Capturing the Adoption Intention and Interest in InOvUS an Intelligent Oven: Segmenting Senior Users to Evaluate the Technology

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Abstract. Cognitive issues associated with aging have become a major concern as it affects how seniors carry on activities of daily living, like cooking. The kitchen has been cited as the key problem area for seniors and it is well cited that almost all senior Americans and Canadians (90%) live independently in their community and wish to remain this way for as long as possible. We propose a solution, InOvUS, which focuses on safety and reducing the risk of fire, burn and intoxication for the rising senior population. We also developed a conceptual adoption model that is specific to the 65+ segment and that is based on existing scales like Consumer Adoption Intention (CAI), Consumer Innovativeness (CI), Technology Acceptance Model (TAM), Perceived Ease of Use (PEOU) and Perceived Usefulness (PU). We evaluate the adoption intention and interest of InOvUS by dissecting seniors' willingness-to-adopt through the application of a cluster analytical procedure. The segments were profiled using K-Means analysis. Our results confirmed that the seniors do not behave like a homogenous group when assessing their need to acquire and use technologies such as InOvUS. Rather, four distinct segments further define the senior population, which differ considerably in terms of their buying intention, perceived usefulness, perceived ease of use, adoption intention and consumer innovativeness.

Keywords: Willingness-to-adopt · Intelligent oven · Safety · Cognitive decline · Seniors

1 Introduction

As the rising number of seniors globally doubles from 12% to 22% between 2015 and 2050, all countries will be facing major challenges to ensure that their health and social systems are ready for this major demographic shift [20]. Cognitive issues caused by aging have become a major concern as it affects how seniors carry on activities of daily living, like cooking. As a matter of fact, the kitchen has been cited as the key problem area for seniors and it is well cited that almost all senior Americans and Canadians (90%) live independently in their community and wish to remain this way for the

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longest possible time. More specifically, in seniors aged 65+ burns and fires have been found to be the 5th leading cause of accidental death [1].

As reported in the American Burn Association [6] 43% of these accidental deaths occur from fire/flame, 34% from scald injuries and 9% from a contact with a hot object. Seniors' limited mobility combined with the physical inability to quickly react and reach safety when faced with danger are one of the main factors that impact their vulnerability to burn injuries. In fact, 23.7% of seniors collapse when they are caught in a fire which aggravates their injuries [17]. Moreover, in a recent leading study on senior patients who were discharged from the emergency unit, it was demonstrated that 68% of all burns among seniors were related to cooking, with the majority of these burns originating in the kitchen [12]. When we take into account that 82.6% of all burn injuries reported actually occurred at home [5], the kitchen embodies a very high majority of all cases of burns.

Indeed, the aging process is said to trigger physical, sensorial and cognitive declines, with all of which have severe impacts on Activities of Daily Living (ADL) and not to mention the side effects of medication. Aging is a complex multi-factorial process that is often associated with increased dependence and requirement for assistance with activities [7]. Even more specifically, some cognitive decline in aging, like problems related to attention and memory, limit people in performing their cooking tasks. As a result, seniors and their family members become strongly concerned with cooking-associated risks (e.g., fire, burn or intoxication) [1].

In Canada there are 5.8 million 65+ Canadians and the number of 80+ has been forecasted to more than double to 3.3 million by 2036 based on a medium growth scenario [23] whereas in the United States, by 2060, the number of 65+ (47.8 million) is projected to double (98.2 million) and 19.7 million will be 85+ [25]. All this making the safety management of cooking risk a vital concern and even more so when taking into account that the vast majority of seniors living independently (90%) want to remain in their environment as long as possible [8]. Consequently, one of the motivations for assistive technologies research is the significant increase of an aging population around the globe which is projected to increase to 2 billion in 2050 [19]. More specifically, the senior population projected growth pattern places a real burden on healthcare facilities and social services, aside caregivers, as ensuring safety of activities of daily life becomes a critical element in helping seniors remain autonomous. This is even more accentuated when seniors engage with what can become a high-risk activity such as cooking. As a result, today there is an increasing number of technologies that focus on specific assistive needs. However, although there have been advances in the sensing and ambient intelligence technologies, the focus has been on the technology side, rather than on building knowledge and methods to understand seniors' willingness-to adopt such technologies.

The research objectives of this paper are: (1) to research the literature to identify the risks and solutions posed for seniors when cooking; (2) to identify the interest in an intelligent oven, such as the Intelligent Oven at the University of Sherbrooke (InOvUS) a safety kitchen solution which focuses on safety and reducing the risk of fire, burn and intoxication, designed to better manage such risks; and (3) to assess whether there are segments within the senior population and examine the ways in which these segments differ in their willingness-to-adopt InOvUS. In fact, the application of a segmentation strategy to our analysis will deepen our understanding of the dynamics of seniors' needs and requirements regarding assistive technologies.

2 Literature Review

The literature was assessed from 2015 to 2018 by conducting a methodological review analysis, a technique which aims at identifying and appraising relevant research to see how researchers addressed a variety of topics ranging from the needs assessment to the conceptual development of intelligent oven as a response to burns, fire and intoxication among the 65+. The focus was on the proof of concept, quantitative and qualitative work, sampling techniques, data collection and data analysis involving the senior population.

Essentially, there are 3 major risks that can emerge while cooking in the kitchen: fire, burn and intoxication [1, 28]. Although, these 3 risks can result in devastating consequences, current research often addresses only fire as a risk in cooking [9, 14, 18, 27] and no global solution for kitchen safety has been reported. As seen in the literature, most work concentrate on identifying the causes and consequences of home fires without addressing specific populations that may present higher risks than others. Yet, a review of studies from 1990 to 1998 on factors that trigger domestic fires demonstrated a correlation between domestic fire sources and the type of people living in the housing unit [9] still no research work has focused on specific populations.

Additionally, the literature has also demonstrated that unattended cooking is the leading main factor responsible for fire in the kitchen [2, 16] and fires related to the usage of the oven, the use of unattended stove burners and the use of portable devices such as toasters [13] have been reported as the three main causes of fires while cooking. Moreover, a three-decade review of senior burn patients showed that for any given type of burn, among the 75+ age category, more serious consequences were reported including higher mortality rates. And although we can extrapolate that intoxication by inhalation is higher in the senior population, the literature has rarely covered this and instead has focused on injuries caused by carbon monoxide [21].

Although it is undisputable that the consequences of fire risks can be fatal to this date, there is a limited range of solutions that have been designed to reduce cooking-related risks affecting seniors in the kitchen. For instance, Doman et al. [11] devised a system that assists seniors avoid potential cooking hazards in the kitchen. By means of video and audio, the system transmits reminders to senior-users to follow the correct steps when performing a cooking task but this system has not been conceived to react in the advent of a dangerous situation. The literature also brings forth other systems that involve the help of a human. For instance, Sanchez et al. [22] designed a system to aid people when they are engaged in a cooking task. The system works by reacting when a potential dangerous situation is detected through rapid variations in temperature and smoke found in the kitchen. In response to rapid temperature variations, the system will send notifications with camera shots to caregivers and to the fire department, activate exhaust fans and a fire-extinguishing suppression system. Although it can be argued that this type of system can help mitigate risks from cooking activities, systems with camera surveillance are generally not well perceived and adopted by users due to the intrusion into the user's private life [15]. This is a critical issue because in the provision of care high usability and acceptance are essential for a system to be recognized as a practical assisted living system.

Some work has been done involving oven monitoring as a part of larger systems to track ADL. More specifically, Alwan et al. [3] focused on measuring oven usage whereas Wai et al. [26] approach was based on detecting unsafe usage of the oven. In the conception of intelligent systems, the key is to understand the user environments such as the surrounding kitchen temperature and senior activities, in order for the system to provide adaptive assistance to seniors. As such, both of these systems use embedded temperature sensors to measure the burner status, ultrasonic sensors to detect the presence of a pot and electric current sensors to detect the usage of the oven and levels of abnormality in the kitchen [26]. Still, similar with Sanchez et al.'s [22] system, these two systems could be considered intrusive, as they either use visible-light cameras or require modifications to the oven to install sensors.

A study by Yuan et al. [29] investigated an automated top oven-monitoring system that used thermal cameras to track dangerous situations. More precisely, this system alerts users or caregivers when a hazardous situation arises. What differentiates this system from Alwan et al. [3], Wai et al. [26] and Sanchez et al. [22] is that Yuan et al. [29] system is based on thermal imaging instead of visible-light cameras, thereby respecting user privacy. In fact, thermal cameras do not process regular images but are constricted to important limitations: they are sensitive to cooking heat and smoke. Although this system addresses the privacy violation concern by using a thermal camera, which in theory would increase the likelihood of such system to be accepted and used by seniors, the accuracy in detecting a dangerous situation in the kitchen environment that is subject to smoke and cooking heat is an issue. In fact, Demiris et al. [10] work showed that for an assistive living system to be accepted and used by seniors three major concerns need to be removed: privacy violation, sensor visibility and accuracy of the assistive living system.

Moreover, the aim of assistive technologies used in assistive living solutions is to provide hands on support to ensure that seniors live safely and independently in their homes. However, in all related work, it is obvious that the systems designed to manage or reduce cooking risks have major limitations that can impact senior's willingness to use and adopt such systems. Paradoxically, although the risks associated with age-related cognitive decline may positively influence seniors to adopt such systems, the invasion of privacy by the cameras of these systems can severely attenuate the interest and willingness of seniors to adopt them. It is clear that with the rapid rise of an ageing population, the numerous statistics on fires, burns and intoxication risks, as well as the restrained technologies available in the market all call out to the urgent need to develop solutions to improve senior quality-of-life while meeting their needs. Despite the fact that systems could provide the best assistive technology solution, if these systems are not easily accessible and user-friendly and if they do not correspond to the needs and concerns of seniors, such systems would not be accepted.

Moreover, to the best of our knowledge, only a limited number of assistive technologies to assist seniors in the kitchen have been developed. However, these previous studies have shown greater interest on the technology side, rather than on building safety (i.e., reducing the risk of fire, burn and inhaling) and knowledge from the perspective of the user. Indeed, almost all related work focuses more on evaluating the technical mechanisms and validating algorithms than on evaluating the end-user perspective of such systems. There is a greater importance that has been attributed to the accuracy of activity recognition for assistive technologies as the accuracy rate varies depending on the number and type of activities, the number and location of sensors used and the activity recognition models that detect ADLs often achieve lower accuracy than models that detect ambulatory activities [30]. Consequently and most importantly, none of the studies seen in the literature addresses the interest and/or adoption intention from the end-user perspective and the studies that focus on the technology side are mostly conducted by using young adults or rely on simulation which might not represent the true activity and reactions of a senior person [30].

To this end, this study aims at proposing an intelligent oven, or a sensor-based cooking safe system, called 'InOvUS'. InOvUS is designed to identify hazardous situations by monitoring and measuring relevant parameters around the oven to specifically reduce the risks of fire, smoke inhalation and burn. As such, InOvUS' fire parameters include concentrations of Volatile Organic Compound (VOC) and Alcohol gases that are found in the cooking environment. The burn parameters are derived from the relative humidity, utensil temperatures, burner temperature and presence of utensils on the burner for burn by splash and contact. Lastly, the concentration of Carbone monoxide (CO) gas is observed for intoxication by gas/smoke. These parameters are extracted based on an in-depth risk analysis [1]. Additionally, a segmentation strategy is incorporated to our analysis as key insight on the needs, requirements and interests of end-users have the ability to provide decisive information to ensure the effective development and design of assistive technologies.

3 Methodology

As the world senior population is projected to about 2 billion by 2050 [19] attention and a more profound understanding of seniors' complex needs is a necessity. As such, this paper is part of a framework for understanding the various components of seniors' willingness-to-adopt InOvUS.

In a previous exploratory phase, we developed a conceptual model to test senior's willingness-to-adopt, which was defined by five constructs in a past study [24]: *Buying Intention* (BI), *Perceived Usefulness* (PU), *Perceived Ease of Use* (PEOU), *Consumer Adoption Intention* (CAI) and *Consumer Innovativeness* (CI). Consumer Adoption Intention (CAI), a 4-item scale, measures and relates to whether consumer level of understanding of a product is strong enough to potentially lead to purchase. As such it is a good metric to utilize as a base to measure, 'Willingness-To-Adopt'. Consumer Innovativeness (CI) has to do with the level of comfort consumers find with the use of new products, in general. The literature has also consistently shown that both the perception of ease of use (PEOU) and usefulness (PU) on the part of consumers are important aspects of a decision of whether to adopt a new product (CAI) or buy it (BI), and therefore are also incorporated in our model. Our conceptual model is specific to the 65+ segment and it is based on existing scales for each construct. Figure 1 shows our research model.

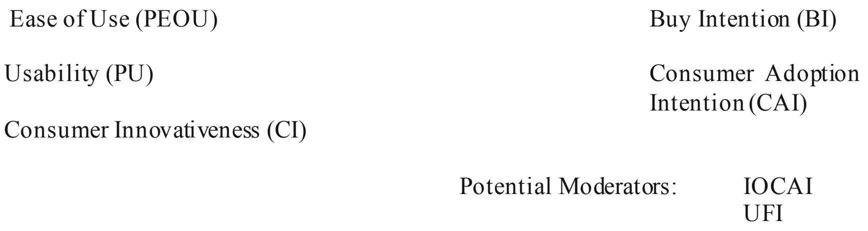

Fig. 1. Model Used: CAI: Consumer Adoption Intention; PEOU: Perceived Ease of Use; PU: Perceived Usefulness; CI: Consumer Innovativeness; IOCAI: Impact on Consumer Adoption Intention (by family members, caregivers); UFI: Usefulness for Family Influencers; BI: Buying Intention.

In total, these five constructs were captured by 14-items. The reliability for each construct was obtained using Cronbach's α and results show that our scales hold satisfactory internal consistency with all Cronbach's α above 0.750 and the Bartlett's Test of Sphericity has an associated p-value of 0.000 thereby confirming the statistical significance of our model. Participants were asked to rate their agreement with each statement on a 5-point scale anchored by "strongly disagree" and "strongly agree". The questionnaire, the detailed factor analysis, and key statistics can be consulted in our previous study [24].

The main objective of this research is to further investigate the interest and needs on an assistive technology such as InOvUS, to be able to better understand the design and development of intelligent ovens for an aging population. Therefore, our methodology is designed to evaluate the adoption intention and interest of InOvUS by further dissecting seniors' willingness-to-adopt through the application of a cluster analytical procedure. The underlying purpose is to see if there are segments within the senior population and examine the ways in which these segments differ in their willingness-to-adopt InOvUS. As such, we use the K-Means analysis to profile the segments. The applicability of segments in the senior population will derive a clearer understanding of seniors' needs and interest to assist and inform the design, development, and implementation decisions of InOvUS.

4 Results

In total, 57 seniors (65+) aged 65 to 95 participated in our study to test our model on seniors' adoption intention and interest of InOvUS as an innovative safety kitchen system. The key demographics of our sample can be examined in Table 1.

Table 1. Demographics of the sample

Gender	Male	44	Female	13
Driver's License	Yes	50	No	7

Age	65 - < 70	70 - < 75	75 - < 80	80 - < 85	85 - < 90	90 - < 95	95+
	20 (35.1%)	18 (31.6%)	12 (21.1%)	3 (5.3%)	3 (5.3%)	1 (1.8%)	0 (0%)

General Health	Excellent	Very Good	Good	Fair	Poor
	17	22	16	1	

Physical Health or Emotional Problems Interference with Social Activities	None of the time	A little bit of the time	Some of the time	Most of the time	All of the time
	42	12	1	1	

Marital Status	Single	In couple	Married	Divorced	Separated	Widow
	4	9	22	9	1	12

Income	0 – 10,000	10,001 – 15,000	15,001 – 20,000	20,001 – 25,000	25,001 – 40,000	> 40,001	not disclose
	1 (1,8%)		13 (22.8%)	3 (5,3%)	9 (15,8%)	30 (52,6%)	1

To test the presence of segments in our sample, K-Means analysis was performed on the regressed factorial scores. The minimal sample size to be included in a cluster analysis is 2^k cases, where K is the number of variables [4]. As there are five factorial scores, the minimum sample size require to perform our analysis is 32.

Results confirm that the seniors do not behave like a homogenous group when evaluating their necessity to acquire and use technologies such as InOvUS. Rather, four distinct segments further define the senior population, which differ considerably in terms of their interest and willingness-to-adopt InOvUS (Cluster Mean Square BI $\alpha = 0.000$, Cluster Mean Square PU $\alpha = 0.000$, Cluster Mean Square PEOU $\alpha = 0.000$, Cluster Mean Square CAI $\alpha = 0.000$, Cluster Mean Square CI $\alpha = 0.000$). In other words, the senior population is composed of four distinct segments that differ considerably in terms of their buying intention, perceived usefulness, perceived ease of use, adoption intention and consumer innovativeness.

The results in Table 2 enable us to start profiling our segments. The most predominant segment in terms of size is segment 2, it is composed of 40% (23/57) of the senior population. 28% (16/57) of seniors are in segment 1, 23% (13/57) fall in segment 3 and 9% (5/57) of seniors form part of segment 4.

One of the benefits of conducting a segmentation analysis on InOvUS is to see how seniors' needs, attitudes and beliefs towards an intelligent oven varies. In more technical terms, these differences are explained by distance found between segments, whereby the distance measures how far apart two segments are from each other. Results in Table 2 show that all of our segments have different interests in InOvUS as there is a fair distance that exists between each segment. Specifically, the greatest distance is noted between segment 3 and 4 (3.646), as these are the two groups that are the least similar to each other followed by segment 2 and 4 (2.793). The differences in InOvUS are more accentuated between seniors in segment 1 and 4 (2.581) than between seniors in segment 1 and 2 (2.304).

Table 2. Segment constitution and segment distances between final segment centers

Segment	Number of cases in each segment	1	2	3	4
1	16.000		2.304	2.360	2.581
2	23.000	2.304		2.660	2.793
3	13.000	2.360	2.660		3.646
4	5.000	2.581	2.793	3.646	

Next, results in Table 3 show how the four segments differ according to their buying intention, perceived usefulness, perceived ease of use, adoption intention and consumer innovativeness.

Table 3. Segments scores per willingness-to-adopt construct

	Segments			
	1	2	3	4
BI REGR factor score	.51169	−.67989	.48647	.22528
PU REGR factor score	−.72958	−.00871	1.12250	−.54376
PEOU REGR factor score	.55983	−.95010	.69214	.77946
CAI REGR factor score	−.01527	.19519	−1.12175	2.06754
CI REGR factor score	.75754	−.26440	−.19059	−.71236

Compared to other segments, seniors forming part of segment 1 attribute the higher importance to CI (0.75754) and their willingness-to-adopt InOvUS is the least affected by PU (−0.72958). CI is the most important element for this segment, this is why we called them the *early adopters*. However, PEOU (0.55983) and BI (0.51169) also play a role in their interest level on assistive technologies such as InOvUS. Segment 2 is the segment that is the most difficult to convince in terms of BI (−0.67989), PEOU (−0.9501), and CI (−0.2644) and these seniors are almost indifferent towards PU

(−.00871). The key characteristic that differentiates them from all other segments is how picky they are when it comes to BI, this segment is called the *technology cautious*.

Segment 3 sees the greatest PU potential in what they can do with InOvUS (1.125) than all other segments. Conversely, they are also the ones that are the least concern about CAI (−1.12175). This segment is called the *technology driven*. For that group, PEOU is the other element that they will take into consideration when evaluating assistive technologies to help them mitigate reducing the risk of fire, burn and inhaling. Lastly, CAI (2.06754) is the key criteria, out of the five constructs that define the willingness-to-adopt, that influences segment 4 in their decision to adopt InOvUS but also when compared to all other segments. Therefore, CAI is what this segment values the most. We call them the *technology vigilant*. PEOU (0.77946) also sets apart seniors who belong in segment 4 as benefits is what interests this segment. Segment 4 also includes seniors that will rely the least on CI (−0.71236) and PU (−0.54376) to evaluate InOvUS.

5 Discussion

The results of our study show that to understand the needs of seniors and thus optimize the technology development, there are greater benefits to be achieved by segmenting the senior users as opposed to undertake a general approach to the needs assessment and interest of an assistive technology solution. More precisely, in our past study we demonstrated that PEOU was the driving force behind seniors' buying intention of InOvUS and that PU influences seniors' actual CAI [24]. However, by pursuing a segmentation approach we were able to see that seniors' interests and needs are actually more complex and can only be well defined by profiling each segment that constitutes the seniors. Additionally, this research demonstrates how different variable sets of the willingness-to-adopt (i.e., *Buying Intention* (BI), *Perceived Usefulness* (PU), *Perceived Ease of Use* (PEOU), *Consumer Adoption Intention* (CAI) and *Consumer Innovativeness* (CI)) impact each segment.

Indeed, the observation of the characteristics that differentiate the *early adopters* (segment 1) reveals that for 26% of the senior market being the first in their circle to adopt a technology such as InOvUS is a key driver behind the interest they will have towards such a device and in their desire to adopt it. After all, the early adopters are trendsetters, therefore, it is important for marketers and developers to understand that early adopters are not interested on how an intelligent oven can enhance their cooking effectiveness, improve their cooking performance or productivity, but that they are rather interested on the new technological advancements that an intelligent oven has to offer including its actual technological features and benefits. These are the key elements that will transform an interest into an adoption resolution. Yet, it is important that the early adopters perceive InOvUS as an intelligent oven that is easy to understand and use.

The technology cautious, segment 2, are seniors that have high expectations regarding what an assistive technology can do. Consequently, in order for them to be interested in adopting and using InOvUS requires that developers possess a thorough understanding of their technological needs for their expectations to be surpassed.

Otherwise, the technology cautious will continue to be reluctant to use InOvUS and they constitute 40% of the senior users. Additionally, as technology does not necessarily speak to them, as they need to see that how their needs can be met, they are negative as to how easy it can be to use and understand an assistive technology.

The key technological features for the technology driven, which represent 23% of the senior population, is what InOvUS can do to help them improve their cooking effectiveness, performance and productivity. These are the technological features that will make them seek to adopt an assistive technology when evaluating assistive technologies to help them mitigate reducing the risk of fire, burn and inhaling. For this segment, understanding what are the trade-offs among the costs and benefits of buying and using InOvUS, or knowing how they will have to change their behaviors to attain the potential benefits of such a technology or even what are the benefits they could expect if they bought it, are the least important technological concerns they can have compared to all other segments. For this group, an assistive technology has to be easy to use, clear and understandable as well as easy to get the technology to do what they want it to do for them to be willing to adopt it.

For the technology vigilant, an assistive technology has to be designed in such a way that the relevant trade-offs between the costs and benefits of using it are very apparent including whether or not a senior person has to change their behavior quite significantly to attain its potential benefits of using it. If developers are successful at this, the technology vigilant, which includes 9% of the senior users, will be inclined to adopt and use assistive technologies as that is the main driver influencing their willingness-to-adopt InOvUS and other assistive technology. Compared to other segments, the easiness to use InOvUS will seal their willingness-to-adopt it. Consequently, it is important that technology vigilant see that InOvUS is easy to use, easy to work with for them to get InOvUS to do what they want it to do and that InOvUS is easy to understand, as these seniors tend to pay more attention to features, in terms of usability, than their peers.

As we can see, our results show that there are more practical implications for targeting seniors by applying a segmentation approach than a general approach. Indeed, segmenting the senior users provides better guidelines for developers on how to address the technology development needs.

6 Conclusion and Limitation

Seniors have specific capabilities, limitations and experiences that affect their ADLs. Assistive technologies such as InOvUS have the potential to provide value in providing proactive support in mitigating the safety management of cooking risk. This is a vital importance especially when we consider that there will be two billion seniors in 2050 and that the vast majority want to live independently and remain in their environment as long as possible. The overall goal of our research work is to develop solutions for seniors, such as InOvUS, compensating for cognitive declines associated with aging. Our research instrument was designed to collect seniors' view on the development of the next generation of assistive technology to improve safety and reduce risks in seniors' home environment. However, many challenges remain to develop technologies that meet senior's needs, support them in performing everyday activities such as cooking, protect their independence and security. Indeed, one of the challenges to the effective design and development a technology like InOvUS is the understanding of the conceptual model of seniors and involving them at an early stage of development early enough in the technology development or design process. The present study makes a contribution that addresses this void. Our methodology of developing a willingness-to-adopt conceptual model that is specific for the 65+ population combined with a segmentation approach provides a unique opportunity to develop user needs studies and concept development for technological products while increasing the odds of seniors' willingness-to-adopt and use such products.

There is a limitation with regards to this study that pertain to a response bias that might have occurred as participants completed the questionnaire on a paper format. There was a section that had all of the 22 original willingness-to-adopt items divided in two pages. This type of survey formatting could have introduced an acquiescence response bias. This means that it is likely that a similar response pattern could have resulted in this section.

Moreover, we recommend that this study be repeated with seniors 65+ living in residence with full and partial autonomy as well as with seniors living at home. Furthermore, we will further evaluate our willingness-to-adopt model to develop other metrics aimed at obtaining an in-depth understanding of seniors' needs and requirements regarding in-home safety assistance.

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