Understanding the Characteristics of Behavior on Elderly Living in a Smart Home

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Objective: The aim of this study is to find and propose the behavioral characteristic of the elderly at their living space through diary study.

Background: Recent development of technology and the emergence of various IT devices is contributing to active research in smart home, services which considers the behavior characteristics of the elderly are still unable to be provided.

Method: This study performed self-diary study method with ten households aged over 65 that lived in smart home. Based on these data collected from the diary study, six behavior characteristics of elderly were drawn.

Results: The elderly were aware of their cognitive and physical limitations and showed fear. They are difficult to adapt in the state of the art. Their activities to acquire information were limited and were against changes, preferring to maintain the old ways.

Conclusion: The result of this study, findings of behavioral characteristics of the elderly reveal that most of them spend their time on personal maintenance, socializing and leisure activities. Therefore, smart home services related to these characteristics should be considered as a top priority.

Application: The results of the behavior characteristics can be utilized for planning out future smart home services and thereby contributing to increase in convenience and satisfaction of the elderly.

Keywords: Smart home, Elderly, Ethnography, Diary study, Activities of daily livings (ADLs)

1. Introduction

The percentage of population aged over 65 increased from 7.2% in 2000, to 11.0% in 2010, and due to extension of life expectancy and low birthrate, it is expected to rise to 24.3% in 2030 (Statistics Korea, 2013). The rising number of patients suffering from senile diseases is making the elderly to be more passive and dependent in their everyday life, and causing worries in their quality of life (Ashworth, 1994; Kai, 1991). Countries which have experienced aging society identified living environment as the most important problem, and since elderly have constrained living area due to the decrease in their physical abilities, studies are being done to create living environment which aid the lifestyle of aged populations. Living environment fulfill the

basic needs and provides shelter for sleep (FR Perez, 2001), and is an important element for increasing quality of life since it is a space which effects inhabitant's physical health and emotional welfare (Fogel, 1994).

These condition along with recent technological development, highlighted smart living space service with higher priority for better quality of life. Also called home automation, connected home, smart home, these concepts aim to converge various technologies and service with living spaces to increase the quality of life (Bierhoff et al., 2007). Applying new technologies to the living space will affect many inhabitants, especially the elderly who are classified to be socially weak (Chappell, 2013). Since the elderly have very low acceptance for new technology, they require more attention compared to the other inhabitants (Beamish and Johnson, 1994).

However, smart home services currently offered do not consider the physical and psychological characteristics of their users, but rather rely on the thoughts of service creators when being planned and offered. This dissonance is making the users unable to fully utilize the functions in smart home and to exploit their convenience. Therefore, smart home services which consider the living habits of the inhabitants should be offered in order to increase the satisfaction in the living space (Mori et al., 2000).

This study aims to understand the elderly better for further development of smart home service. Therefore, this study investigates the types of actions of the elderly in the living space and attempts to understand the behavioral characteristics of the elderly in the living space.

2. Related Work

A number of studies on smart homes aiming to have been carried out understand large frame of inhabitant's behavior. Early studies on smart home were centered on technological utilization. Frank (2001) claimed the quality of life of the elderly can be increased with the help of technologies such as video monitoring and health monitor. Yamamoto (2003) developed a smart home which provides the safe and independent living space for all inhabitants including the elderly. Christoffer Bjorkskog (2009) conducted an assessment of interfaces of ubiquitous devices developed to be used in smart home, and Martin Krafft (2009) established design trends for health smart home for the elderly through technological solution by conducting interview on health smart homes.

Recently, the focus of studies are actively shifting from technological utilizations to valuing the needs of the users. Many of these studies reflect the characteristics of smart home services that require the ability to cope with individual is life pattern and commonly put value on 'responsiveness' and 'flexibility' (Balta-Ozkan et al., 2013; Stringer et al., 2006). Also, interactions between user and system in smart home services present the ease of use, simplicity, receptiveness and the ease of learning as their requirements. (Baillie et al., 2008; Bartram et al., 2011; Green et al., 2004). Kwon (2011) suggests a service plan in accordance with the living space through investigating the lifestyle of the resident and attempts to understand the characteristics of usage corresponding to the living space. Furthermore, Lee (2011) analyzed the needs of service that the elderly have and proposed a variety of intelligent smart home services for them.

Stringer et al. (2006) emphasized the needs for smart home service to be integrated with its user's living habits since individual living patterns differ and continue to change. The increasing complexity of smart home service escalates the importance of individual characteristics. The research in users' living habits and their lifestyle is essential for this study to analyze the behavioral characteristics of the users. Therefore, we select the methodology of diary study of which the subjects are required to record their actions by themselves.

Diary study is a method to observe human behavior while minimizing opinion and interpretation of the observer and to study

more natural human behavior (Axup and Viller, 2006). Diary study is further divided into two methods depending on how it is recorded, the time-based method and the event-based method. The time-based method requires the recorder to record events and actions on the time basis, while the event-based method requires the recorder to record specific action as it is taken (Palen et al., 2002). Methods which involve user interview or observation create rooms for the user to be affected by the existence of the observer and are therefore impossible to research emotional information of the user. Meanwhile, diary study allows observer to see records which is recorded by the subject, and recorded data can be analyzed in quantitative and qualitative ways to provide insight on the daily behavior of the user (John R Robinson, 2002; Elliot, 1997). Therefore, diary study would be the suitable method for in this study with its ability to collect practical elderly's behavioral data.

This study review the current situation of smart home studies and the importance of behavioral characteristics of the users in living spaces. Most of studies offer broader and general frame of approach, however there is comparative lack of studies focusing on human centered viewpoint on the users including the aged. Therefore, analysis on the elderly's behavioral characteristics from the human centered point of view is needed for practical implementation of smart home.

3. Method

3.1 Participants

We aim to understand the behavioral characteristics of the elderly in living a smart home. Therefore, we select the ten households aged over 65. They live in a smart home, spend most of time in their living space. We investigated ten households for 8 weeks.

3.2 Procedure

In this study recording forms for the diary study was distributed and told to perform a self-diary study method which require recording of actions 24 hours a day for a week in scale of minutes. Kahnerman et al. (2004) used diary study to record 'when', 'what' happened, and 'how it felt'. This study added 'device used' and 'place', as seen in Figure 1, to analyze the behavioral characteristic of the elderly.

	Minute	Activity	Device	Place
14:00				
	15	Change clothes in the dress room		Dress room
	19	Watching TV	Television	Living room
	31	Have a snack		Kitchen
	35	Watching Television	Television	Living room
15:00	00	Received the parcel		Front entrance
	10	Doing the laundry	Washing machine	Bathroom
	15	Watching Television	Television	Licing room
	37	Going to the toilet		Bathroom
16:00				

Figure 1. Self-diary study record form

When proceeding diary study with elderly, insufficient explanation of the recording method could cause difficulty in collecting intended data (Bolger et al., 2003). Guideline were drawn to help the understanding of the diary study recording method for the elderly, and a day prior to the start of the recording was used to provide sufficient time for explanation and practice, and the practice material was evaluated for final decision to participate in the study. During a week of diary study, participant's home was visited every day to motivate periodical recording. Also, short interview was conducted to overcome the insufficiency that might be caused by the diary study.

4. Results

4.1 Behavior type of elderly in smart home

We categorized five behavior types based on the materials from prior studies and classification of living type of the elderly from data created by the Statistics Korea (Table 1). Using this behavior type categorization, all actions of elderly collected from the diary study were distributed into categories. After comparing the time consumed for each behavioral types. Analysis showed personal maintenance to be the most time spent category, followed by relationship and leisure, family maintenance.

Table 1. Classification of behavior type of the elderly

Classification	Description
Personal Maintenance	Basic living requirements including eating meal, and sanitization
Health care	Actions for health care, including taking medicine and fitness.
Family Maintenance	Looking after living environment including preparing meal, cleaning home.
Family caring	Actions involving taking care of partner and family.
Relationship and leisure	Actions involving interrelationship, and inessential activities such as reading and watching TV.

Personal maintenance, the most time spending category, was mostly occupied by sleeping activity and most of relationship and Leisure category was occupied by watching TV activity. When sleeping activity was excluded, watching TV was biggest part of elderly's daily behavior, showing too much weight being put on a single leisure activity within their living space. This shows that the limited physical ability of the elderly caused reliance on specific activity and personal maintenance when spending time at home, and draws consideration to support the physical ability of the elderly to enable them to fulfill basic needs.

4.2 Behavior characteristics of elderly in smart home

While analyzing the behavior types, some characteristics of the elderly's action were observed. We analyzed the characteristic of the elderly's behavior and defined six types of the characteristic of their behavior.

(1) Social interaction of the elderly seems to be limited to family interaction.
When looking at the social interaction shown in the diary study, internal family relationship is shown in cases like 'conversation with daughter' 'supper with son, daughter, and daughter-in-law'. Social interaction for the elderly was centered mostly within the frame of their family, providing big roles for family members to play their everyday life. Elderly's tends to adapt to the living pattern of the family members. This tendency is show when they don't go to senior citizen's center to meet with visiting family

members and eating meal after waking up their son or daughter. However, when away from home, they maintained strong relationship centering on certain distance from their main living area.

"06:40 pm, phone call with daughter-in-law"
"07:40 pm, phone call with daughter"
"09:10 pm, husband came back from work, so stopped folding laundry to prepare dinner"
"06:00 pm, usually have dinner at 09:00 pm, but waited until 07:00 pm when daughter told she would come"

(2) Elderly keep a predictable and well regulated life.
Elderly's lifestyle analyzed from the diary study showed very periodical pattern with time as standard. Example of this pattern includes reading newspaper after breakfast, and watching TV after lunch. Taking medicine is also periodic activity shown by the elderly, showing stronger pattern as number of medicine increase. Basic activities such as eating, waking up and sleeping were very periodical pattern allowing estimation for certain action at certain time. Also, other activities like reading newspaper, watching TV, and working out showed similar repetition in scale of a whole day.

"04:30 am, walk up to attend early-morning pray session everyday"
"06:40 am, always walk up around 06:00 am, performing basic hygiene activities before 20 minute physical therapy from medical device"
"07:40 pm, take blood pressure medication (Antihypertensive drug) every day after dinner"
"09:00 pm, at this time, always listen to radio in the bedroom"

(3) Elderly are aware of their own physical, cognitive abilities and endeavor to overcome.
As shown in behavior analysis result, the elderly experience clear decrease in their physical ability. To overcome this weakness in cognitive and physical ability, the elderly utilized various functions provided to use it fittingly to their condition. Most smart door lock systems require number codes, but limitation in cognitive ability and worries for forgetting the number codes, motivate them to carry and use a physical access card. Also while they admit their limitation in physical ability, shows desire to maintain physical through moving their body in performing basic actions. These actions are simple as turning off lights or closing the window, and shows disappoint for too-much automation for basic actions they can perform themselves.

"Card key, I memorize the code but sometime slips away from the memory and decreasing eye sight prevent me from smooth input, making card key the most convenient measure".
"All the automation at home is great, but sometime feels like I could become an old person who cannot do anything by myself".

(4) Elderly are difficult to adapt in the state of the art.
The elderly have low ability to adapt to technologies, and show fear and rejection to see and learn automated technology. They consider smartphone to be very inconvenient and troublesome to learn to function. They feared causing error while operating and prefer old style of living compared to the convenience of using new technology. While they could call the elevator from home before going out, they prefer to directly press the elevator button and personally check the gas valve and light with their eye.

"01:40 pm, before going out, checking the living room and the kitchen to make sure the gas valve is closed and lights are off".
"Why call elevator from home, learning it would be more difficult when I can just go out and press a button".

(5) Elderly prefer traditional media to social media.
The elderly show little credibility to various types of data acquiring methods, and preferred traditional media. Data acquiring methods is limited to newspaper and TV, and show high credibility to the information they have obtained. They showed negative

opinions for information shown from new media they are not use to, saying "weather information at the internet is strange", "prefer electricity bill to electricity use statistic from computer".

"These days, even elevator show news and weather, but seem different from information from the newspaper"

(6) Elderly prefer to maintain the current living environment.

The elderly don't prefer change, and show comfort when everything continues to be the same. They tend to keep their living environment as same and show fear to possible changes. The don't change channels a lot, but stay on one channel for a long time when watching TV, and show difficulty when using smart device for the first time, preferring to maintain the old ways. Also, they show this pattern outside of their living space, moving in certain pattern like always going to a bank after visiting a supermarket.

"I always watch MBC. Don't usually change channel a lot"
"But I prefer to see it with my own eye just to make sure. Operating it is inconvenient. It is my usual way"

5. Conclusion

Many smart home studies were conducted in order to increase the quality of life of the inhabitants, rarely to find out the characteristics of the inhabitants. This study escaped the frame of technology-centered smart home research and utilized diary study method to research behavior characteristics of the elderly in smart home living environment.

Daily living of the elderly included much time spent for personal maintenance, relationship and leisure. These are essential activities in life, showing tendency for 'basic' activities rather than 'various' activities in the lifestyle. In case of fitness, while it did not take much proportion of the time, the elderly commonly showed to have high interest in health care. Common activities including working out could be utilized as a guideline for planning out smart home services. Additionally, excluding very basic actions such as sleep made watching TV become the most time spent activity. Most of the elderly watched TV at home to spend their time, and this should be considered with the main interest 'health care' of the elderly when preparing smart home services.

After analyzing the intentions of the actions performed by the elderly, six behavior characteristics of the elderly at their living space were drawn. Their action showed 'repetitiveness' and 'fixedness' in the observation, the elderly were happy when comfortable and a day is spent through their normal living pattern untouched from any changes. Elderly cognitive and physical limitation and showed intention to overcome it through setting provided functions to be used fittingly to their conditions. However, while development of technology showed emergence of various new devices, they were reluctant to adapt and learn the new technologies around them. Most of the elderly who participated in the diary study showed low credibility to the new methods to acquire information they were not used to, not trusting the information from internet and mobile phone while showing high credibility to the traditional method such as newspaper and TV.

We observed and analyzed the behaviors of the elderly to draw behavioral characteristic of the elderly at their living space. The result of study can be utilized for planning out future smart home services, and contribute to increase in convenience and satisfaction of the elderly. In the follow-up study, we should confirm the definitions of the drawn behavior characteristics through practical implementation, and go on to find out the need values of the smart home service users.

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References

Ashworth, J.B., Reuben, D.B. and Benton, L.A., Functional profiles of healthy older persons, *Age and Aging*, 23(1), 34-39, 1994.

Baillie, Lynne and David Benyon, Place and technology in the home, *Computer Supported Cooperative Work '08*, 17, 227-256, 2008.

Bartram, Lyn, Johnny Rodgers and Rob Woodbury, Smart homes or smart occupants? Supporting aware living in the home, *Human-Computer Interaction-INTERACT 2011*, 52-64, 2011.

Beamish, J. and Johnson, M., Acceptance of Housing Alternatives for the Elderly: Consumer Perspectives, *Housing and Society*, 21(3), 17-26, 1994.

Bierhoff, I., Berlo, A., van, Abascal, J., Allen, B., Civit, A., Fellbaum, K., Kemppainen, E., Bitterman, N., Freitas, D. and Kristiansson, K., Smart Home Environment. In: Towards an Inclusive Future: Impact and Wider Potential of Information and Communication Technologies - edited by Patrick R. W. Roe., *COST, Brussels*, 110-147, 2007.

Bolger, N., Davis, A. and Rafaeli, E., Diary methods: Capturing life as it is lived*, Annual Review of Psychology*, 54, 579-616, 2003.

Christoffer Bjorkskog, Human Computer Interaction in Smart Homes, http://www.hiit.fi/~oulasvir/5830711/smarthomes.pdf, 2009.

Elderly statistics, *Statistics Korea*, http://sgis.kostat.go.kr/publicsmodel, 2013.

Elliot, H., The use of diaries in socialogical research on health experience, *Sociological Research Online*, 2(2), 1997.

Fermina Rojo Perez, Gloria Fernandez-Mayoralas Fernandez, Enrique Pozo Rivera and Jose Manuel Rojo Abuin, Ageing in Place: Predictors of the Residential Satisfaction of Elderly, *Social Indicators Research*, 54(2), 173-208, 2001.

Frank, G., Miskelly, Assistive technology in elderly care, *Age and ageing*, 30, 455-458, 2001.

Jeff Axup and Stephen Viller, Exploratory Research Methods for the Extremely Mobile: Supporting Community, *Interaction amongst Backpackers*, 2006.

Kahneman, Daniel, Alan B Krueger, David A Schkade, Norbert Schwarz and Arthur A Stone, A Survey Method for Characterizing Daily Life Experience: The Day Reconstruction Method, *Science*, 306(5702), 1776-1780, 2004.

Kai, I., Ohi, G., Kobayashi, Y., Ishizaki, T., Hisata, M. and Kiuchi, M., Qaulity of life: a possible health index for the elderly. *Asia Pac J Public Health*, 5(3), 221-227, 1991.

Kwon, O.J., Lee, Y.M., Ha, H.H., Shin, H.I. and Kim, H.W., Characteristics of Space Usage Patterns by Types of Single or Couple Elderly Households- Focused on an Analysis of Time Use Survey, *Journal of the Korean Housing Association*, 22(4), 33-41, 2011.

Lee, H.S., Park, S.J., Jung, H.W. and Lee, M.A., A Study on a Correlation between Senior Lifestyle and Intelligent Home Service,

Journal of the Architectural Institute of Korea, 27(6), 131-142, 2011.

Palen, L. and Salzman, M., Voice-mail diary studies for naturalistic data capture under mobile conditions, *Computer Supported Cooperative Work '02*, 87-95, 2002.

Martin Krafft and Kemal Coskun, Design Aspects for Elderly Using Health Smart Home, Bachelor of Software *Engineering & Management Thesis*, 2009.

Mori, T., Sato, T., Asaki, K., Yoshimoto, Y. and Kishimoto, Y., One-room type sensing system for recognition and accumulation of human behavior, *Proceeding of the 2000 IEEE/RSJ International conference on Intelligent Robots Systems*, 345-350, 2000.

Nazmiye Balta-Ozkan, Rosemary Davidsonb, Martha Bicketa and Lorraine Whitmarshc, Social barriers to the adoption of smart homes, *Energy Policy*, 63, 363-374, 2013.

Neena L. Chappell and Marcus, J., Hollander, Aging in Canada, *Oxford University Press*, 2013.

Robert W. Fogel, The Relevance of Malthus for the Study of Mortality Today: Long-Run Influences on Health, Mortality, Labor Force Participation, and Population Growth, *NBER Historical Working Paper*, 231-284, 1994.

Robinson, J.P., Kestnbaum, M., Neustadtl, A. and Alvarez, A., Information technology and functional time displacement, *IT and Society*, 1(2), 21-37, 2002.

Stringer, Mark, Geraldine Fitzpatrick and Eric Harris, Lessons for the future: Experiences with the installation and use of today's domestic sensors and technologies, *Pervasive computing*, 383-399, 2006.

William Green, Diane Gyi, Roy Kalawsky and David Atkins, Capturing user requirements for an integrated home environment, *Proceedings of the third Nordic conference on Human-computer interaction*, 2004.

Yamamoto, H., Inoue, S., Tanaka, S., Noguchi, E., Matsumura, Y., Kometani, T., Fukushima, K., Yoshioka, M., Ohta, K. and Matsuoka, K., Measuring Human behavior for safe and secure life, *SCIE Annual Conference in Fukui*, 2003.

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