watch. 2011. Technology Survey Age 65 to 100. Retrieved from http://www.ageinplacetech.com.

Nuno Baptista, Rui Prior, and Manuel E. Correia. 2009. Telephone interface for the email service. In *Future Computing, Service Computation, Cognitive, Adaptive, Content, Patterns (COMPUTATIONWORLD'09)*. Computation World. IEEE, 437–442.

Michael T. Braun. 2013. Obstacles to social networking website use among older adults. *Computers in Human Behavior* 29, 3 (2013), 673–680.

Kathy Charmaz. 2000. Grounded theory: Objectivist and constructivist methods. In *Handbook of Qualitative Research*, 2nd ed., N. Denzin and Y. Lincoln (Eds.). Sage, Thousand Oaks, CA, 509–535.

Raymundo Cornejo, Mónica Tentori, and Jesús Favela. 2013. Ambient awareness to strengthen the family social network of older adults. *Computer Supported Cooperative Work* 22, 2–3 (2013), 309–344.

Erin Cornwell and Linda Waite. 2009. Measuring social isolation among older adults using multiple indicators from the NSHAP study. *Journal of Gerontol* 64B (2009), i38–i46. Issue suppl_1.

Shelia R. Cotten, George Ford, Sherry Ford, and Timothy M. Hale. 2012. Internet use and depression among older adults. *Computers in Human Behavior* 28, 2 (2012), 496–499. DOI:http://dx.doi.org/10.1016/j.chb.2011.10.021

Sara Czaja, Neil Charness, Arthur D. Fisk, Christopher Hertzog, Sankaran N. Nair, Wendy Rogers, and Joseph Sharit. 2006. Factors predicting the use of technology: Findings from the center for research and education on aging and technology enhancement (CREATE). *Psychology and Aging* 21 (2006), 333–352. Issue 2.

Fred D. Davis, Richard P. Bagozzi, and Paul R. Warshaw. 1989. User acceptance of computer technology: A comparison of two theoretical models. *Management Science* 35 (1989), 982–1003.

Anna Dickinson and Robin L. Hill. 2007. Keeping in touch: Talking to older people about computers and communication. *Education and Gerontology* (2007), 613–630. Issue 33.

Anna Dickinson, Allan 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. *Interacive Computing* 17, 6 (2005), 621–642.

Sara Ferlander. 2007. The importance of different forms of social capital for health. *Acta Sociologica* 50 (2007), 115–128.

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*. DOI:http://dx.doi.org/10.4017/gt.2005.03.03.010.00

Vaibhav Garg, Lesa Lorenzen-Huber, L. Jean Camp, and Kay Connelly. 2012. Risk communication design for older adults. *ISG* ISARC.* Retrieved from http://www.ljean.com/files/RiskOlderAdults.pdf.

Vicki L. Hanson. 2009. Age and web access: The next generation. In *Proceedings of the W4A*. ACM, 7–15. http://dl.acm.org/citation.cfm?id=1535658

Nic Hollinworth and Faustina Hwang. 2011. Investigating familiar interactions to help older adults learn computer applications more easily. In *Proceedings of CHI*.

Alexis Hope, Ted Schwaba, and Anne Marie Piper. 2014. Understanding digital and material social communications for older adults. In *Proceedings of CHI*. 3903–3912.

Juan Pablo Hourcade, Christopher M. Nguyen, Keith B. Perry, and Natalie L. Denburg. 2010. Pointassist for older adults: Analyzing sub-movement characteristics to aid in pointing tasks. In *Proceedings of CHI*. 1115–1124.

Eun Ju Lee, Clifford Nass, and Scott Brave. 2000. Can computer-generated speech have gender?: An experimental test of gender stereotype. In *Ext Abs of CHI*.

Siân E. Lindley. 2012. Shades of lightweight: Supporting cross-generational communication through home messaging. *Universal Access in the Information Society* 11, 1 (2012), 31–43.

Siân E. Lindley, Richard Harper, and Abigail Sellen. 2008. Designing for elders: Exploring the complexity of relationships in later life. In *Proceedings of BCS-HCI*. 77–86.

Siân E. Lindley, Richard Harper, and Abigail Sellen. 2009. Desiring to be in touch in a changing communications landscape: Attitudes of older adults. In *Proceedings of CHI*. 1693–1702.

Lorna Lines and Kate S. Hone. 2002. Older adults' evaluations of speech output. In *Proceedings of ASSETS*. New York, NY, 170–177. DOI:http://dx.doi.org/10.1145/638249.638280

R. C. Littell, G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. *SAS System for Mixed Models*. 633 pp. pages.

James Lubben and Melanie Gironda. 2003. Centrality of social ties to the health and well-being of older adults. In *Social Work and Health Care in an Aging Society: Education, Policy, Practice, and Research*. Springer.

Tracy L. Mitzner, Julie B. Boron, Cara Bailey Fausset, Anne E. Adams, Neil Charness, Sara J. Czaja, Katinka Dijkstra, Arthur D. Fisk, Wendy A. Rogers, and Joseph Sharit. 2010. Older adults talk technology: Technology usage and attitudes. *Computers in Human Behavior* 26, 6 (2010), 1710–1721. Online Interactivity: Role of Technology in Behavior Change.

Karyn Moffatt, Jessica David, and Ronald M. Baecker. 2012. Connecting grandparents and grandchildren. In *Connecting Families: The Impact of New Communication Technologies on Domestic Life*, Carman Neustaedter, Steve Harrison, and Abigail Sellen (Eds.). Springer, 173–193.

Clifford Nass and Scott Brave. 2005. *Wired for Speech: How Voice Activates and Advances the Human-Computer Relationship*. MIT Press, Cambridge, MA.

Chris Norval, John L. Arnott, and Vicki L. Hanson. 2014. What's on your mind?: Investigating recommendations for inclusive social networking and older adults. In *Proceedings of CHI*. 3923–3932.

Neil Patel, Sheetal Agarwal, Nitendra Rajput, Amit Nanavati, Paresh Dave, and Tapan S. Parikh. 2009. A comparative study of speech and dialed input voice interfaces in rural india. In *Proceedings of CHI*. 51–54.

Paul Resnick. 1992. HyperVoice: A phone-based CSCW platform. In *Proceedings of CSCW*. 218–225.

Nithya Sambasivan, Julie Weber, and Edward Cutrell. 2011. Designing a phone broadcasting system for urban sex workers in India. In *Proceedings of CHI*. 267–276.

Sergio Sayago and Josep Blat. 2010. Telling the story of older people e-mailing: An ethnographical study. *International Journal of Human Computer Studies* 68, 1–2 (2010), 105–120. DOI:http://dx.doi.org/10.1016/j.ijhcs.2009.10.004

Chris Schmandt. 1993. Phoneshell: The telephone as computer terminal. In *Proceedings of ICME (MULTIMEDIA'93)*. 373–382.

Aaron Smith. 2014. *Older adults and technology use*. Pew Research Center.

Shima Sum, R. Mark Mathews, Ian Hughes, and Andrew Campbell. 2008. Internet use and loneliness in older adults. *Cyberpsychology and Behavior* 11 (2008). Issue 2.

S. Shyam Sundar, Anne Oeldorf-Hirsch, Jon Nussbaum, and Richard Behr. 2011. Retirees on Facebook: Can online social networking enhance their health and wellness? In *Proceedings of CHI*. 2287–2292.

Maria Wolters, Kallirroi Georgila, Johanna D. Moore, Robert H. Logie, Sarah E. MacPherson, and Matthew Watson. 2009b. Reducing working memory load in spoken dialogue systems. *Interactive Computing* 21, 4 (Aug. 2009), 276–287. DOI:http://dx.doi.org/10.1016/j.intcom.2009.05.009

Maria Wolters, Kallirroi Georgila, Johanna D. Moore, and Sarah E. Macpherson. 2009a. Being old doesn't mean acting old: How older users interact with spoken dialog systems. *ACM Transactions on Accessible Computing* 2, 1 (2009).

World Health Organization. 2015. Definition of an older or elderly person. Retrieved from http://www.who.int/healthinfo/survey/ageingdefnolder/en/.

Kathryn Zickuhr, Lee Rainie, Kristen Purcell, and Maeve Duggan. 2013. How Americans value public libraries in their communities. Retrieved from http://pewrsr.ch/1d8eKBD.

Received April 2015; revised August 2015; accepted October 2015