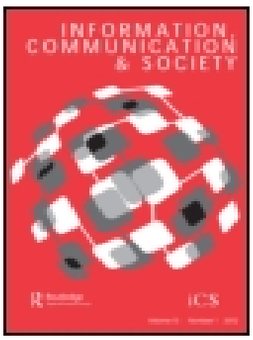

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Information, Communication & Society

ISSN: 1369-118X (Print) 1468-4462 (Online) Journal homepage: http://www.tandfonline.com/loi/rics20

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To cite this article: Barbara Barbosa Neves , Rachel L. Franz, Cosmin Munteanu & Ron Baecker (2017): Adoption and feasibility of a communication app to enhance social connectedness amongst frail institutionalized oldest old: an embedded case study, Information, Communication & Society, DOI: 10.1080/1369118X.2017.1348534

To link to this article: http://dx.doi.org/10.1080/1369118X.2017.1348534

INFORMATION, COMMUNICATION & SOCIETY, 2017
https://doi.org/10.1080/1369118X.2017.1348534

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Adoption and feasibility of a communication app to enhance social connectedness amongst frail institutionalized oldest old: an embedded case study

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ABSTRACT

The risks of social isolation and loneliness are becoming emergent issues for older adults (aged 65+) in industrialized countries, particularly for oldest old people (80+) who are frail and institutionalized. Socially isolated and lonely older people are more likely to experience depression, social disengagement, cognitive and physical decline, morbidity, and early mortality. In response to these significant negative health and socioeconomic costs, research suggests using new technologies to enhance opportunities for social connectedness as a strategy to help alleviate both social isolation and loneliness. In this context, following a participatory design method, we developed an accessible communication app with and for frail institutionalized older adults. To test the adoption of this innovative technology and its feasibility to address social isolation and loneliness, we conducted a two-month deployment of the app in a long-term care home with five oldest old and their relatives. Due to access, recruitment, and ethical challenges, the oldest old are a specially understudied group. Using an embedded case study (based on interviews, psychometric scales, field observations, and usability and accessibility testing) and a recursive approach to technology studies, our findings show that technology adoption is based on a complex set of interrelated factors: social, attitudinal, physical, digital literacy, and usability. We also discuss the feasibility of the app to enhance perceived social connectedness amongst our target population, provided that at least one strong tie is involved and communication norms and expectations across generations are considered.

ARTICLE HISTORY
Received 15 September 2016
Accepted 23 June 2017

KEYWORDS
Oldest old; technology adoption; digital communication; social connectedness; social isolation; loneliness

Introduction

The risks of social isolation and loneliness are pressing issues for older adults (people aged 65+) in industrialized countries (Dykstra, Van Tilburg, & de Jong Gierveld, 2005; Keefe, Andrew, Fancey, & Hallet, 2006; Prieto-Flores, Forjaz, Fernandez-Mayoralas, Rojo-Perez, & Martinez-Martin, 2011; Victor, Scambler, & Bond, 2009). Socially isolated and lonely older adults are more often depressed, socially disengaged, in functional decline, and die prematurely (Cornwell & Waite, 2009; Perissinotto, Cenzer, & Covinsky, 2012;

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Steptoe, Shankar, Demakakos, & Wardle, 2013). Social isolation and loneliness are related, but one can occur without the other: social isolation is a lack of quality and quantity of social ties and low social participation and support, whereas loneliness is a subjective feeling of lacking companionship (Cornwell & Waite, 2009; Perissinotto et al., 2012).

In particular, frail institutionalized *oldest old people* (i.e., people aged 80+ years as defined by the demographic term, see Andersen-Ranberg, Petersen, Robine, & Christensen, 2005), such as those living in long-term care homes, are especially vulnerable to social isolation and loneliness due to poor health, reduced social networks, and low social interaction (Prieto-Flores et al., 2011). Globally, the oldest old are the fastest growing demographic group, projected to account for 19% of the senior population in 2050 (Andersen-Ranberg et al., 2005; United Nations, 2013), but compared to younger older adults (people aged 65–79) are more likely to be unhealthy and institutionalized (Baltes & Smith, 2003). Research focusing on frail oldest old remains scant, because of access, recruitment, and consent (Neves, Franz, Munteanu, Baecker, & Ngo, 2015; Harris & Dyson, 2001).

New communication technologies can help reduce isolation and loneliness by enhancing opportunities for social connectedness (Findlay, 2003; Masi, Chen, Hawkley, & Cacioppo, 2011). Social connectedness is more than social interaction; it relates to meaningful contact with social ties especially with close relatives and friends – it is quality, not quantity of interaction that mitigates the risk of social isolation and loneliness (Cooney, Dowling, Gannon, Dempsey, & Murphy, 2014; Gierveld, Van der Pas, & Keating, 2015). However, when compared to other age groups, older adults are less likely to adopt new technologies (e.g., the Internet), tend to engage in fewer online activities, and are more likely to discontinue use with age (Neves, Amaro, & Fonseca, 2013; Berkowsky, Rikard, & Cotten, 2015). Critical factors for this non- or limited adoption include functional issues, such as lack of digital literacy and accessibility (Neves et al., 2013; Quan-Haase, Martin, & Schreurs, 2016). These issues appear more limiting for frail institutionalized oldest old people, as they report struggling with communication technologies (Neves et al., 2015). As such, following a participatory design approach, we developed an accessible communication app; by engaging institutionalized older adults as co-creators of the technology we captured their needs and aspirations.

This article discusses the adoption and feasibility of this app to enhance social connectedness amongst institutionalized frail older adults. Through a recursive approach, we studied adoption and outcomes of technology for social connectedness, considering that users, contexts, and technologies are related (Greenhalgh & Stones, 2010). We used an embedded case study design to involve different dimensions of analysis, namely the voices of five frail oldest old and their relatives. Our study included interviews, scales, usability and accessibility tests, and field observations collected in a two-month deployment. The richness of this design allowed us to uncover the sociotechnical dynamics of adoption and its implications for social connectedness amongst this understudied group.

The app project: accessible technology to combat loneliness and social isolation

A growing body of literature shows that using new communication technologies can reduce loneliness among older adults (Cotten, Anderson, & McCullough, 2012). In a

meta-analysis of experiments in which the intervention was computer and Internet training, Choi, Kong, and Jung (2012) found loneliness decreased significantly post-intervention, as participants communicated online with family and friends. Loneliness also decreased in older adults after using the Internet for less than a year (Morris et al., 2014). Yet, in a randomized controlled trial, Cotten et al. (2012) found older adults' feelings of isolation did not change with Internet use. Moreover, Sum et al. (2008) showed that older adults reported greater family disengagement when using the Internet to talk to strangers. However, social media can facilitate seeking connection with existing ties and alleviate isolation for older adults (Ahn & Shin, 2013). A few studies also concluded that older adults seek social connectedness by using technology to primarily strengthen existing close ties (Cotten et al., 2012; White et al., 2002) and to bridge geographic distance (Rodríguez, Gonzalez, Favela, & Santana, 2009; Sum, Mathews, Hughes, & Campbell, 2008). Although scant, this research suggests that new communication technologies can increase opportunities for social connectedness and consequently help reduce both loneliness and social isolation among older adults. However, little attention has been paid to frail institutionalized oldest old people – a vulnerable group at high risk of social isolation and loneliness. Even amongst those that used digital technologies, socioeconomic dimensions related to the life course, such as frailty-related institutionalization and reduced social interaction, affect active use (Berkowsky et al., 2015). Although this group is concerned about keeping in touch with relatives through different media, they feel limited by the lack of accessibility of digital devices (Barnard, Bradley, Hodgson, & Lloyd, 2013; Buckley & McCarthy, 2009).

To meet these needs, we developed an accessible tablet-based communication app with and for older adults at risk of social isolation and loneliness, namely for those who are frail, institutionalized, and struggle with standard technology due to motor issues or no digital experience. Our Android tablet-based app supports asynchronous communication,

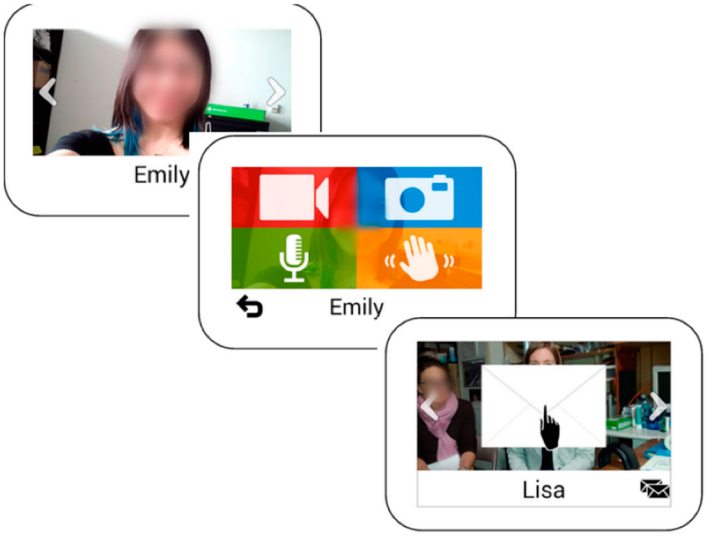

Figure 1. The contact list interface showing one contact (top), the message options interface with four option (middle), and the new message notification interface (bottom).

enabling users to send a 'wave' (represented by a hand icon), which appears to the recipient as a 'I'm thinking of you' email, as well as audio, video, and images captured with their tablet (see Figures 1–4). Recipients receive these as email attachments on their own devices and can reply with text messages, pictures, videos, and audio recordings. Contacts are arranged in a list, which users swipe through as a digital picture frame (Figure 1). The interface has large non-textual touch icons (no typing, only swiping and tapping), to accommodate users with visual and motor issues – as informed by our design and exploratory studies with older adults suffering from chronic pain and impairments due to arthritis and aphasia (Baecker, Sellen, Crosskey, Boscart, & Barbosa Neves, 2014).

This technology was developed through a participatory design and a social shaping of technology approach (MacKenzie & Wajcman, 1999) – the app is an 'outcome of processes of negotiation between social actors, artefacts, interests, and diverse framings of problems and solutions' (Clausen & Gunn, 2015, p. 74). It is the result of prototyping with older adults; for example, the app's asynchronicity derives from their need to control time of communication. The seven-week pilot testing with one participant in a retirement home indicated that the app helped reduce feelings of 'being left out' of family interaction, and allowed us to improve information given to participants and relatives, particularly to avoid jargon and technical terms (Baecker et al., 2014).

To examine the feasibility of this app to help enhance social connectedness amongst frail oldest old, we conducted a two-month deployment in a Canadian long-term care home. By giving residents an accessible technology that allows for different communication modalities, we aimed to analyze the adoption of the tool to supplement social contact.

Contextualizing technology adoption and use among older adults

Due to recruitment challenges, most studies on adoption of novel communication technologies in later life tend to focus on younger older adults – especially in the 65–70 age bracket (Neves et al., 2015). For these individuals, three main factors influence adoption of communication technology: attitudinal, social, and usability (Barnard et al., 2013; Tsai,

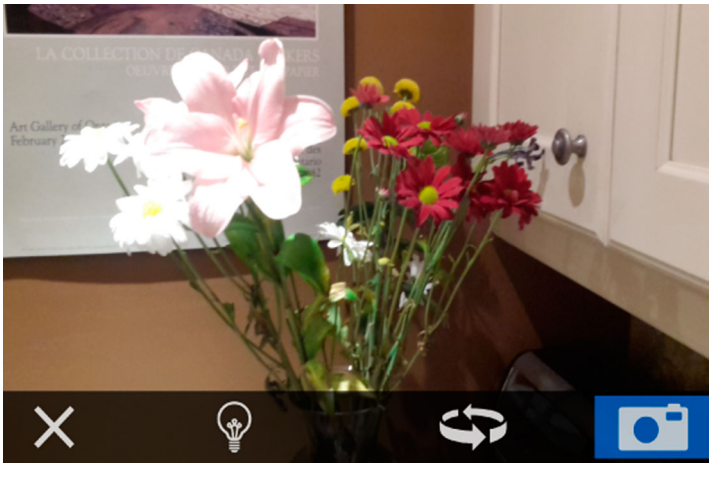

Figure 2. Taking a picture message as the user.

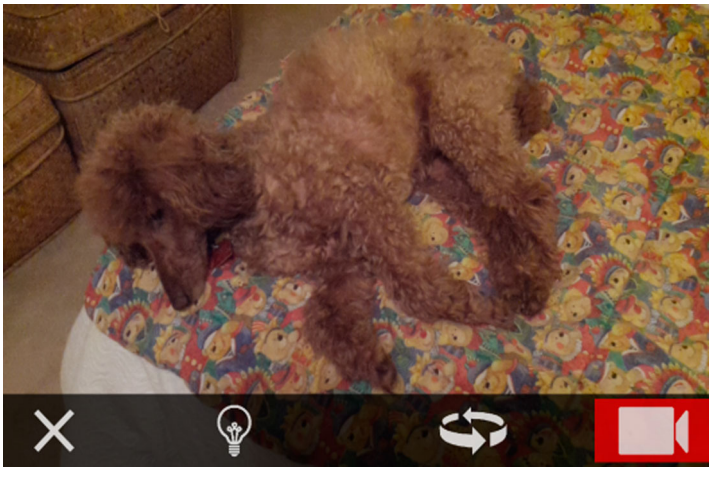

Figure 3. Recording a video message as the user.

Shillair, & Cotten, 2015). Considering attitudinal factors, computer anxiety and initial resistance to technology lead to decreased interest (Vroman, Arthanat, & Lysack, 2015). Perceptions of age ('being too old') also hinder technology adoption (Vroman et al., 2015). Regarding social factors, social support plays a critical role in technology adoption and perception: for example, peer and family use of technology and encouragement positively influence older adults' technology self-efficacy and acquisition (Lam & Lee, 2006; Tsai et al., 2015).

Usability-wise, design, size, and portability affect adoption (Tsai et al., 2015). For example, older adults find tablets easier to use than desktops due to fewer navigation steps (Findlater, Froehlich, Fattal, Wobbrock, & Dastyar, 2013; Tsai et al., 2015). However, Barnard et al. (2013) found that older adults had difficulty using smartphone touchscreens, possibly due to screen-size rather than touch accuracy (Findlater et al., 2013). In addition to lagging in technology adoption due to social and attitudinal issues, current

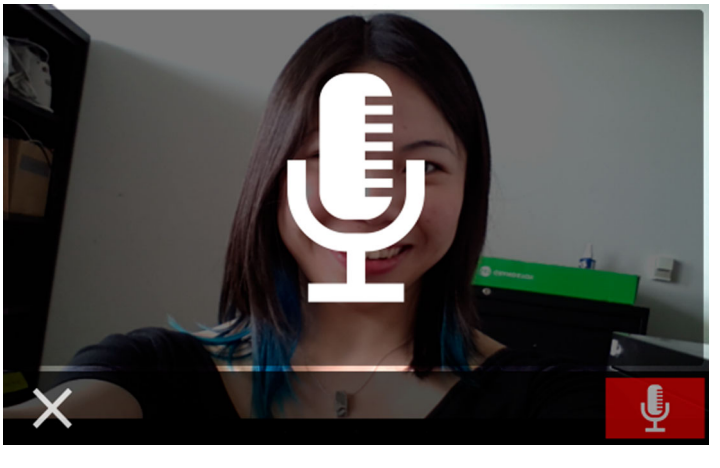

Figure 4. Recording an audio message as the user.

design trends seem to disadvantage older adults (Chen, Savage, Chourasia, Wiegmann, & Sesto, 2013). Nonetheless, tablets seem more usable for older adults than other devices because of direct manipulation of the interface (Murata & Iwase, 2005). Older adults also prefer to use 'standard' tablets to avoid feeling inadequate, which stresses the importance of accessible software, training, and support for impaired older adults (Baecker et al., 2014; Waycott et al., 2014). We add to this literature, by focusing on factors for adoption of novel technologies by the oldest old, considering that technology use is potentially affected by frailty and social aspects, such as access.

To frame adoption of novel technology, the Technology Acceptance Model (TAM) (including 'Perceived Usefulness', 'Perceived Ease-of-Use', and 'Attitude Toward Using/ Behavioral Intention' indicators) and its extensions (TAM 2, etc.) have been used to study older adults (Davis, 1989; Giger et al., 2015). Although TAMs offer a structure to assess technology adoption, they neglect the interplay of psychosocial and contextual factors (Neves et al., 2015; Chuttur, 2009). We lack contextual approaches to overcome these limitations and explore the lived experience of technology appropriation (i.e., embodied interaction between technology and practices) and domestication (i.e., exploration of practical and symbolic elements) among older adults (Dourish, 2004; Quan-Haase, Martin, & Schreurs, 2016). To bring together these perspectives, we follow a recursive approach – that is, integrative and situational – to technology adoption, emphasizing the interrelation between the user's context and technology (Greenhalgh & Stones, 2010). This theoretical and analytical approach examines technologies as used 'in the wild', combining social context, human agency, and technology. Specifically, within this recursive approach, we employ SST – the Strong Structuration Theory (SST), developed by Rob Stones (2005), to refine Anthony Giddens' Structuration Theory (1984). Giddens bridges social structure and human agency by defining social structures as an internalization of what people know and how they understand the world, which in turn is externalized in their actions. However, critics claim that social structures are external to individuals; therefore structure and agency need differentiation (Archer, 1995). To overcome this duality, SST combines internal and external aspects of social structure (Stones, 2005). Adapted to technology studies, SST expands on other recursive approaches, such as Social Construction of Technology (SCOT) and Actor-Network Theory (ANT) (Bijker, Hughes, & Pinch, 1987; Latour, 2005), to theorize the relationship between agency, social structure, and technology. In describing the relationship between context and technology use, SST considers (Greenhalgh & Stones, 2010):

(1) external structures (conditions of action),
(2) internal structures (one's knowledge and capabilities),
(3) active agency (individual action),
(4) outcomes (intended/unintended impacts).

By combining these elements, SST provides a comprehensive framework to study technology adoption and use in later life because it illuminates sociotechnical processes that are embedded in technology development and implementation. Contrary to other recursive approaches, SST does not under-theorize the technical dimension as in some SCOT accounts, nor does it present a linear ontology that excludes established levels of structure and agency as in ANT. For example, while recognizing the importance of having

technologies and human agents as part of the same network as advanced by ANT, SST does not ascribe to the symmetry postulation between people and technology: humans and technologies act differently and should be examined accordingly (Greenhalgh & Stones, 2010). SST guides our assessment of a novel communication app through different voices and circumstances. Drawing on the aforementioned literature and on a recursive framework, we asked:

> RQ1: What sociotechnical factors facilitate adoption of a new communication app by frail oldest old people living in long-term care?
>
> RQ2: Is this a feasible app to enhance perceived social connectedness amongst this population?

Our study focused on the adoption of the app and on outcomes according to its predefined function: social communication with relatives and friends.

Methods

Design and data

We conducted a feasibility study based on a two-month deployment of our app in 2014. Feasibility studies test an intervention previously unexamined, a population for whom we lack in-depth knowledge, and emphasize real-life settings and constraints over ideal experimental settings (Bowen et al., 2009). We studied the feasibility of our app to enhance perceived social connectedness by assessing its 'acceptability' and 'efficacy' (Bowen et al., 2009). For this, we designed an embedded case study – a type of case study that includes different subunits of analysis and integrates qualitative and quantitative data (Scholz & Tietje, 2002). Within a recursive framework, our subunits include a purposive sample of frail oldest old, their relatives, and a long-term care home that mainly caters to Chinese Canadians.

Our study had a pre, mid, and post-deployment stage. Pre-deployment included an individual training session to demonstrate the app and the tablet (the tablet had only our app installed), the administration of a social support and loneliness scale, and a baseline profiling of each participant (social networks composition, social interaction, and sociodemographics). Afterward, we gave participants a tablet with our app to use for two months as they saw fit. One month after the initial training, in mid-deployment, we re-administered the scales and conducted usability and accessibility tests. These tests included tasks and questions about app use (Franz, Munteanu, Neves, & Baecker, 2015). During post-deployment, we repeated the scales and conducted semi-structured interviews with participants and relatives. At least one relative/caregiver was enrolled in the study (attending the training session and interviewed in post-deployment). Throughout the study, we visited participants weekly to collect field observations and to recap the app's functionality, including swiping and tapping gestures since they were inexperienced with touchscreens.

We used the *Abbreviated Duke Social Support Index*, comprising social interaction and satisfaction rating subscales (Wardian, Robbins, Wolfersteig, Johnson, & Dustman, 2012), and the *Short Revised UCLA Loneliness Scale* (Hughes, Waite, Hawkley, & Cacioppo, 2004), which includes yes/no questions about lacking companionship, feeling left out, and feeling isolated. The semi-structured interviews explored their experience with the

app, use and non-use, communication with relatives, and social engagement. The semi-structured, usability, and accessibility interviews lasted around 40 minutes.

We worked with Chinese Canadians for three main reasons: (1) our design and pilot studies were conducted with English-speaking Canadians (Baecker et al., 2014; Neves et al., 2015), and we aimed to assess if our icon-based app would be adopted cross-culturally; (2) the local Chinese community is one of the largest in North America and the largest non-European ethnic origin group in Canada (Lindsay, 2007); and (3) non-European immigrants in Canada are likely to be lonelier than other groups (Gierveld et al., 2015).

We recruited participants with staff, excluding residents with dementia or impairments rendering them unable to consent. We enrolled 5 participants, despite recruiting 10 potential participants (because of health concerns). Recruitment of frail institutionalized oldest old is challenging due to declining health, life expectancy compression, and ethical issues (Hall, Longhurst, & Higginson, 2009), which also affects timeframes of longitudinal studies – our study was restricted to two months, as negotiated with the research locale and ethics committee. Nevertheless, our two-month deployment and our purposive sample were appropriate to our in-depth approach.

Participants

Participants included five frail institutionalized oldest old and five relatives (pseudonyms used throughout). However, our first participant, Angeline, withdrew due to dementia. Although we did not collect mid and post-deployment data of Angeline and relative, we mention her case because health must be considered in the adoption of technologies.

Table 1 details our older participants' sociodemographics. Ages ranged from 81 to 93 ($M = 87.2$; $SD = 4.8$). Four spoke Cantonese and one Mandarin; all had a basic English level. Data were collected in their native languages with the assistance of staff and a Cantonese-speaking researcher. Interviews with relatives were conducted in English as per their preference.

Relatives that participated were: Angeline's granddaughter, a student in her twenties; Bei's daughter, a mid-40s retail worker; Chris' son (mid-40, working in technology); David's son (also mid-40, working in the service sector); and Evelyn's daughter, early forties and unemployed.

Bei described a close-knit social network and frequent visits from her daughter and granddaughter. Chris mentioned his wife (living apart) and son, with whom he communicated occasionally. David talked about his son and daughter-in-law in Canada, and a daughter and grandsons living in the US. He used a pay phone twice a month and his son visited weekly. Most of Evelyn's relatives lived in China, but her daughter visited daily. Overall, their social networks were small and based on family ties.

Table 1. Sociodemographics.

Pseudonym	Age	Gender	Previous occupation	Marital status	Impairments
Angelica	90	F	N/A	Widowed	Stroke survivor; Wheelchair-user
Bei	81	F	Factory worker	Widowed	Parkinson's disease
Chris	88	M	Businessman	Married	Stroke survivor; Wheelchair-user; One-handed
David	84	M	Teacher	Widowed	Stroke survivor; Wheelchair-user; One-handed
Evelyn	93	F	Farmer	Widowed	N/A

Our University REB approved the study and all participants signed an informed consent form. Participants kept the tablet and app at the end of the study.

Setting: long-term care home in a Canadian city

The research locale was a large privately-run long-term care home in Canada (80% of residents being Chinese speakers), characterized by bustling activity:

> There was constant noise; conversation from all directions, carts being pushed up and down the halls, televisions, the occasional cry, intercom noises, and sometimes a building-wide alarm. The wide hallways were often lined with residents resting in wheelchairs and busy staff. (Field Notes)

Each participant shared a room with two other residents, and all mentioned the lack of space and small public areas. There was no computer room. Since their rooms could not accommodate guest seating, we were encouraged to sit on their beds.

Within the care home, all except Bei seemed to have few or no friends. Chris noted 'I don't have many friends … I live here in this very small place'. David had limited interaction with other residents, because he spoke Mandarin whereas most residents spoke Cantonese. And Evelyn confided: 'I rarely get close to those people [residents].' Despite several daily social activities at the care home, their connectedness with other residents seemed low.

Analytic procedures

All interviews were transcribed, including verbal and non-verbal utterances. We analyzed interviews, field notes, and usability and accessibility tests with profiling and thematic analysis. The profiling technique contextualized participants; thematic analysis uncovered themes within and across cases. The thematic analysis was based on a mixed approach (inductive and deductive), that is, themes 'emerged' from the data but also from a-priori themes related to technology adoption (e.g., usefulness). Two authors coded independently to identify categories and then coded together and converged; a third researcher ensured reliability.

All scales were measured in pre, mid, and post-deployment, resulting in three rounds of data points for each participant. To examine differences over time, we analyzed the scales descriptively, and with Friedman and Sign tests (nonparametric techniques suiting our sampling). To assess individual patients over time, clinicians use these scales, as they provide baseline information (Hughes et al., 2004). As more advanced statistical analysis is unfeasible due to our sample size, we follow a similar approach and use individual scores over time to complement the main qualitative data. Frequency of use was measured through a combination of self-reports, logs from the device, and family and staff reports.

Results

Uptake and patterns of communication

Of the five participants, four adopted and used the app. Angeline, albeit enthusiastic at the beginning of the study, did not entirely adopt the app due to health decline. Of the four

active participants, three only used the app and one also used the tablet's built-in browser to search for information online (our app was the only feature purposely installed, but we did not restrict access to the browser app usually delivered with an Android table). Even in a small group, we observed different uptake and use. Following a recursive approach, we contextualize use within each case:

Bei was the most frequent user (four days per week, on average) and enjoyed receiving and sending messages, namely receiving text and sending audio messages. She had a high level of communication with relatives through the app, especially with her grandchildren, even though Bei's daughter reported that her family did not use email as much as WhatsApp. This, along with the asynchronous aspect of the tool and the lack of immediate replies from Bei, especially to her grandchildren, precipitated a decline in the quantity of messages she received. We found similar results with a pilot participant: her grandchildren expected a response within 24 hours, whereas our participant would take longer to reply (Baecker et al., 2014). Nevertheless, Bei continued to use the app frequently until the end of the study.

David used the app three days per week, and (like Bei) was also an active user, that is, liked to receive and reply to messages. He also preferred to receive text and send audio messages. Due to prior experience with computers, David was the only participant to display a sense of ownership of the technology. He changed the keyboard to Chinese and in addition to our app, also used the tablet to 'see news from the world' and translate medication. This additional use of the tablet was merely to search for information online. David showed a high level of communication with relatives through the app, namely with his son, daughter, and grandson. His son reported receiving frequent audio messages and sending pictures and text messages in Chinese because of his father's hearing impairment.

Evelyn also used the app three days per week. Unlike Bei and David, Evelyn was a passive user because she preferred to receive messages and 'look at pictures'. She was also a dependent user, needing her daughter's assistance. This reliance on her daughter seemed connected to her age-related self-perception ('I forget', 'I'm old and … dumb'); perceptions that underline age norms, health, and ability for self-presentation in old age. As such, she reported a medium level of communication through the app: she received several picture and video messages from her relatives living in China and daughter, but sent out few messages.

Chris was the least frequent user (twice every two weeks) and had a low level of communication with relatives through the app. He had one app contact, his son, who sent few messages and did not perceive the tool as useful. Although Chris used it in the first half of the study with a social worker (who reported: 'we used it back in the summer … once a week. And we would send a text message or a picture to his son'), his usage declined when he stopped receiving messages. In the last interview, he said:

> I have used nothing. I don't even need it.

Despite this low level of use, Chris (like Bei and David) also preferred different communication modalities, that is, to receive text and send audio messages. However, their preferences clearly differed from the communication patterns of relatives. Although they preferred text, relatives mostly sent picture messages. Evelyn was the exception; because she was illiterate she preferred pictures.

In brief, we found different usage across our participants and contrasting preferences among relatives. Our older participants used the app at least three days per week, with the exception of Chris as his use declined once he did not receive feedback. While Bei and David were active users, enjoying receiving and sending out messages, Evelyn was a more passive user, preferring to receive messages. Additionally, divergent intergenerational expectations emerged in terms of communication modalities (older participants preferred audio and text, relatives video and pictures) and reply time.

Adopting the app: enablers and inhibitors

Answering our RQ1, the thematic analysis uncovered five main factors that can facilitate but also hinder adoption of communication technology, namely social, attitudinal, physical, digital literacy, and usability factors. Social factors included context, social support, and cultural issues, whereas attitudinal factors related to perceived usefulness of the technology and attitudes toward learning. Digital literacy included prior and current digital skills. Physical factors encompassed motor skills, and usability factors covered ease of use of the app and the tablet. These factors were transversal to all participants but due to the richness of the individual lived experience, we describe these factors within each case:

Although Bei had never used digital technology before, her family was engaged in the project and critical to her app adoption. Both daughter and granddaughter guided her in using the app and motivated her to communicate with relatives. Likewise, Evelyn's family was crucial in her adoption of the app. For Evelyn and Bei, the strong social support given by relatives during the study enabled them to become frequent users and compensated for prior lack of digital literacy. Despite having more dexterity issues, Bei displayed more positive attitudes about learning than Evelyn. Bei reported that sometimes her 'hand doesn't listen' to what she wants to do, but that wouldn't stop her from using the app. For Evelyn, context was also a key social factor in her app adoption, since she only used the tablet in her room to avoid being seen by residents:

> Don't want them to think that it's because the committee board likes me (…) and I don't get along with [other residents].

As observed with all participants, their social setting hampered social engagement. For example, this care facility required locking tablets to participants' beds for security reasons – adding another barrier to usage.

All participants except David were digitally illiterate and struggled with touchscreen gestures, such as tapping and swiping. Although David used a computer before, he noted difficulties with standard desktops after a stroke. But he was the only participant comfortable with the tablet and the app's functions since pre-deployment and even suggested features to enhance communication with grandchildren: voice-to-text and a translation option. Adding to his pre-existing digital literacy, David's attitudes as an independent learner enhanced his relationship with the app. Despite being the most enthusiastic about the app for family communication, his context affected types of messages sent: he did not use the video option frequently 'because things around my bed are always the same'.

In contrast, Chris thought that the app was useful for family communication in the first month of the study but reported low usefulness at the end of the study. All participants

reported high-perceived usefulness of the app for social interaction due to different message types and uses (active and passive); however, the usefulness of the app changed for Chris as he did not get messages from his only contact in the app, his son, as the study progressed. This lack of communication hindered his app use and he became our least frequent user. Nonetheless, his son reported that 'having no place to put it, having locking mechanisms' were the main hindrances to Chris' adoption of the app.

Similar to all participants were cultural, physical, and usability issues. Firstly, cultural aspects hindered adoption: the preset message feature had a waving hand icon (Figure 1), which was perceived as 'cancel' rather than a greeting sign. They interpreted the waving hand-gesture as 'no' in Chinese culture. Although we reiterated its meaning throughout the deployment, their cultural signifier was stronger and this feature seldom used (contrary to our pilot participant, Baecker et al., 2014).

Secondly, participants chose a 10″ tablet and due to their physical impairments, they seemed to compensate for the tablet's weight by resting it on their arms. We also colored the on/off button on the side as they struggled to find it due to sensitivity loss in their fingertips. Although the app (software) was accessible, the tablet (hardware) was not. Thirdly, we found two nuanced usability factors related to the app: *conceptual ease of use* (i.e., on a conceptual level it is easy to use) and *practical ease of use* (i.e., it was easy to complete some tasks). Most felt that with practice, it would be easier to complete the usability tests. In particular, they required time to adapt to touchscreen gestures.

These factors interacted to provide specific contexts of adoption and use. In some cases, social support (engagement of relatives) compensated for lack of digital literacy or prior digital literacy compensated for a social setting that hindered adoption. Although each case highlighted rich individual situations, the five factors were observed across all cases.

Is this app a feasible tool to enhance perceived social connectedness?

To answer our RQ2, two overarching themes emerged from our data: media replacement value and social impact of the app. Replacement related to the value of the app when compared to other communication forms, whereas impact was mostly felt on their perceived social interaction, connectedness, and sense of family involvement.

For Bei, the app had a high media replacement value for communication, replacing letter handwriting, which became difficult with her Parkinson's. However, for her daughter the app only had a medium replacement value since she preferred synchronous communication. Bei reported a high-perceived impact of the app for her social interaction and connectedness as she communicated more often and 'felt closer' to her family through the app. But again, her daughter had a different perspective as the app had only a medium impact on their social interaction.

For David the app had a high media replacement value – he only had to use the pay phone for 'urgencies', using the app for other communication. David emphasized the advantage of the app for interacting with his family more often since he 'didn't have to pay for it' and had multimedia 'options'. His son shared this perception:

> I think it's better than the telephone … but when you need a long discussion on a topic face-to-face is better … but for daily support, it's very helpful …

David contacted his relatives more frequently with the app using it for long 'conversations' and short interactions (e.g., to inform about a doctor's appointment). Additionally, the app enhanced his perceived levels of social connectedness with family in Canada and abroad. David's son also reported that before they would only talk on the weekends but now they communicated during the week as well. In his words:

> Actually, [the app] has already improved our communications and also reduced our family members' load. It also helps him to be active and improved his quality of life.

Both Evelyn and daughter reported a medium replacement value. For Evelyn the telephone was more convenient, although she liked the app to see videos and pictures of grandchildren in China. The daughter preferred a synchronous option. The app had a medium social impact for Evelyn: she saw pictures of relatives frequently, which enriched conversations with her daughter. For Evelyn's daughter, the impact of the app was moderate for social connectedness, as Evelyn mostly used it as a photo album, instead of a bi-directional medium. Nevertheless, her daughter emphasized that Evelyn was now in touch with grandchildren in China and could see 'them growing up'. The daughter also indicated that the app contributed to 'personal discovery':

> She never thought she could use a tablet and see pictures of family … she would say 'Oh, my god, here I can see my great-great-grandson.'

For Chris, the app had low value and the telephone was still the most important medium. Of our participants, Chris had the least contact with relatives – be it in-person or on the telephone. For Chris' son there was a low replacement value because the app 'doesn't do anything better than what he already has [telephone]'. Interestingly, the son suggested that lonely residents would find the app useful but not this dyad. His negative attitude toward the app was chiefly due to its asynchronicity; his disinterest could have affected Chris' perceptions. The app had no impact on Chris' reported levels of social connectedness.

All participants, except Chris, reported feeling more engaged with their families and especially with grandchildren while using the app. Adding to these findings, the psychometric scales serve as illustrative baseline information as our sample does not warrant advanced statistical analysis. Only scores of social interaction and support seemed to increase over time but not significantly ($\chi^2(2) = 4.667$, $p = .097$; $\chi^2(2) = 4.500$, $p = .105$). Of interest are three participants reporting a higher number of relatives living nearby they could depend on at the end of the study, which taps into their perceived connectedness. Relatives, except Chris' son, reported similar outcomes regarding increased family engagement and were 'more relaxed' about sharing contact responsibilities with other relatives.

In sum, the app seems to be a feasible tool to enhance perceived social interaction and connectedness amongst frail institutionalized oldest old people if at least one social tie is involved and responsive.

Discussion

This embedded case study allowed us to examine different dimensions of adoption and outcomes of an app, considering participants, residential context, and relatives. The longitudinal two-month design added to that in-depthness and lessened initial impression

management efforts by participants, such as curated displays of social interaction and technology use (e.g., overly positive narratives of family interaction and the app).

We found different types of use among our seniors, but also different communication patterns across participants and their family. These patterns related to preferred communication modalities (e.g., text vs. pictures) and expectations (e.g., reply time), especially between grandparents and grandchildren. Contrary to relatives with a preference for pictures and video messages, older participants preferred to receive text and send audio messages probably due to their familiarity with the telephone and the written form. Not replying immediately to their relatives was based on their perceptions of appropriate reply time. These patterns did not appear to be constrained by ethnic-cultural values (filial piety, etc.), since also visible in our pilot with a North-American family (Baecker et al., 2014). The restricted living conditions of our participants, however, might have influenced these patterns, inhibiting type and use, and explaining the asynchronicity preference, which was not shared by relatives.

Our findings highlight the complexity of technology adoption among frail institutionalized oldest olds. Social, attitudinal, digital literacy, physical, and usability factors interplayed to provide contexts of adoption. For example, Bei and Evelyn's lack of digital literacy was compensated by strong social support during the study; David's digital literacy mitigated the constraints of his residential settings, including language barriers and living space. Adoption factors interact recursively and cannot be studied in isolation, supporting a SST approach (Greenhalgh & Stones, 2010). Within this approach, context is a cause and outcome of adoption: user's context and technology interrelate through those adoption factors and SST's elements: external structures, internal structures, agency, and outcomes. Firstly, *external structures* included social factors, such as residential settings, family norms and expectations, and cultural signifiers. Secondly, *internal structures* comprised digital literacy, attitudes, physical conditions and usability factors. Thirdly, *agency* was linked to different forms of adoption and use that drew on internal and external structures. Fourthly, *outcomes* in this case related to specific use and implications for social connectedness. These elements worked together to influence adoption of our app and its outcomes.

Findings also shed new light on social, attitudinal, and usability factors uncovered in the literature (Lam & Lee, 2006; Tsai et al., 2015). As in Tsai et al.'s study (2015), staying in touch with family was a major reason for our oldest old to adopt the app. When technology self-efficacy was not already in place, family was critical in encouraging some participants' learning ability. But we also observed how family influenced technology use and expectations through intergenerational norms of communication. Despite lack of digital literacy amongst most participants, we found no evidence of computer anxiety or resistance (Vroman et al., 2015), which might relate to their positive learning attitudes or social support. While existing studies (Barnard et al., 2013; Chen et al., 2013; Findlater et al., 2013; Tsai et al., 2015) evince the importance of design, size, and portability, we found that hardware and software usability issues can counteract: although participants enjoyed the tablet's portability and size and the app design, the hardware required adjustments for people with motor impairments (e.g., coloring on/off buttons). Though older adults prefer using standard tablets to avoid stigma, there is a trade-off between usability and self-presentation concerns (Coughlin, 2010). The SST perspective helps to extend literature on

adoption by showing how critical factors amongst this group impart in a situational perspective.

Notwithstanding inhibitors of adoption, our results suggest that an accessible app is a feasible tool to enhance perceived social connectedness amongst frail institutionalized oldest old (as proposed in Findlay, 2003; Keefe et al., 2006; Masi et al., 2011). But this enhanced connectedness is only visible when at least one strong tie is engaged, as in the case of Bei, David, and Evelyn. Even Evelyn, a passive user, reported feelings of family closeness after using the app. The opportunity to bridge geographic distances and connect with family in China and the US added to this perceived social connectedness among our participants (Rodríguez et al., 2009; Sum et al., 2008). However, for Chris, the app could have made him more aware of his lack of social connectedness as his son did not reply to his messages and his wife did not use digital devices – we were apprehensive about this possibility but staff monitored closely to intervene if negative effects surfaced. If there is no meaningful interaction with social ties, new technologies can be limiting, especially among this group that seems to avoid weak ties such as acquaintances (Cotten et al., 2012; White et al., 2002). Our participants only wanted to include family and were resistant to making new friends in the home. This might relate to this care facility, but supports research showing a tendency for network selectivity in old age (Stevens & Van Tilburg, 2011). For some participants, the app seemed to replace other media (letters and telephone) in communication with strong ties, which departs from prior understandings of digital use such as the Media Multiplexity Theory (Haythornthwaite, 2005). Contrary to this theory that posits those strongly tied use more media to interact, media replacement emerged amongst our group of frail institutionalized older adults. This might result from a combination of specific external and internal structures, agency, and outcomes in later life, as made visible by the SST approach.

Finally, although new communication technologies can enhance opportunities for social connectedness to help alleviate social isolation and loneliness (Findlay, 2003; Masi et al., 2011), different communication norms and expectations across generations – such as communication styles, feedback processes, adjustment periods, and tie closeness or availability – must be considered in the assessment of any similar tool and intervention.

Conclusion

This study advances a situational understanding of frail oldest olds and novel communication apps, contributing to the literature on older adults and technologies. This understanding is crucial as research shows that digital exclusion can lead to social exclusion, since it prevents older adults from accessing information and services that can increase well-being, social participation, and social capital (Rainie & Wellman, 2012; Robinson et al., 2015; Neves, 2015). For example, as public services continuously migrate to online-only, lacking access or digital literacy affects the ability to exercise citizenship rights and autonomy. Older adults are not only less likely to adopt new technologies; they are more likely to discontinue use with age, impairments, and institutionalization. Moreover, the oldest old group is growing and seems particularly susceptible to social isolation and loneliness due to life-course events. Our study also provides new insights on technology-based initiatives to tackle social isolation and loneliness among this group. Yet, it is not without limitations: we relied on purposive sampling, one setting, and a cultural group.

Furthermore, we were limited by a small sample size – although typical for studies with 'hard-to-reach' populations and longitudinal and mixed designs (Bowen et al., 2009), future research should consider larger samples. In addition, this was a feasibility study and not a randomized controlled trial so we cannot measure or isolate effects. For example, one participant was using the tablet for online browsing alongside the app. Although this was not another form of communication with his relatives, as he was not emailing or using social media, rather seeking information (news and translation), his ability to access it could have also affected his sense of social connectedness with relatives. We are not able to account for this possible interplay. Nevertheless, our unique mixed data allowed us to explore technology adoption and outcomes in an under-researched and under-theorized area that needs further attention. While acknowledging recruitment challenges with frail institutionalized older adults, future work should also compare asynchronous and synchronous tools as well as residential settings.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by GRAND NCE as well as by AGE-WELL NCE Inc., both members of the Government of Canada's Networks of Centres of Excellence research program.

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