

Identifying Smart Home Needs and Readiness in the Elderly: Segmentation by Residentially-Based Lifestyles

Jiyeon Yu, Angélica de Antonio, Elena Villalba-Mora

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Jiyeon Yu^{1*}; Angélica de Antonio^{1*}; Elena Villalba-Mora^{1*}

¹ Universidad Politécnica de Madrid Boadilla del Monte ES

*these authors contributed equally

Corresponding Author:

Elena Villalba-Mora

Universidad Politécnica de Madrid
Campus de Montegancedo
Boadilla del Monte
ES

Abstract

Background: Globally, the elderly population is increasing rapidly. In Spain, the population aged 65 years and older reached 18% of the total population in 2020. Smart homes encompass a wide variety of functions, including assistive technologies that may help older people stay healthy and independent. Older people are not a homogeneous group and, as with any assistive technology, the functions must match the real needs of the target users to ensure adoption.

Objective: In this study, as a step forward towards the adaptability of smart home technology, we present a method to analyze the practical needs of smart home functions for older people. An online survey was conducted on residentially-based lifestyles, health conditions, and smart home function preferences, targeting older adults in Spain.

Methods: A total of 102 valid responses were analyzed. Then, we classified the elderly group according to their residentially-based lifestyles, and analyzed the preferences and needs of smart home functions for each group.

Results: Four clusters emerged according to the information provided by the older adults who participated in the survey: 1) High quality of life and independent life; 2) Poor quality of life; 3) Social centered life; 4) Creative and personal-centered hobbies at home. Based on this, each particular group's needs for smart homes were discovered and we could estimate how prepared each group is to embrace different aspects of technology. As a result of the analysis, the top priority smart home functions for each group were identified.

Conclusions: This research helps to understand the practical user needs of smart homes as an assistive technology for older people and provides a method to anticipate and prioritize the required functions for a specific user according to the characterization of the cluster it belongs.

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Original Paper

Identifying Smart Home Needs and Readiness in the Elderly: Segmentation by Residentially-Based Lifestyles

Jiyeon Yu¹, Angelica de Antonio^{1,2}, Elena Villalba-Mora^{1,2, 3*}

¹Madrid HCI Lab, Research Group on Human-Computer Interaction and Advanced Interactive Systems, Universidad Politécnica de Madrid (UPM), Boadilla del Monte, 28660 Madrid, Spain

²Centre for Biomedical Technology (CTB), Universidad Politécnica de Madrid (UPM), Pozuelo de Alarcón, 28223 Madrid, Spain

³Centro de Investigación Biomédica en Red en Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN), 28029 Madrid, Spain

* **Correspondence:** Elena Villalba-Mora, elena.villalba@upm.es

Abstract

Background: Globally, the elderly population is increasing rapidly. In Spain, the population aged 65 years and older reached 18% of the total population in 2020. Smart homes encompass a wide variety of functions, including assistive technologies that may help older people stay healthy and independent. Older people are not a homogeneous group and, as with any assistive technology, the functions must match the real needs of the target users to ensure adoption.

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Keywords: older people, smart homes, assistive technology, user needs, user segmentation, residentially-based lifestyles

Introduction

Population aging is a global challenge [1]. It is of utmost importance for older people to stay healthy and independent in their homes where they feel comfortable. To support independent life, technology that can quickly detect hazards and respond appropriately in emergency situations becomes crucial for older people living in their own homes [2].

Smart home technology has made significant advances in the fields of remote management and elderly assistance [3]. Smart home services improve comfort, safety, and security at home with IoT

technology and allow the elderly to receive medical treatment or check their health at home [4]. It is becoming a very important technology to support healthy and independent lives for older people [5]. Ultimately, this technology can help to improve Quality of Life in older population [6].

However, most older adults perceive smart technologies to be difficult to use, and there may be many barriers to adopting the technology in real life. In addition, older people may not be even aware of how the smart home functions can meet their needs. For these reasons, it is expected that commercialization and widespread use of smart homes for the elderly will take still some time [6]. In order for this technology to pervade their lives, older users should not be classified into a single group, but should be subdivided according to the service purpose, so their special needs can be identified and satisfied accordingly [7].

In this study, we segment older people according to their lifestyles within residential facilities, where smart homes are used. That is, our segmentation will be based on residentially-based lifestyles (RBL). Some studies claim that lifestyles related to a specific domain can provide meaningful results for segmentation of the population under study [8]. For example, Thøgersen [9] considered food-related lifestyles for analysis related to food consumption, and Sanquist et al. [10] proposed use of energy-related lifestyles as a domain to identify patterns of energy consumption.

This study applies questionnaires on RBL and smart home needs developed in a previous Korean study [11]. We have already confirmed that this is a tool that can lead to meaningful results through previous investigation. Using this survey tool, we present a method for segmenting the elderly in Spain and analyzing the smart home needs of each group, so their readiness and needs can be evaluated and used to improve considerably the user adoption of smart home technologies.

Figure 1 presents the study process. The resulted outcomes are: (1) RBL based segmentation of older adults in Spain, (2) analysis of the needs of smart home functions for each segment. This study proves that segmentation according to RBL and analysis of smart home needs through the questionnaire and method presented is useful to analyze the perception and detailed needs of smart homes, which are essential as assistive technologies for the elderly.

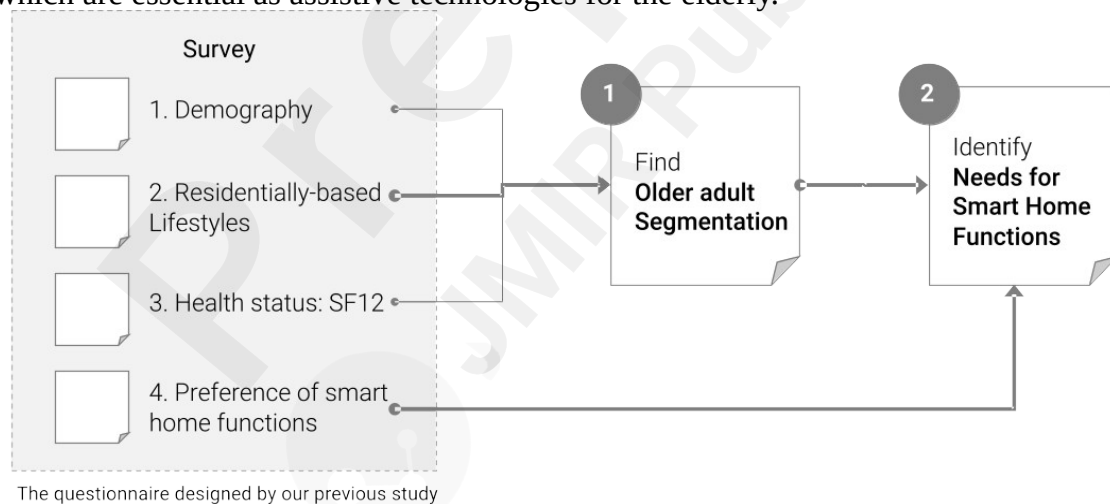


Figure1. Study process.

Materials and Methods

Participants

This study targeted the elderly in Spain, a representative country facing an aging society. In the previous Korean study, the survey was conducted with elderly aged 65 or older. Considering that the Internet usage of the elderly in South Korea decreases at higher ages than in Spain [12, 13], we set the lower age limit at 60, five years below that of South Korea.

Therefore, the survey subjects were designated as senior citizens aged 60 and over, living in Spain

(Figure 2). The criteria for a valid response were: (1) Age of 60 or older; (2) No missing answers to questions; (3) Responses received within the specified survey period. We collected a total of 102 valid answers over five consecutive weeks. Regarding the proportion of women and men, our sample is 41 males and 61 females, which corresponds to a 4.1:6.1 ratio, similar to Spain that is 4.5:5.5 [14]. The average age of the respondents was 68 years old.

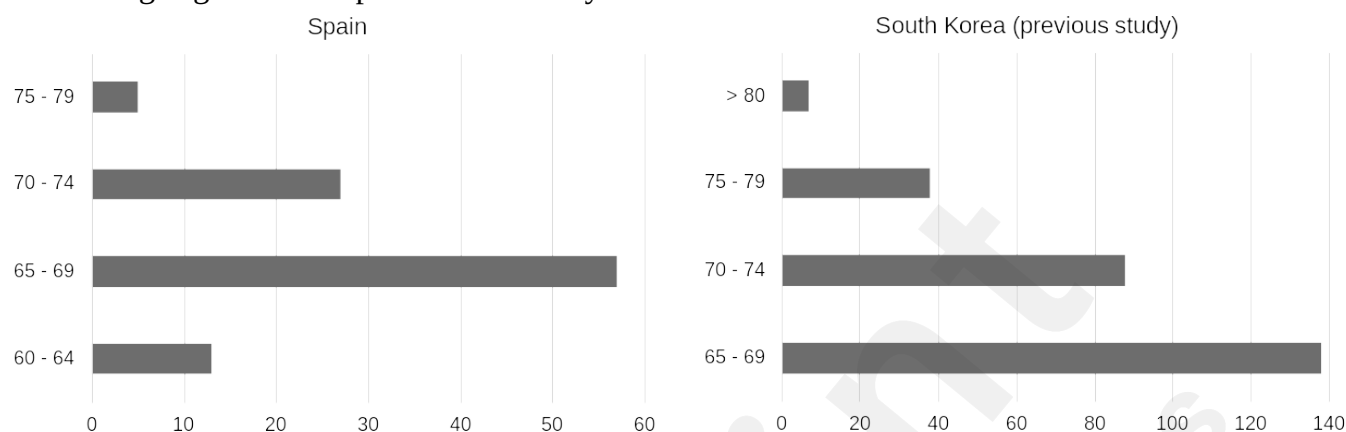


Figure 2. Age comparison of participants in two countries.

Instruments

The questionnaire used in the study was developed in the previous Korean study [11] and consisted of a total of four sections: (1) demographics; (2) residentially-based lifestyles (RBL); (3) health status; (4) smart home function preferences. The demographics section consisted of eight questions: gender, age, marital status, resident type, caregiver, time spent out of home, education, and monthly income. Questions for RBL were constructed by analyzing existing relevant studies [15–23] and explored the following: (1) quality of home life and needs for daily life; (2) daily home activities; and (3) social events at home.

In addition, the health status was checked through the Short Form Health Survey (SF-12) of 12 items, so that the physical and mental health of each group could be compared after segmentation by RBL questions. With proven reliability and validity, the SF-12 was developed to measure the health status of respondents in a short time. This survey calculates a physical component summary (PCS) and a mental component summary (MCS), which can be assessed based on the US average of 50 points. A high score means good status of physical or mental health [24].

Finally, regarding smart home function preferences, functions considered were based on a systematic review of smart home research [25]. Based on the results of this study, we could extract 26 functions in 8 categories. This section of the questionnaire demands the participant to select from 1(not necessary) to 5(most necessary) how much each of the 26 smart home functions is needed.

All questionnaires were carefully revised by experts in gerontology research and smart home technology.

Procedure

Data collection was conducted as an online survey, a non-face-to-face survey tool. This survey used convenience sampling, which is one of non-probability sampling. And the questionnaire was distributed among elderly in different areas of the Madrid region via day care centers. The questionnaire was translated into Spanish, and the questionnaire was distributed via Google Forms, together with a guide on the purpose of the study and the information that the survey responses would not be used for any other purpose except for research. Responses were collected over five weeks. We did not gather any personal data that could be linked in any way to the identity of the respondents, therefore according to the rules of our Ethical Committee at Universidad Politécnica de Madrid, there was no need to request the prior approval of the committee. The survey does not

require any personally identifiable data (name, phone, email, and personal address) and does not require going through a login process in which personal information may be collected. Also, respondents could voluntarily choose whether to participate in the survey or not; therefore, starting the survey constitutes a valid consent to participate. The collected responses were stored and analyzed anonymously. Moreover, the collected answers were not used for any purpose other than research analysis, and all initial data of the survey were deleted after analysis. No interventions or treatments were included in this research.

Data analysis

The items on RBL were dimensionally reduced to main factors through Principal Component Analysis (PCA). For reliability analysis of the resulted factors, internal consistency was verified with Cronbach's alpha value. K-means clustering based on these RBL factors could segment Spanish elderly respondents with similar patterns of RBL and characteristics. After segmentation by RBL, the demographics and health status of each group were compared. And then, through the questions on smart home function preferences, the needs for smart home functions for each group were measured. To verify significant differences among groups, chi-square validation was applied to the demographic data, and ANOVA analysis was used on the health status scores (PCS, MCS) and smart home needs scale.

Results

Principal component analysis of RBL

The mean Kaiser-Meyer-Olkin (KMO) of the RBL items was 0.604. After removing factors with commonalities of low scores, principal component analysis was performed. In Bartlett's sphericity test, all items were found to be meaningful (455.893***, $p=0$). Principal component analysis (PCA) was selected to reduce the dimension to the main factors of each assessment item and analyzed by Varimax rotation. Table 1 shows the PCA results of the RBL items. Five principal factors were extracted by allowing factor loadings greater than 0.4: (1) Independent living and quality of life; (2) Social event at home; (3) Regular life routine; (4) Creative and healthy; (5) Time spent alone. The reliability of each factor was confirmed by Cronbach's alpha value. Although Cronbach's alpha values of three factors were measured somewhat lower, those were accepted considering that the questionnaire was newly developed in the previous study and the survey was conducted with a limited number of people. Each factor has at least an eigenvalue of 1, and the total variance explained by these five factors is 58.69%.

Table 1. Principal component analysis on residentially-based lifestyles (RBL questions [11])

	1	2	3	4	5
RBL question	Independent living and quality of life	Social event at home	Regular life routine	Creative and healthy	Time spent alone
My chronic disease doesn't affect the quality of my daily life.	0.828				
My medication or treatments doesn't affect the quality of my daily life.	0.827				
Generally, I feel satisfied with my daily life.	0.718				
I don't need help to clean the house, wash the dishes or do the laundry.	0.695				
I am satisfied with how I share my time.	0.599				

I eat at least 3 times a day.	0.415				
Invite friends		0.788			
Visits of another type		0.784			
Family visit		0.636			
My diet is varied and balanced.			0.732		
I am not sleepy during the day.			0.707		
Take care of my house			0.489		
Cook or bake				0.732	
Creative and artistic activities				0.646	
Do light exercise				0.539	
Use a computer or smartphone or tablet at home					0.775
Read books, newspapers or magazines					0.626
SS loadings	3.051	2.034	1.674	1.625	1.593
Proportion Var	17.949	11.965	9.847	9.56	9.372
Cumulative Var	17.949	29.914	39.761	49.32	58.692
Cronbach's alphas	0.8	0.651	0.489	0.424	0.449

Segmentation based on RBL

Based on the five RBL factors, a hierarchical cluster analysis by Ward's method was conducted, and it was judged that classification into four clusters was the most stable and convincing. After that, final clustering was performed through K-mean cluster analysis. Table 2 shows the clustering results segmented into the four groups. ANOVA analysis was conducted to explore differences in RBL factors by clusters. The analysis shows that all factors are significantly different: 1. Independent living and quality of life (50.80***, $p < 0.001$); 2. Social event at home (6.83***, $p < 0.01$); 3. Regular life routine (21.29***, $p < 0.001$); 4. Creative and healthy (5.98**, $p < 0.01$); 5. Time spent alone (25.43***, $p < 0.001$). Figure 3 shows the differences among the factors for each cluster.

Table 2. Cluster analysis for RBL of older people.

	Cluster 1 (n=47)	Cluster 2 (n=5)	Cluster 3 (n=25)	Cluster 4 (n=25)	F-value
Independent living and quality of life	0.45	-3.16	0.07	-0.28	50.80***
Social event at home	-0.36	-0.19	0.67	0.04	6.83***
Regular life routine	0.36	1.05	-1.05	0.16	21.29***
Creative and healthy	-0.08	0.07	-0.48	0.62	5.98**
Time spent alone	-0.47	-1.08	0.04	1.06	25.43***

*** $p < 0.001$, ** $0.001 \leq p < 0.01$, * $0.01 \leq p < 0.05$.

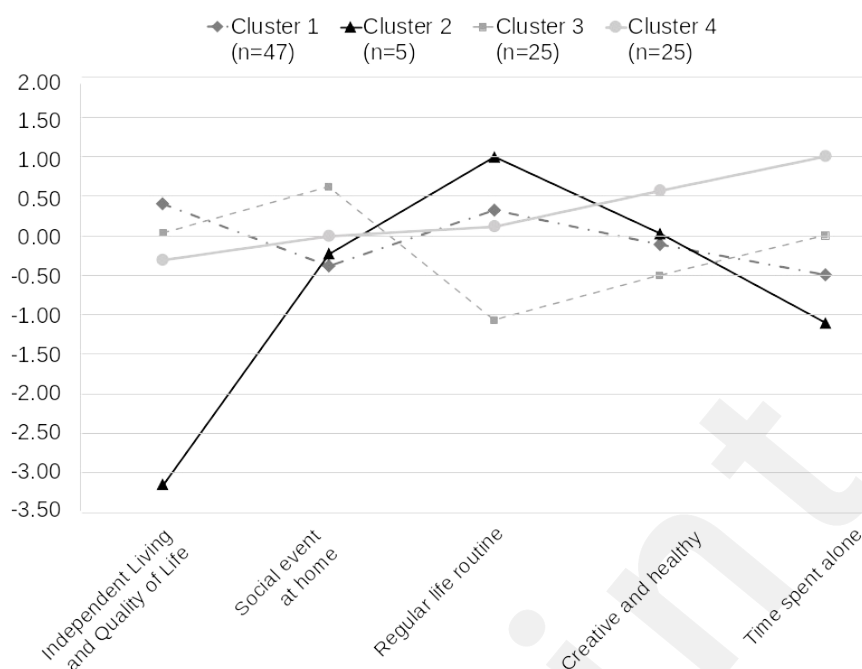


Figure 3. Clusters for older people by the RBL.

The lifestyle patterns and characteristics of each group were defined according to the five factor values in the RBL.

- Cluster 1 “High quality and independent life” is a group that shows the highest quality of life and independent living ability.
- Cluster 2 “Poor quality of life” has the lowest quality of life compared to other groups and the least amount of time spent on hobbies at home alone. It also displays the most regular life routine.
- Cluster 3 “Social centered life” has a lifestyle with the most frequent visits by friends and family to their homes and the least regular life routine.
- Cluster 4 “Creative and personal-centered hobbies at home” is a group of people who have many creative hobbies and activities that they can do alone.

Table 3 shows the demographic characteristics of each group. There is a significant difference in gender of each group. Clusters 1 and 4 have more females with a male to female ratio of approximately 1:2, and cluster 2 is made up of 100% females. Cluster 3 is the only group in which the proportion of men is higher.

The MCS score of Cluster 1 “High quality and independent life” is the highest, the PCS score of Cluster 4 “Creative and personal-centered hobbies at home” is the highest. On the other hand, Cluster 2 “Poor quality of life” has the lowest both PCS and MCS (Table 4).

Table 3. Demographics of each cluster.

	Cluster 1 (n=47)	Cluster 2 (n=5)	Cluster 3 (n=25)	Cluster 4 (n=25)	
Residentially-based lifestyles	They have independent life, high QoL and low social activity at home	They have low QoL and less personal time	They have many social events and low time spent alone	They spend a lot of time at home and do various activities alone	X²
Cluster name	High quality of life and independent life	Poor quality of life	Social centered life	Creative and personal-centered hobbies at home	

Gender	Male	15 (31.9)	0 (0.0)	17 (68.0)	9 (36.0)	12.92**
	Female	32 (68.1)	5 (100.0)	8 (32.0)	16 (64.0)	
Age	60 - 64	6 (12.8)	0 (0.0)	4 (16.0)	3 (12.0)	6.64
	65 - 69	26 (55.3)	4 (80.0)	13 (52.0)	14 (56.0)	
	70 - 74	14 (29.8)	0 (0.0)	6 (24.0)	7 (28.0)	
	75 - 79	1 (2.1)	1 (20.0)	2 (8.0)	1 (4.0)	
Marital status	Married	32 (68.1)	2 (40.0)	18 (72.0)	13 (52.0)	16.34
	Single	3 (6.4)	2 (40.0)	5 (20.0)	2 (8.0)	
	Widowed	3 (6.4)	1 (20.0)	2 (8.0)	4 (16.0)	
	Separated	9 (19.1)	0 (0.0)	0 (0.0)	6 (24.0)	
Resident type	Alone	12 (25.5)	2 (40.0)	6 (24.0)	11 (44.0)	11.94
	with Spouse	30 (63.8)	2 (40.0)	14 (56.0)	10 (40.0)	
	with Family	4 (8.5)	0 (0.0)	4 (16.0)	4 (16.0)	
	Others	1 (2.1)	1 (20.0)	1 (4.0)	0 (0.0)	
Caregiver	Spouse	33 (70.2)	2 (40.0)	18 (72.0)	13 (52.0)	12.16
	Son or daughter	3 (6.4)	1 (20.0)	2 (8.0)	5 (20.0)	
	Other family	1 (2.1)	0 (0.0)	3 (12.0)	1 (4.0)	
	Friends or neighbor	5 (10.6)	1 (20.0)	1 (4.0)	2 (8.0)	
	Others	5 (10.6)	1 (20.0)	1 (4.0)	4 (16.0)	
Spent time out of home	less than 1 hour	2 (4.3)	2 (40.0)	2 (8.0)	4 (16.0)	10.53
	1 hour - 3 hours	23 (48.9)	3 (60.0)	12 (48.0)	10 (40.0)	
	3 hours - 6 hours	18 (38.3)	0 (0.0)	8 (32.0)	8 (32.0)	
	more than 6 hours	4 (8.5)	0 (0.0)	3 (12.0)	3 (12.0)	
Education	Basic	1 (2.1)	1 (20.0)	2 (8.0)	0 (0.0)	8.32
	Intermediate	8 (17.0)	2 (40.0)	4 (16.0)	4 (16.0)	
	University	38 (80.9)	2 (40.0)	19 (76.0)	21 (84.0)	
Income (euro)	less than 1,500	5 (10.6)	1 (20.0)	2 (8.0)	2 (8.0)	5.50
	1,500 - 2,000	7 (14.9)	1 (20.0)	3 (12.0)	4 (16.0)	
	2,001 - 2,999	15 (31.9)	3 (60.0)	7 (28.0)	10 (40.0)	
	more than 3,000	20 (42.6)	0 (0.0)	13 (52.0)	9 (36.0)	

*** $p < 0.001$, ** $0.001 \leq p < 0.01$, * $0.01 \leq p < 0.05$.

Table 4. Health score for each cluster.

Health SF 12v2	Cluster 1. High quality of life and independent life	Cluster 2. Poor quality of life	Cluster 3. Social centered life	Cluster 4. Creative and personal-centered hobbies at home	F-value
Physical component summary	50.33	25.73	47.74	50.45	0.01
Mental component summary	52.88	43.48	52.87	51.66	0.15

Needs for smart home functions

In this section, we compare the needs for smart home functions of each cluster. The respondents could choose from 1 (not necessary) to 5 (most necessary) for 26 detailed smart home functions in 8

categories. Higher numbers should be interpreted to mean “more necessary functions” for their lives (Table 5). As a result of ANOVA analysis, there was a significant difference in the preference of the *Sensors you can wear as clothes* function. The smart home needs of Cluster 2 “Poor quality of life” are the highest, with an average score of 2.06 for a total of 26 functions, while the needs of Cluster 1 “High quality of life and independent life” are the lowest, with an average score of 1.75.

Table 5. The needs for smart home functions (function list [11]).

Smart home functions	Cluster 1 n=47 (46.1%) High quality of life and independent life	Cluster 2 n=5 (4.9%) Poor quality of life	Cluster 3 n=25 (24.5%) Social life centered	Cluster 4 n=25 (24.5%) Creative and personal-centered hobbies at home	F-value
Smart washing machine	1.85	2.20	1.84	1.80	0.045
Smart refrigerator	1.45	2.20	1.60	1.76	1.374
Smart cooker and smart coffee maker	1.43	2.40	1.72	1.76	2.468
Schedule reminder	1.49	2.40	1.44	1.76	0.673
Reminder to take medicine	1.55	2.60	1.32	1.52	0.409
Open windows/doors detection	1.62	2.00	1.48	1.64	0.035
Automatic watering in the garden	1.77	1.00	1.52	1.96	0.128
Automatically checked postbox	1.72	1.00	1.68	1.88	0.366
Automatic heating	2.28	2.80	2.24	2.52	0.359
Gas leak detection / smoke detection	2.38	1.80	2.12	2.48	0
Remote controlled electricity	2.06	1.40	2.28	2.40	1.93
Remote controlled lights	1.77	1.80	1.80	2.08	1.269
Light mode settings	1.77	1.80	1.88	2.24	3.23
TV auto-play function, notifications from my channel	1.66	2.40	1.72	1.88	0.779
Personalized learning TV content	1.79	1.60	1.44	2.00	0.072
Automatic cinema mode setting	1.72	2.00	1.80	1.76	0.053
Fall detection	2.23	2.80	1.92	2.00	0.985
Monitoring in your absence	1.74	1.80	1.56	1.96	0.216
Measure sleep health	1.77	1.80	2.00	2.04	1.77
Sensors you can wear as clothes	1.53	2.20	1.88	1.96	3.965*
Mental health detection	1.47	2.40	1.84	1.84	3.035
Telehealthcare	2.06	3.00	2.16	2.40	0.002
Home Management Assistant Robot	1.60	2.40	2.00	1.76	1.115
Equipment to help you up and down stairs	1.34	2.00	1.20	1.68	1.313
Robot like a friend	1.28	1.20	1.28	1.32	0.073
Call the family in case of emergency	2.13	2.60	2.12	2.04	0.098
Average of needs	1.75	2.06	1.76	1.94	

We compared the needs of smart home functions above the median, based on the Spanish responses (value: 2) (highlighted with a grey background in Table 5 and ordered by decreasing priority in Table

6). Cluster 2 “Poor quality of life” needed more smart home functions compared to other groups. On the other hand, “High quality and independent life” and “Social centered life” had relatively few needs for the smart home functions.

There was also difference in the most essential functions for each group. Cluster 1 “High quality and independent life” required the *Gas leak detection / smoke detection* function the most, Cluster 2 “Poor quality of life” required the *Telehealthcare* function, Cluster 3 “Social centered life” required the *Remote controlled electricity* function, and Cluster 4 “Creative and personal-centered hobbies at home” required the *Automatic heating* function the most.

However, it is important to highlight that there are three functions: *Automatic heating*, *Telehealthcare*, and *Call the family in case of emergency*, which are essential in all 4 groups. That shows that the Spanish older population is ready to adopt such services. On the other hand, we observed the functions that are not considered important in any of the groups: *Automatic watering in the garden*, *Automatically checked postbox*, *Monitoring in your absence*, and *Robot like a friend*. Table 6 lists which smart home functions are needed according to the perceived priority in each group.

Table 6. Smart home function priority for each cluster.

Priority	Cluster n=47 (46.1%)	1 Cluster n=5 (4.9%)	2 Cluster n=25 (24.5%)	3 Cluster n=25 (24.5%)	4
	High quality of life and independent life	Poor quality of life	Social centered life	Creative and personal-centered hobbies at home	
1	Gas leak detection / smoke detection	Telehealthcare	Remote controlled electricity	Automatic heating	
2	Automatic heating	Automatic heating	Automatic heating	Gas leak detection / smoke detection	
		Fall detection			
3	Fall detection	Reminder to take medicine	Telehealthcare	Remote controlled electricity	
		Call the family in case of emergency		Telehealthcare	
4	Call the family in case of emergency	Smart cooker and smart coffee maker	Gas leak detection / smoke detection	Light mode settings	
		Schedule reminder	Call the family in case of emergency		
		TV auto-play function, notifications from my channel			
		Mental health detection			
		Home Management Assistant Robot			
5	Remote controlled electricity	Smart washing machine	Measure sleep health	Remote controlled lights	
	Telehealthcare	Smart refrigerator			
		Sensors you can wear as clothes			
6		Open windows/doors detection		Measure sleep health	
		Automatic cinema mode setting		Call the family in case of emergency	
		Equipment to help you up and down stairs			

Discussion

Principal findings

This study identifies the smart home needs of the elderly in Spain through a segmentation according to RBL. This way, we can assess the readiness of older people to use and adopt concrete smart homes functions. Concretely, we found out four clusters of the Spanish elderly, identified the smart home functions that each group considers important, and analyzed how the smart home needs of older users relate to RBL.

Porawat Visutsak and Mohamed Daoudi attempted to identify the perceptions, accessibility factors, and needs of the elderly for smart homes through a survey. They asked about 7 smart home features in total and received responses from 20 stakeholders (doctors, nurses, the elderly, and their adult children) [26]. In the study on perception of smart home technologies [4], a survey was conducted with general population, including working people in hospitals and nursing homes, to identify awareness of six smart home technologies for the elderly and concerns for using. This identified perceptions of usefulness for key technologies and their concerns from 18 respondents. Different from previous studies, our study focuses on the elderly who will be the actual primary users. Also, our questionnaire asked about the needs and perceptions of 26 detailed functions in a total of 8 categories of smart homes, covering a wider range of functions than previous studies. In addition, we compared and analyzed the particular needs of each group by segmentation based on the RBL.

In this study, rather than targeting the elderly with a specific status (cognitive level, health status), the participants were segmented according to RBL. Also, after segmentation, the average physical and mental health status of each group could be analyzed in connection with smart home needs. Although smart home technology could have great benefits for older people who need physical assistance or have mild cognitive impairment, we believe that smart home technology will help maintain independent living both for the healthy elderly and those with poor health.

Four segmented groups were identified in Spain: 1) High quality of life and independent life; 2) Poor quality of life; 3) Social centered life; 4) Creative and personal-centered hobbies at home. We figured out the priority of smart home functions for each group and found that the priority of each group and the number of required functions were different. In particular, Cluster 2 “Poor quality of life”, which is the group with the weakest mental and physical health, required more smart home functions than the other clusters. Their top priority is *Telehealth*, a system that allows them to receive medical care without going to a hospital. Besides that, they valued almost all categories of features as important, especially they considered the *Automation of daily routines* category, and the *Assist mobility* category as more important than the other groups. Also, since they spend more time at home than other groups, it was confirmed that they were interested in setting up TV programs and movie modes to enjoy at home.

Comparing these results with the segmentation and smart home needs analyzed previously in the Korean study [11], we noticed that the median value of smart home needs in South Korea was 3, higher than in Spain (median: 2). We believe that the difference in the popularization of smart homes in the two countries [27, 28] and Internet use among the elderly can affect overall smart home perception and needs. It is possible to establish some parallelism between clusters in Spain and in Korea. For instance, Cluster 1 “High quality of life and independent life” in Spain and Korea’s “High quality of life and healthy” have similar RBL and had the lowest demands for smart home functions compared to other groups. However, we can highlight that although Spain and Korea have similarities, the segmentation extracted different clusters and needs. That is because instead of

imposing a top-down classification, we obtained the clusters in a bottom-up fashion, maintaining this way the particularities of each country. We believe this is a very useful tool to understand the idiosyncrasy of each culture and to better design smart home technologies that satisfy elderly needs.

Limitations

A first limitation can be pointed out regarding the number and heterogeneity of participants: Due to the characteristics of the non-face-to-face survey, we could not target all the elderly in Spain but only those elderly who could respond to an Internet survey. Also, the number of responses collected is related to unfamiliarity with online surveys for the elderly in this country. However, the use of ICT is increasing year by year in Spain. In particular, the daily internet usage rate among those aged 65 to 74 increased to 50.7% in 2020, compared to 43.3% in 2019 [29, 30]. We believe it is a practical method to quickly gather data and reach conclusions for the elderly population and we are confident that it will become a more effective method in Spain.

The channel for the distribution of the survey could also have an impact on the educational level of respondents. We collected a 78,43% of responses from older people with university education, which is significantly higher than the percentage of Spanish adults which have reached tertiary education (around 38%). Also, because participants were able to complete this online survey alone, we acknowledge there could be a bias in our survey to older adults with good cognitive status. This can pose a threat to the representativeness of the sample, as the smart home is a technology that could also benefit the elderly with mild cognitive impairment. Given that the survey was anonymous, and we were not controlling who was the person answering the questionnaire, there was a risk of collecting responses from participants who do not meet the target profile. However, the channels that we used for the distribution of the questionnaire increase our confidence on effectively being able to reach the target population.

Another issue to be highlighted is the low number of respondents that were classified into Cluster 2 "Poor quality of life" (n=5). As a result, the demographic characteristics and responses of each individual member have a considerable influence in the definition of the cluster. We were concerned about the small dimension of Cluster 2, so we tested grouping in various ways, but these 5 adults could not be tied to other groups. Although the cluster with 5 people was a small group, we think it is a meaningful group because of their distinct characteristics and residentially-based lifestyle(RBL). We believe the reduced number of subjects in this group may be due to limited internet access of older people with this profile. We observe that the proportion of members above 75 years in this cluster is the highest (20%), while the representation of this age segment in the other three clusters is much lower (with a maximum of 8%). Considering that the quality of life tends to decrease with age, this cluster might be biased to be defined by the low quality of life of its members. We would like to explore this issue by collecting more responses on the older age segment.

A more fundamental limitation of this study (but also one of its strengths) is that the results are inherently dependent on the target population. Spanish residentially based lifestyles may differ to those in other countries and cultures. Being a data-driven research process, the factors that emerge through PCA are different, and the clustering process also leads to groups that are not necessarily comparable to the ones in another population. Direct generalization of the conclusions to another population should therefore be avoided. However, we consider this as a major strength of our method. The independent results of the segmentation by countries (Spain and South Korea) are evidence that smart home technology must be tailored to each specific context. This method may help to investigate the context and guide the tailoring process in technology development and deployment. This is also an interesting tool to guide policymakers in deciding concrete actuaciones to foster the integration of smart home technologies with existing services.

Conclusions

Smart home is an assistive technology that can improve the quality of life in old age and lead to an independent life. In order for this rapidly growing technology to fulfill its role in the lives of older people, it is necessary to first identify and analyze the actual needs of potential users. Older people are generally going through stages that may be physically and mentally debilitating, but their lifestyles at home cannot be defined as homogeneous. If the specific needs of older people are met by analyzing and segmenting life patterns at home, this assistive technology can fully perform its role. Our main contribution is a method that can be applied to any elderly group to analyze their smart home needs. In this study we applied previously defined methods and questionnaires in a different geographical context. As confirmed through the analysis results, there was a difference in the priority of smart home functions and the number of required functions according to segmentation by RBL. It was also confirmed that RBL-based smart home needs analysis is meaningful even for studies conducted in different countries with different cultures. This second study demonstrates that the proposed questionnaire and research method are generally useful and not limited to specific countries or contexts. The results of this study and the previous study in South Korea show that this method can be used to investigate the perception of smart home technology in the elderly and identify the actual needs of the groups that emerge.

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