European Review for Medical and Pharmacological Sciences 2021; 25: 3709-3717

Attitude and perceptions of older and younger adults towards ambient technology for assisted living

M.A. CHOUKOU[1,2], Y. SAKAMOTO[3], P. IRANI[3]

[1]Department of Occupational Therapy, College of Rehabilitation Sciences, Rady Faculty of Health Sciences, University of Manitoba, Winnipeg (Manitoba), Canada
[2]Centre on Aging, University of Manitoba, Winnipeg, (Manitoba), Canada
[3]Human-Computer Interaction Lab, Department of Computer Science, University of Manitoba, Winnipeg (Manitoba), Canada

Abstract. – OBJECTIVE: Healthcare systems are challenged by the rapidly increasing number of older adults requiring services to maintain at-home independence. Technology, such as ambient sensing, has been identified as one potential solution to address these issues. This study's aim is twofold: (1) to explore the general perception of older and younger adults about the transformative role technology can play in their health care as they age, and (2) the generation of health solutions in home care.

SUBJECTS AND METHODS: This study explores data collected from an online survey involving 367 participants from North America and South Asia.

RESULTS: Our analyses yielded that the older adult participants had a generally positive attitude toward employing technologies and that younger adults were less concerned about the use of ambient sensing. Notably, however, they all reported relatively deep concerns about the potential use of homecare service technologies. Our results showed heterogeneity of technology literacy among older adults.

CONCLUSIONS: Both older and younger adults perceive ambient technology for assisted living as a promising solution to enable older adults' at-home independence. Regardless of age, potential users of these technologies showed concerns with possible breaches of individual privacy, personal data, and personal health information.

Key Words:
Ambient sensors, Smart devices, Age, Aging, Perception, Challenge.

Introduction

The increasing proportion of older adults (OAs) is continuously challenging the healthcare systems, especially in the countries members of the Organisation for Economic Co-operation and Development. The global population aged 65 and over are projected to rise from 9% in 2019 to 16.7% by 2050[1]. For example, according to a report released by Statistics Canada in September of 2019, the number of OAs aged 80 and older is expected to triple by 2068[2]. Further, the rising number of OAs requiring healthcare is expected to increase costs and levels of strain on the healthcare system[2,3]. There has been growing interest in developing strategies to allow OAs to remain in their homes as they age for various reasons. Not only do OAs prefer to stay in their homes as long as possible[4,5], but there is potential to decrease strain on institutions providing healthcare. Technology has been identified as one potential solution to address these issues[6].

Over the last three decades, wearable sensors have been introduced in different health-monitoring applications such as wrist-worn devices for heart rate monitoring. Wearable devices have clinical relevance when evaluating rehabilitation programs' efficiency outside the clinical setting (e.g., cardiac rehabilitation[7], home rehabilitation after hip fracture[8]). However, limitations related to the use of wearables have also been noted. Some of the main concerns centre around privacy violations, comfortability, and practicality of the devices, initiation required by the user, feelings of embarrassment or causing a burden to others, the negative effect on the identity associated with reliance on this technology, and a lack of fit between what specific devices can provide and the users' needs[6,9-13].

Although a variety of wearable technologies are currently being used in the home to address the needs of OAs, ambient sensors are a prom-

Corresponding Author: Mohamed-Amine Choukou, Ph.D; e-mail: Amine.choukou@umanitoba.ca

ising alternative and addition to wearable smart devices. Ambient sensors consist of a "set of ubiquitous technologies … embedded in the living space of the patient to monitor and react to his contextual needs by providing computerized assistive services"[14]. Instead of active participation and activation from the user, ambient sensors use automatic behavioural detection to send alerts to end-users; usually caregivers or emergency communication centres[10]. Not only do ambient sensors outline events, but these technologies can provide information on how and why a given event occurred (e.g., tripping over a rug[15]), which is valuable information to follow-up with the patient, and take interventional decisions (e.g., exercise therapy, home accessibility assessment). Ambient sensors can also be used to fill gaps in missing information, such as when a client with cognitive impairment cannot recall "how" or "why" they fell. Such information is critical to prevent future falls by adapting to the home environment. Ambient sensors enable activity, sleep, and fall detection monitoring[14-24], and allow for automated emergency systems (e.g.,[25]) and automated health assessments (e.g., cognitive health assessment[26]). New health applications of ambient sensors are continuously emerging.

To the best of our knowledge, quality attributes such as acceptance, concerns, and satisfaction are not sufficiently explored in research yet, especially on ambient technology for assisted living[10,12,27-29]. The literature points towards acceptance by many caregivers, such as people with dementia[23]. However, the OAs users and their families might not accept such technologies[10,12,30]. Acceptance has been identified as a barrier/facilitator to successful new system implementation[23,31]. Therefore, there is still a need to study and demystify techno-legal privacy and cybersecurity[32]. From a user perspective, there is a need to understand and consider the OAs perceptions about ambient sensors. There are many divergence and discrepancies between users to take into account. OAs' situation may vary in age, education, and geographical location, determining access to education and basic infrastructure (Internet connection, servers). Such a portrait will help understand the readiness of OAs to embrace digital health and adopt ambient sensors as part of imminent healthcare system digital transformation. This portrait will allow us to specify the needs according to geographic location and culture by comparing OAs living in different places with different needs. Therefore, the purpose of this paper is to explore the attitude and perceptions of OAs about health-related ambient sensors. For that purpose, we surveyed a group of younger (YA) and older adults in North America and South Asia, asking them their perspectives and readiness to use ambient sensing.

Subjects and Methods

Survey Design

We created an online survey using Qualtrics (2020, Provo, UT, USA). The survey focused on four main topics: use of general technologies, openness to using ambient technologies; concerns about homecare technologies; fear for using homecare technologies (Table I). Additionally, participants' demographic background information (e.g., age, gender) was collected. The study was approved by the University of Manitoba Joint-Faculty Research Ethics Board. Note we chose to conduct the survey digitally as it is a COVID-19 compliant methodology.

Data Collection

A pool of 300 international participants was targeted using the Amazon M-Turk platform[33], a convenient[34,35]. Participants received $0.50 US as compensation for their time after completing the survey. On average, participants spent 3.03 minutes to complete the survey (*SD* = 1.92). Participants had to be aged 18 years and older to enroll in our study. A total of 498 individuals participated in our survey. Three hundred forty-six participants completed the survey and answered the Gotcya questions correctly. Thus, only 346 responses were considered in our analyses. While we asked about their ethnic background, 146 (42.6%) described themselves as either White or Caucasian, 80 participants described themselves as East Asian (23.1%). Twenty-one of them described them as having a North American background (3.5%), while 15 of them (4.3%) responded as South Asian. Forty-two participants did not provide their answers (12.1%), and the rest were smaller groups (e.g., one English, one Greek and so on). Their age ranged between 20 and 75 years (*M* = 45.54, *SD* = 12.91) while 2 did not respond. Twenty-eight (or 8.1%) of the participants reported that they are 65 or older. There were 210 males (60.7%) and 134 females (38.7%), and 2 (.6%) who chose "Prefer not to say". To maintain higher data quality, we recruited participants who had a higher than 95% approval rate according to Amazon Turk eligi-

Table I. Major constructs explored.

Construct/number of Items	Questions
Use of general technologies: 3 items	"Currently, do you use the following technologies at home for care/support purposes?" Internet, Camera Surveillance, and Camera Surveillance with video recording (*)
Openness to use assistive technologies: 3 items	"Would you be open to installing the following sensors in your home if they were available and useful?" Bed Sensor, Motion Sensor, and Temperature Sensor (*)
Concerns about home care: 3 items	"Imagine you are deciding whether you should have home care or not: Would you be concerned about any of the following? Please note that home care means any regular support from professionals provided at one's home to carry on his/her daily life. This does NOT include yard cleaning or painting as they are not regular nor about daily life. In contrast, someone who runs errands, arranges appointments, meal planning/preparation, toilet care and so on are considered as home care." Concerns regarding Individual Privacy, Personal Data, and Personal Health Status. 5-point Liker scales were used; 1 (Not Concerned at All) to 5 (Extremely Concerned). (*)
Trust in the use of the Internet	One question assessed participants' trust level in the use of the internet "I believe that the internet is secure enough so sensitive personal information can be sent confidentially." A 7-point Liker scale was used; 1 (Strongly Disagree) to 7 (Strongly Agree).
Perceived risk associated with using assistive technologies and their fear of losing information: 3 items asked to OAs only	7-point Liker scales were used; 1 (Strongly Disagree) to 7 (Strongly Agree). • I think I would find it risky to disclose my personal details and health information to the private smart home service provider. • I think I would find it risky to disclose my personal details and health information to the public smart home service provider. • I think I would be scared of using a smart home service because I might lose personal data and privacy.

*Adapted from Alsulami & Atkins (2016)[36].

bility ranking and more than 5000 HITs. 95% of Hit Approval Rate indicates that the participants' responses thus far were approved by the requesters 95% of the time. For example, if an M-Turk worker has completed 100 tasks (e.g., surveys) since their registration with M-Turk, the participants' responses have been approved by more than 95 requesters/the researchers who organized the survey. This index implies that their responses are relatively reliable. Statistical Analyses for data were conducted in SPSS (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp).

Results

Usage of General Technologies

We explored the usage of commonly used technologies (Internet, Surveillance video, Surveillance video with recording). We focused on these technologies as they are widely used in daily lives and are closely related to ambient technologies. Interestingly, the overall pattern suggested that OAs were well familiar with selected technologies (Table II) per recent statistics[37]. AGE-WELL reported a relatively high technology usage by older adults in Canada[37]: 88% of them used the In-

Table II. Usage of general technologies among older and younger adults.

	OA (> 65)			YA (20 to 64)		
	Yes	No	Missing	Yes	No	Missing
Internet	27 (96.4%)	1 (3.6%)	0	219 (69.3%)	96 (30.4%)	1 (0.3%)
Camera Surveillance	16 (57.1%)	12 (42.9%)	0	127 (40.2%)	186 (58.9%)	3 (0.9%)
Camera Surveillance with video recording	20 (71.4%)	8 (28.6%)	0	120 (38%)	193 (61.1%)	3 (0.9%)

All OAs *vs*. YAs comparisons were significant (except for the comparison for missing values).

ternet daily. Over a quarter (29%) use social media for health, wellness, and independence among those daily internet users.

Moreover, 13% of older Canadians now use exercise or activity apps or trackers, and 11% of Canadians aged 50+ use voice-assisted tech at home (e.g., Google Home)[37]. Perhaps, the most exciting part of these results was that only 58% of their participants owned a smartphone in 2019. Still, it increased to 65% when the same question was asked in 2020 amid Covid-19 lockdown: OAs made the necessary adjustment in their lifestyle. The use of – and adoption of –technology is increasing among older adults, and many of them make necessary technological adjustments. Altogether, these indicate OAs' potential readiness to use more sophisticated technologies, namely, ambient sensors, when they perceive such technology necessary. The presence of the current pandemic may have triggered this need.

To further explore how the use of technology by OAs differs from YAs, we compared our results across these two groups. Binomial tests compared the proportions of 'Using-' *vs.* 'Not Using general technologies'. Interestingly, compared to YAs, a significantly larger proportion of OAs used the Internet (OAs: 96.4% *vs.* YAs: 69.3%), Camera Surveillance (OAs: 57.1% *vs.* YAs: 40.2%), and Camera Surveillance with Video at home (OAs: 71.4% *vs.* YAs: 38%; $p < .001$; Table II).

Based on these results, OAs rely on technologies more than YAs do, at least on these three types of technologies we investigated (Internet, Camera Surveillance, & Camera Surveillance with recoding). Further, a relatively high percentage of OAs use technologies. They can adopt new technologies when they perceive it is necessary to do so (indicated by the AGE-WELL poll). In sum, they together indicate the possibility of employing ambient sensors to assist OAs' independent lifestyle.

Openness to Using Ambient Technologies

Next, we explored participants' willingness to use three major ambient sensors (Bed Sensor, Motion Sensor, and Temperature Sensor). Again, Binomial tests explored the proportion difference of the data (i.e., 'Open-' *vs.* 'Not Open to use the relevant technology'). A larger proportion of OAs (67.9%) was open to using Bed Sensor compared to their counterparts (46.2%, $p < .001$). No other significant effects were found (Motion sensor; OAs 64.3% *vs.* YAs 62%, $p = .228$, Temperature Sensor; OAs 78.6% *vs.* YAs 66.5%, $p = .206$) (Table III). Results on openness to the placement of bed sensors in OAs' homes are consistent with the literature, since physiological information collected during the night is informative of many diseases in OAs such as cardiac, respiratory, stress and mental disorders[38]. However, precautions should be taken regarding the efficacy of these biofeedback products[39]. The use of motion and temperature sensors seems less of a priority from a health and aging standpoint. We further explored the patterns in OAs' responses. Chi-square tests were conducted. The proportion of those who are willing to use sensors was greater with temperature sensors only (22 *vs.* 6); χ^2 (1, n = 28) = 9.143, $p = .002$.

Smaller proportions of YA participants' openness towards the use of sensors could be potentially explained by their perceived lower necessity of using technology to monitor health, such as sleep monitoring. The needs of YAs would lean more towards wearables to actively increase their health literacy[40] or for health promotion[41] and disease prevention[41,42].

Concerns About Technology-Enabled Home Care

Participants were asked to imagine they were deciding whether they should have home care or not. We then asked how concerned they would be on; (1) Individual Privacy, (2) Personal Data, and (3) Personal Health Status. 5-point Likert scales

Table III. Openness to use assistive technologies.

	OA (> 65)			YA (20 to 64)		
	Yes	No	Missing	Yes	No	Missing
Bed Sensor	19 (67.9%)	9 (32.1%)	0	146 (46.2%)	166 (52.5%)	4 (1.3%)
Motion Sensor	18 (64.3%)	10 (35.7%)	0	196 (62%)	119 (37.7%)	1 (.3%)
Temperature Sensor	22 (78.6%)	6 (21.4%)	0	210 (66.5%)	106 (33.5%)	0

were used. Mann-Whitney U tests revealed no significant age-group differences with very small effects in the level of their concerns; Individual Privacy (OAs; *Md* = 4.00, *n = 28*, and YAs; *Md* = 4.00, *n* = 315; *U* = 4379.500, *z* = -.064, *p* = .949, *r* = .003); Personal Data (OAs; *Md* = 4.00, *n* = 28, and YAs; *Md* = 4.00, *n* = 315; *U* = 3983.000; *z* = -.891, *p* = .373, *r* = .048); and Personal Health Status (OAs; *Md* = 4.00, *n* = 28, and YAs; *Md* = 4.00, *n* = 316; *U* = 4294.500; *z* = -.268, *p* = .789, *r* = .015). Note all the medians were at 4.00 on 5-point scales indicating that participants had rather high levels of concerns regardless of their age group. While OAs were open to using some ambient technologies (e.g., bed sensors), they were concerned about losing privacy, sharing personal data, and health status. YAs also indicated similar levels of concerns as OAs did, which allows for generalizing that privacy is a main concern in adopting ambient technologies. This result is in accordance with many previous studies[19-21,23,43,44]. However, observations are mitigated. For example, according to Karlsen et al (2017)[6], privacy was not seen as a problem among older adults who already benefited from telehealth as a home care modality. The technology is intended to help them live safely in their own home[6]. In particular, this is the case of people living with dementia who require more assistance from their caregivers[23]. Indeed, the latter requires surveillance technologies to assist the former[23]. The level of concern about technology-enabled home care seems to vary according to the need for monitoring. The safety issues arise, such as falling at night, forgetting a stove on or wandering, and accepting more ambient technologies. Concerns would increase when the need for the caregivers to be alerted is low to absent. The concerns about technology-enabled home care are likely to be dependent on the need to receive home care.

Trust on the Internet for Sensitive Data

Participants' comfort level in using the Internet for their personal data ("I believe that the internet is secure enough so sensitive personal information can be sent confidentially") was assessed using a 7-point Likert scale; 1 (Strongly Disagree) to 7 (Strongly Agree). Once again, OAs and YAs did not vary (OAs; *Md* = 5.00, *n* = 28, and YAs; *Md* = 5.00, *n* = 315; *U* = 3617.500; *z* = -1.607, *p* = .108, *r* = .087). The pooled mean for this item was *M* = 4.46 with *SD* = 1.67. Overall, the data showed that our participants were relatively comfortable with using the Internet for sensitive data.

Fear of Using Ambient Technologies

We assessed older adults' level of concerns related to using systems for ambient technologies. Since such questions were more relevant to OAs but not so much for YAs, we asked these questions only to OAs. Two questions compared their trust levels between 'public-'*vs.* 'private service providers' ("I think I would find it risky to disclose my personal details and health information to the public smart home service provider" and "I think I would find it risky to disclose my personal details and health information to the private smart home service provider"). Results from Wilcoxon signed-rank test showed that the levels of their concern did not vary (z = .000, p = 1.000; *Med* for both questions = 6.00, *Ms* for both questions = 5.50). While their concerns did not vary based on the type of service provider (i.e., public vs. private), we should note that their overall concern level was rather high (i.e., 5.5 in 7-point Likert Scale). Next, since their results did not vary, we aggregated the data for these two questions and entered it as a dependent variable in a simple linear regression model, and used the data for one question as a predictor ("I think I would be scared of using a smart home service because I might lose personal data and privacy") (Figure 1). The model explained 39.4% of the variance; F (1, 26) = 16.869, $p < .001$, R^2 =.394, B = .535. Thus, the perceived fear of trusting service providers partially explained their fear of using smart home services.

Liking of Assisted Lifestyle: By A Person and Technology Communication

Two questions were asked: "How would you like to be assisted in your daily living?" and "By a person/By technology?". The first question was

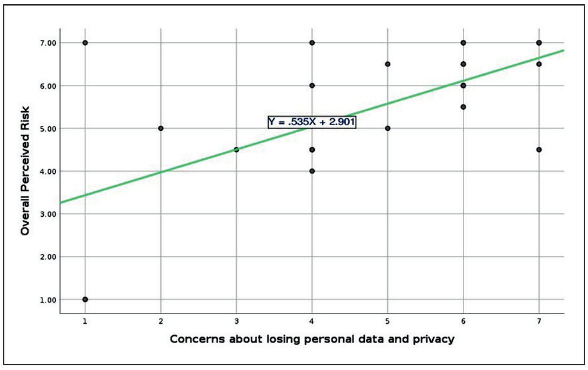

Figure 1. OAs' risk perception regarding using smart home technology for home care was predicted by their fear of losing their personal data and privacy.

asked using a five-point Likert scale where 1 was "Dislike this option very much" and 5 was "Like this option extremely"). A Wilcoxon Signed Ranks test yielded that participants' liking of assisted lifestyle supported by a person (M = 3.61, Mdn = 4.00, SD = 1.066) differed marginally with a medium-sized effect[45] (z = -1.809, p = .070, r = .342) from assisted lifestyle supported by technology communication (M = 4.04, Mdn = 4.00, SD = .922). While a future study with larger sample sizes should investigate these questions again, at least, we found that OAs liked the idea of assisted lifestyle by a technology communication marginally more than they liked assisted lifestyle by a person. While many types of research focus on OAs' concerns about their use of technologies, to understand the full picture of OAs perception and attitude toward ambient technology, understanding their perception towards the alternative (person assisted lifestyle) is also valuable.

Discussion

Compared to YA counterparts, a greater proportion of OA participants exhibited a generally positive attitude toward using ambient technologies to support aging-in-place: a greater proportion of OAs had already adopted general technologies in their daily lives (e.g., surveillance camera), a greater proportion of OA participants were open to use ambient sensors including bed sensors, which a smaller proportion of YA counterparts indicated their openness in adopting these technologies. Thus, our results indicate that OAs are equally or more eager to adopt ambient technologies compared to the counterparts, very probably due to the timing and perceived necessity of use. YAs were asked hypothetically about the potential adoption of technology as they age. They may not have recognized the need for monitoring as they are currently healthy. However, we need to note that our OA participants indicated relatively high levels of fear/apprehension regarding receiving homecare technology service, regardless of the source (i.e., public or private), at least partially due to their perceived risk of losing personal data and privacy. While older adults are willing to try novel technologies, they are not free from the fear of using these technologies. Since ambient technologies will be essential to support independent living for a growing aging population, alleviating OAs' fear of using ambient technologies is an essential next step. Education and access would also facilitate the use the ambient technologies by older adults as an understanding of the digital world and health information would be optimum. Literature indicates that education is a key in improving health literacy, using technology, and adapting to new technologies[46]. Access to education among the existing and future aging population will depend on each country's characteristics such as digital infrastructure, health policies, insurance regulations, and end users' financial situation. Disparities in access to digital care among countries and regions needs further exploration.

Finally, we would like to note that the generalizability of our results could be potentially low. Our OA participants aged between 65 and 70 were able to sign up for M-Turk to participate in online studies: while we needed data from older adults to explore their perception and attitude toward technologies, this created unwanted potential obstacles (i.e., possible sampling error). Specifically, our OA participants could have exhibited a more positive inclination towards using technologies than those OAs who did not participate, as they are more likely familiar with technology anyway. It is essential to recruit OAs for research to incorporate their perspectives but collecting large data from them remains challenging. Thus, based on our experience with the current study, we suggest designing and deploying innovative data collection methodologies to recruit a larger OA population, such as through social media[47], as the use of social media among OAs is steadily increasing[48]. In Canada, 29% of OAs aged 65+ use social media for "health, wellness and independence"[37]. Our OA participants have more positive views toward technologies than the OA in the general population; we interpret our data with caution and speculate further that even those who hold a positive attitude toward technologies fear using the home service system. Then it is expected that general OAs (i.e., not necessarily with a positive attitude toward technologies) could be more reluctant to adopting ambient technologies supporting aging-in-place. For the adoption of these technologies, further exploration for *OAs' awareness and readiness* is needed.

Limitations

Modality of data collection needs to be considered while reading and interpreting the results. In particular, data collected with participants aged 65+ need to be interpreted with caution, as they were older than 65 while participating in online studies via M-Turk, meaning that this subgroup possibly has high digital proficiency and familiarity with extensive internet use. Besides, the fact that we had fewer older adult participants could limit the portrait presented in this article.

Conclusions

Altogether, our results indicated that the use of ambient technology for supporting aging-in-place has excellent potential. Currently, novel technologies are advancing rapidly, and there is an increasing number of options available. In parallel to such development, we need to explore OAs' readiness (Psychological, Cognitive, and Physical) to adopt these technologies. However, we have also learned that collecting data with OA participants is more challenging than collecting data from YA participants. A better approach for research with OAs is needed urgently. In this paper, we deliberately share all our experience with the methodology used and the challenges faced to allow for more documented and transparent research on OAs at risk of social isolation and loneliness, in line with the literature recommendation[49]. A future study exploring means to assuage general OAs' fear/apprehension for emerging technologies, such as interactive workshops, webinars, or informational content distribution, will be a fruitful next step.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Statement of Ethics

This research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. The study was approved by the University of Manitoba Joint-Faculty Research Ethics Board [Protocol # J2020:034 (HS23978)].

Informed Consent

All participants have given their electronic informed consent.

ORCID

Mohamed-Amine Choukou 0000-0001-9477-2412.

Funding Source

This study was supported by funds from The University of Manitoba College of Rehabilitation Sciences.

Authors' Contribution

Dr. Mohamed-Amine Choukou holds the Gerry McDole Professorship in Improved Healthcare Delivery to Rural, Remote and Underserved Populations of Manitoba. Dr. Yumiko Sakamoto is a Research Associate in the University of Manitoba HCI Lab and has extensive experience in social cognition during interpersonal and human-Computer interactions. Professor Pourang Irani is Canada Research Chair in Ubiquitous Analytics, working on a vision for the next generation of analytic tools in which ubiquitous computing will facilitate insight-driven interaction with data anywhere. Dr. Mohamed-Amine Choukou has initiated the study and built the initial draft of the questionnaire and the manuscript. Dr. Mohamed-Amine Choukou and Dr. Yumiko Sakamoto contributed to data collection. All the authors contributed to data analyses, interpretation, and the paper's final version.

References

1) UN. Department of Economic and Social Affairs, Population Division. World Population Ageing 2019: Highlights. New York 2019.
2) STATCAN. Statistics Canada (2019). Population projections: Canada, provinces and territories, 2018 to 2068 [online:https://www150.statcan.gc.ca/n1/daily-quotidien/190917/dq190917b-eng.htm?CMP=mstatcan] (Accessed March 2, 2021).
3) Muscedere J, Andrew MK, Bagshaw SM, Estabrooks C, Hogan D, Holroyd-Leduc J, Howlett S, Lahey W, Maxwell C, McNally M, Moorhouse P, Rockwood K, Rolfson D, Sinha S, Tholl B; Canadian Frailty Network (CFN). Screening for frailty in Canada's health care system: a time for action. Can J Aging 2016; 35: 281-297
4) Binette J, Vasold K. 2018 home and community preferences: a national survey of adults 18-plus. AARP.ORG/Research 2018, August.
5) Turcotte P-L, Carrier A, Roy V, Levasseur M. Occupational therapists' contributions to fostering older adults' social participation: a scoping review. Br J Occup Ther 2018; 81: 427-449.
6) Karlsen C, Ludvigsen MS, Moe CE, Haraldstad K, Thygesen E. Experiences of community-dwelling older adults with the use of telecare in home care services: a qualitative systematic review. JBI Database System Rev Implement Rep 2017; 15: 2913-2980.
7) Sokas D, Petrenas A, Daukantas S, Rapalis A, Paliakaite B, Marozas V. Estimation of heart rate recovery after stairclimbing using awrist-worn device. Sensors 2019; 19: 2113.
8) Pol MC, Ter Riet G, van Hartingsveldt M, Kröse B, de Rooij SE, Buurman BM. Effectiveness of sensor monitoring in an occupational therapy rehabilitation program for older individuals after hip fracture, the SO-HIP trial: study protocol of a three-arm stepped wedge cluster randomized trial. BMC Health Serv Res 2017; 17: 3.

9) Hall A, Boulton E, Stanmore E. Older adults' perceptions of wearable technology hip protectors: implications for further research and development strategies. Disabil Rehabil Assist Technol 2019; 14: 663-668.

10) Lapierre N, Neubauer N, Miguel-Cruz A, Rios Rincon A, Liu L, Rousseau J. The state of knowledge on technologies and their use for fall detection: a scoping review. Int J Med Inform 2018; 111: 58-71.

11) Li J, Ma Q, Chan AH, Man SS. Health monitoring through wearable technologies for older adults: Smart wearables acceptance model. Appl Ergon 2019; 75: 162-169.

12) Neubauer NA, Lapierre N, Rios-Rincon A, Miguel-Cruz A, Rousseau J, Liu L. What do we know about technologies for dementia-related wandering? A scoping review: Examen de la portee : que savons-nous a propos des technologies de gestion de l'errance liee a la demence? Can J Occup Ther 2018; 85: 196-208.

13) Fang YM, Chang CC. Users' psychological perception and perceived readability of wearable devices for elderly people. Behav Inf Technol 2016; 35: 225-232.

14) Aloulou H, Mokhtari M, Tiberghien T, Biswas J, Phua C, Lin JHK, Yap F. Deployment of assistive living technology in a nursing home environment: methods and lessons learned. BMC Med Inform Decis Mak 2013; 13: 42.

15) Bayen E, Jacquemot J, Netscher G, Agrawal P, Tabb Noyce L, Bayen A. Reduction in fall rate in dementia managed care through video incident review: pilot study. J Med Internet Res 2017; 19: e339.

16) Larizza MF, Zukerman I, Bohnert F, Busija l, Bentley SA, Russell RA, ReesG. In-home monitoring of older adults with vision impairment: exploring patients', caregivers' and professionals' views. J Am Med Inform Assoc 2014; 21: 56-63.

17) Stack E, King R, Janko B, Burnett M, Hammersley N, Agarwal V, Hannuna S, Burrows A, Ashburn A. Could in-home sensors surpass human observation of people with parkinson's at high risk of falling? An ethnographic study. Biomed Res Int 2016; 2016: 3703745.

18) Wild K, Boise L, Lundell J, Foucek A. Unobtrusive in-home monitoring of cognitive and physical health: reactions and perceptions of older adults. J Appl Gerontol 2008; 27: 181-200.

19) Claes V, Devriendt E, Tournoy J, Milisen K. Attitudes and perceptions of adults of 60 years and older towards in-home monitoring of the activities of daily living with contactless sensors: an explorative study. Int J Nurs Stud 2015; 52: 134-148.

20) Coughlin J, D'Ambrosio LA, Reimer B, Pratt MR. Older adult perceptions of smart home technologies: implications for research, policy & market innovations in healthcare. Annu Int Conf IEEE Eng Med Biol Soc 2007: 2007; 1810-1815.

21) Gövercin M, Költzsch Y, Meis M, Wegel S, Gietzelt M, Spehr J, Winkelbach S, Marschollek M, Steinhagen-Thiessen E . Defining the user requirements for wearable and optical fall prediction and fall detection devices for home use. Inform Health Soc Care 2010; 35: 177-187.

22) McKenzie B, Bowen ME, Keys K, Bulat T. Safe home program: a suite of technologies to support extended home care of persons with dementia. Am J Alzheimers Dis Other Demen 2013; 28: 348-354.

23) Mulvenna M, Hutton A, Coates V, Martin S, Todd S, Bond B, Moorhead A. Views of caregivers on the ethics of assistive technology used for home surveillance of people living with dementia. Neuroethics 2017; 10: 255-266.

24) Park KS, Choi SH. Smart technologies toward sleep monitoring at home. Biomed Eng Lett 2019; 9: 73-85.

25) Li KF. Smart home technology for telemedicine and emergency management. J Ambient Intell Humaniz Comput 2013; 4: 535-546.

26) Dawadi PN, Cook DJ, Schmitter-Edgecombe M. Automated cognitive health assessment from smart home-based behavior data. IEEE J Biomed Health Inform 2016; 20: 1188-1194.

27) Memon M, Wagner SR, Pedersen CF, Beevi FHA, Hansen FO. Ambient assisted living healthcare frameworks, platforms, standards, and quality attributes. Sensors 2014; 14: 4312-4341.

28) Son H, Park WS, Kim H. Mobility monitoring using smart technologies for Parkinson's disease in free-living environment. Collegian 2018; 25: 549-560.

29) Uddin MZ, Khaksar W, Torresen J. Ambient sensors for elderly care and independent living: a survey. Sensors 2018; 18: 2027.

30) Memon M, Wagner SR, Pedersen CF, Beevi FH, Hansen FO. Ambient assisted living healthcare frameworks, platforms, standards, and quality attributes. Sensors 2014; 14: 4312-4341.

31) Davis FD. A technology acceptance model for empirically testing new end-user information systems: theory and results. MA, USA: Massachussetts Institute of Technology 1986.

32) Al-Shaqi R, Mourshed M, Rezgui Y. Progress in ambient assisted systems for independent living by the elderly. Springer Plus 2016; 5: 624.

33) Amazon. Amazon Mechanical Turk [online: https://www.mturk.com/] (Accessed March 2, 2021).

34) Keith MG, Tay L, Harms PD. Systems perspective of amazon mechanical turk for organizational research: review and recommendations. Front Psychol 2017; 8: 1359.

35) Smith NA, Sabat IE, Martinez LR, Weaver K, Xu S. A convenient solution: using MTurk to sample from hard-to-reach populations. Ind Organ Psychol 2015; 8: 220-228.

36) Alsulami MH, Atkins AS. Factors influencing ageing population for adopting ambient assisted living technologies in the Kingdom of Saudi Arabia. Ageing Int 2016; 41: 227-239.

37) AGE-WELL. COVID-19 has significantly increased the use of many technologies among older Canadians: poll [online: https://agewell-nce.ca/archives/10884] (Accessed March 2, 2021).

38) Dias D, Paulo Silva Cunha J. Wearable health devices-vital sign monitoring, systems and technologies. Sensors 2018; 18: 2414.

39) Peake JM, Kerr G, Sullivan JP. A critical review of consumer wearables, mobile applications, and equipment for providing biofeedback, monitoring stress, and sleep in physically active populations. Front Physiol 2018; 9: 743-743.

40) Goodyear VA, Armour KM, Wood H. Young people learning about health: the role of apps and wearable devices. Learn Media Technol 2018; 44: 193-210.

41) Do TTT, Le MD, Van Nguyen T, Tran BX, Le HT, Nguyen HD, Nguyen LH, Nguyen CT, Tran TD, Latkin CA, Ho RCM, Zhang MWB. Receptiveness and preferences of health-related smartphone applications among Vietnamese youth and young adults. BMC Public Health 2018; 18: 764.

42) Saberi P, Siedle-Khan R, Sheon N, Lightfoot M. The use of mobile health applications among youth and young adults living with HIV: focus group findings. AIDS Patient Care ST 2016; 30: 254-260.

43) Chung J, Demiris G, Thompson HJ, Chen KY, Burr R, Patel S, Fogarty J. Feasibility testing of a home-based sensor system to monitor mobility and daily activities in Korean American older adults. Int J Older People Nurs 2017;12: e1212.

44) Demiris G, Oliver DP, Dickey G, Skubic M, Rantz M. Findings from a participatory evaluation of a smart home application for older adults. Technol Health Care 2008; 16: 111-118.

45) Cohen J. Statistical power analysis for the behavioral sciences. New York Routledge, 1988.

46) Willis SL. Technology and Learning in Current and Future Older Cohorts. In: National Research Council (US) Steering Committee for the Workshop on Technology for Adaptive Aging. Pew RW, Van Hemel, S.B., editor. Washington (DC): National Academies Press (US); 2004.

47) King DB, O'Rourke N, DeLongis A. Social media recruitment and online data collection: a beginner's guide and best practices for accessing low-prevalence and hard-to-reach populations. Can Psychol 2014; 55: 240-249.

48) Bell C, Fausset C, Farmer S, Nguyen J, Harley L, Fain WB. Examining social media use among older adults. In: HT '13: Proceedings of the 24th ACM Conference on Hypertext and Social Media 2013: 158-163.

49) Ige J, Gibbons L, Bray I, Gray S. Methods of identifying and recruiting older people at risk of social isolation and loneliness: a mixed methods review. BMC Med Res Methodol 2019; 19: 181.