Preference and usability of Smart-Home services and items - A Focus on the Smart-Home living-lab –

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ABSTRACT

With the development of the information technology industry, including artificial intelligence (AI) platforms, a Hyperconnected-society has arrived. Smart-Home technologies and services are continuing to overcome early challenges and expanding our expectations for their capabilities to the expectation that they will change our daily lives. The purpose of this study is to examine the theoretical background and trends of Smart-Home development in residential spaces as a recent trend and to derive suggestions for resident-centred Smart-Home planning and development through a questionnaire survey. For this, we collected information on the smart technology (service) and item preferences of visitors to the Smart-Home Living-lab and prepared an evaluation of our findings. From this, a broader understanding of Smart-Home was derived by viewing our data through the lens of usability. Our survey, which interrogated all age groups indicated a high preference for items associated with health care, and emergency and safety response items. Second, in particular, there was a high interest in daily health and body change management, yet, contrary to expectations, the preference for health-related services and items was in the more senior group. It is also notable that reference scores were high for items corresponding to automatic sensing, that is, services and items that respond to daily behavior. This research is meaningful as a basic study in specific smart space planning in that uses a practical experience and evaluation of Smart Home where new smart services and items have been implemented, but which have not yet become common. It is also expected to contribute to improving effectiveness and satisfaction by analysing the experience and usability of items and services associated with smart home technology.

1. Introduction

With the growth of information technologies, including artificial intelligence (AI) platforms, a hyper-connected society has arrived where people, objects, space, and information are connected to the network. In particular, the development in Korea of Smart-Home technologies and services by large construction companies, provides residents with internal and (external) environment sensing, daily living support services, and residential space management. The spread of such apartments is expected to provide a new paradigm for Smart-Home and contribute to the development of residential spaces that can embrace diverse lifestyles. Current approaches to smart home technology design are focused items that provide convenience to residents’ daily lives. However, in alignment with social issues such as population aging and low birth rates, studies show that the smart home is set to expand in various aspects, including integrated support and management of health and social life as well as the enhancement of residents’ daily lives. Consequently, related research and markets are opening up in the field of smart home technologies and services and are increasingly overcoming earlier limitations to change the way we look in our daily lives.

However, smart technology applied to housing causes a rise in construction costs, and, as yet there is little data on the feasibility and utilization of the technology. The competitively expanding Smart-Home market is criticized for reducing the utilization of technology and maintaining a pipeline industry perspective. The aim of the engineering and construction (E&C) sector is to sell apartments, while information and communication companies and those for consumer electronics are focused on selling services and home appliances. Therefore, applied smart home items and services lack mechanisms to receive or reflect residents’ feedback (Kim 2019). As a result, the research on smart homes is centered on technology, while the understanding of users (residents) is low. In particular, as the development of Smart-Home is centred on related technologies and services, residents have insufficient evaluation and feedback on satisfaction and usability. Also, research is focused on healthcare and elderly housing as the main application of Smart-Home technology, so understanding of various age groups is also insufficient (Yang et al. 2018).

Against this backdrop, this study aims to explore the theoretical background and recent trends of Smart-
Home development through surveys, and then, to derive implications for user-centred Smart-Home planning. In particular, this study seeks to find direction by viewing the data through the lens of usability, focused on the operation method along with the evaluation of Smart-Home services and items through Living-lab experiences of users of various ages.

1.1. Research methods and procedures

This study was conducted through a survey and analysis after examining Smart-Home trends and related prior studies. The procedures for the study are as follows.

First, analysed the theoretical background and trends related to a Smart-Home, reviewed prior research, and collated some implications of that research.

Second, we classified services and items in the Smart Home Living lab for analysis and established the usability of each item. We then used this classification as a frame for analysis.

Third, we analyzed our survey data. A total of 586 valid samples were collected from Smart Home Living Lab visitors. We used descriptive statistics for understanding preferences and factor analysis to deduce the influencing factors for the preference scores.

Finally, we derived user-centered implications for the smart home by analyzing the preferences and factors of each age group and applying usability for each service and item.

In conclusion, we derived implications for future smart home plans based on the analysis results of preference and usability for smart home services and items.

2. Related theories, trends and previous research

2.1. Smart-Home

“Smart-Home” is a concept of building automation applied to homes, and the Korean Smart-Home Industry Association defines it as a “human-centred smart life environment that promotes the welfare and safety of residents by converging IT into a residential environment.” This concept of a Smart-Home has something in common with concepts such as home automation, ubiquitous home, and the intelligent home,” and builds on earlier plans for Information and Communication Technology (ICT) in the residential space (Table 1). However, such past endeavors failed to establish as a trend in the housing market due to inconvenience in use and rising construction costs, overriding any convenience felt by users (Kim 2019).

Recently, with the rapid development of ICT and the spread of the concept of “the fourth industrial revolution”, there have been active conceptual discussions on industry approaches to the smart home. Currently, Smart-Home are presented as a form of future housing and an alternative to the upcoming super-aged society, which provides automated intelligent services and supporting various living services such as residents’ health, safety, and general support based on artificial intelligence (AI) and ICT.

Above all, as it is expected to improve residents’ quality of life and maximize convenience, large domestic construction companies are also actively participating in the development of smart apartments in order to compete in the new market. As shown in Table 2, apartments of various brands promote similar services. For example, services offering visitor notification, lights control with entry and exit, and the detection of

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Table 1. Smart-Home’s prior concept theorem.

| Category            | Definition                                                                 |
|---------------------|-----------------------------------------------------------------------------|
| Home-automation     | A concept that began to develop in the 1970s, based on home appliances that are remotely monitored and controlled through the Internet. Developed by residential automation technology through remote-management appliances. (Tatsuya 2007) |
| Intelligent Home    | A term that began to be used in 1983. Concepts of ‘integration of building facilities’ and ‘building automation. In the case of housing, the resident control system for public service interworking’ connected to ‘one’s own house network. (KAIA Ministry of Construction and Transportation 2019) |
| Ubiquitous Home     | The term was first used by Mark Weiser in 1991, meaning ‘at anytime, anywhere at the same time’. In other words, a residential environment in which users can freely access the network from anywhere without being aware of the computer or network. (Tatsuya 2007) |

Table 2. Trend of Smart-Home in apartments.

| Service                                         |
|------------------------------------------------|
| Dae**Co. One-pass(visitors, parking etc manage), Smart Lighting Management, Smart Air Ventilation System, Smart air conditioning and heating |
| Sam**Co. One-pass(visitors, parking etc manage), Smart Lighting Management, Smart Air Ventilation System, Smart air conditioning management |
| G**E&C One-pass(visitors, parking etc manage), Smart Lighting Management, Smart Air Ventilation System |
| Hyun* One-pass(visitors, parking etc manage), Smart Lighting Management, Smart Air Ventilation System |
| E&C One-pass(visitors, parking etc manage), Smart Lighting Management, Smart Air Ventilation System |
| Po*** One-pass(visitors, parking etc manage), Smart Lighting Management, Smart Air Ventilation System, Smart Energy management, Smart parcel service |
| E&C Service                                      |
environmental pollution; or a service that controls home appliances using the “Internet of Things” (IoT) platform. In many cases, external cloud platforms are currently being applied. In order to connect and utilize the updated platform with various home appliances, users need to learn the technology continuously and actively. Nevertheless, most of the provided services remain in the basic stages, that is, under the management of the residential environment using home appliances and support for daily life. Therefore, the development of differentiated services and technologies with high realistic adaptation is required in order not to repeat the pattern of comparable initiatives in the past. Moreover, it is necessary to understand the needs of prospective residents.

2.2. Ambient assisted living

AAL (Ambient Assisted Living) as a concept focused on positive screening and, for the elderly means an independent life assisted by the surrounding environment. The concept emphasizes the services and roles of housing and society that enable Assisted Living using Advanced Intelligence. Specifically, it is a term based on a program created in Europe, where societal aging was first, identified, to support residents’ daily lives, manage their health, and realize a more active aging by utilizing IoT technology. AAL aims to manage chronic diseases to improve the quality of life by utilizing Smart-Home and IoT, as well as to manage health in daily life, by working in partnership with medical institutions. It also emphasizes the all-weather-subsidy role of housing so that the socially disadvantaged can live their daily lives more within the community through the integration of such support technologies. AAL JP (Joint Programme) research and projects (Table 3), which began in 2007 focused on EU countries (23 countries) with the aim of improving the independence and general quality of life in the communities and homes of the socially disadvantaged, to aid their greater participation in society. Many program such as UniversALL, CARE, SmartSenior, and Diamond’s House are now in progress (Belbachir, Drobics, and Marschitz 2010) and related healthcare items are being developed rapidly and vast in extent (Choi, Choi, and Shon 2019). The same is now true in countries other than Europe such as Japan and Singapore (Choi, Hwang, and Bae 2016, Table 3).

The main aims are to gradually expand the scope of support to prevent and manage chronic diseases (primary), social exchanges (second), independent living and social participation (third), mobility enhancement (fourth), self-management at home (fifth), and participation in production activities (sixth), and to realize active aging through an integrated approach not only from a physical perspective but also from a mental and social perspective. A major feature of the AAL concept is that it aims to minimize user intervention. It is based on the premise of a system that recognizes the user’s needs and supports them automatically, without any operation, for customized services centered on the elderly and the disabled.

2.3. Domestic Smart-Home related national R&D projects

The Ministry of Science and ICT as begun to lead the world in the field of smart research and development (R & D) in Korea. In 2004, it began with the development of 10 million digital home networks. Its spread was hampered, however, due to the lack of wireless communication technology at the time. Since 2015, it has been striving to develop open interworking technologies that interoperate Smart-Home products and services and has recently supported the discovery and demonstration of IoT home appliances and related small and medium enterprise collaborative convergence services. The Ministry of Trade, Industry, and Energy has supported the development of core technologies in the robot industry for the Smart-Home, through digital homes and intelligent homes in the past and also the development of media industry technologies in information and communication, such as sensing, data processing, and smart CCTV. In the early 2010s, the Ministry of Land, Infrastructure, and Transport switched from policy research to healthcare-based elderly housing research (Hwang 2015; Ministry of Construction and Transportation Korean Housing Association, 2005). Their AI-based smart housing platform and service technology development research, which will be launched in 2020, presents “platform development”

| Nation         | Content (Hwang 2015; Choi, Hwang, and Bae 2016)                                                                 |
|----------------|----------------------------------------------------------------------------------------------------------------|
| Europe (AAL)   | - Promotion as part of the project to improve the quality of life using ICT                                    |
|                | - Medical Health Monitoring Safety and Security Emergency System Social Participation                           |
| UK (Telecare)  | - Remote-support, remote-management project for independent living support                                     |
|                | - Focus on medical social welfare such as emergency system monitoring and remote medical service                |
| Japan (E-Japan)| - Construction of independent living support housing through social sensors and information appliances that can be generalized by 2010 |
|                | - NTT Healthcare System                                                                                         |
| Singapore (N2015) | - Moving from doctor’s diagnosis to self-management and diagnosis, including patient-centered, integrated service health information sharing and electronic medical records |
as an issue for future smart homes, as well as “user-participating problem-solving measures through the establishment of living labs.” It can, therefore, understood that it emphasizes the importance of first, developing customized housing services that reflect actual and specific residents’ opinions, and second, developing a open platform to spread and distribute smart homes system (KAIA Ministry of Construction and Transportation 2019).

2.4. Related Work

Early research into smart homes began to appear in 2002 after the concept of ubiquitous living was introduced in Korea, and has increased since 2010, when the aging of the population accelerated. Research on IoT-based products and services such as Smart-Home and related appliances has been steadily increasing in recent years, along with smartphones and the Internet of Things. Looking at current research (Table 4) in the architectural field related to Smart-Home, the focus is shifting from survey for concept studies such as domestic and foreign use cases and guidelines to the development of Smart-Home and healthcare services for the elderly.

AAL-related research (Table 4) has emerged in recent years along with Smart-Home research, and many of the findings parts have yet to be addressed. Existing studies mainly focus on all-weather life support services and technologies that support Active Aging, and overseas case studies of AAL Branch Programme. AAL as a concept of Assisted-Living support related to positive discrimination and a system that provides integrated support for independent living and health care service for the management of chronic diseases and active aging of residents is difficult to distinguish clearly in research on Korean cases for the elderly.

2.5. To Sum up

As mentioned above, studies on Smart-Home are related to new technologies and services that have not yet become common in residential environments. There have been many exploratory case studies on specific overseas cases, domestic demonstration or smart homes with limited implementation. In particular, in the case of healthcare services, which appear to be an important topic along with the social phenomenon of aging, there have been many basic studies on concept establishment in front of the sticking point called telemedicine. For example analyzing the characteristics of those subject to the service, assessing the prior preference of related convenience services and items, and how to apply findings from overseas cases to Korean settings. In the future, as much previous research points out, the introduction of new types of homes incorporating Smart-Home services requires research that fully reflects usage satisfaction and needs thorough research for various generations.

| Table 4. Preceding research analysis on Smart-Home and AAL. |
|-------------------------------------------------------------|
| **(Smart-Home) Research**                                  |
| Goh Il-Du et al. (2011) Establishing the concept of U-healthcare and conducting a case study on domestic and international pilot projects to derive strategies for spreading Smart-Home in Korea | |
| Kwon Oh-Jun (2012) A Study on the demand for Ubiquitous Home Service by single-family housing type and proposal for residential space planning with service | |
| Kim Dae-Jin et al. (2012) Suggestions for application of healthcare Smart-Home system through domestic and foreign case studies and expert interviews | |
| Park Jung-Ah et al. (2013) A Study on the introduction of health care system in residential space and proposal of application according to self-reliance and size | |
| Choi Bong-Moon et al. (2013) Suggestion of Legal System improvement direction for each functional space of elderly-friendly Smart-Home such as residential households and public spaces through comparative analysis of guidelines | |
| Yang Dong-Suk et al. (2013) A Proposal for the development of low cost, high efficiency, aging-friendly Smart-Home through the analysis of domestic and foreign healthcare cases | |
| Kim Sung-Kyung et al. (2015) A Study on the preference of the baby boom generation after derivating the Smart-Home modification item with IoT technology | |
| Lee Eun-Joo et al. (2015) A survey of single-person households in their 20s and 30s on their preference by Smart-Home service, along with acceptance and recognition of new Smart-Home technologies. | |
| Cho Myung Eun et al. (2018) Development of Smart-Home Services for the Elderly and Middle-aged. Based on prior research, the characteristics of daily life and activities are analyzed through surveys to infer appropriate health support Smart-Home services. | |
| Yang Hyeon-jeong et al. (2018) A Study on the Development Direction of Smart-Home/Based on the Analysis of Smart-Home Technology Trends in researches | |
| Lee Bogyeong et al. (2018) Extracting information such as space utilization, order, frequency, etc. of observations by time zone through indirect sensing method to infer patterns of daily activities of senior citizens in Smart-Home environment and visualize their results (AAL) Research | |
| Cho Yong-Kyun et al. (2014) Derive the demand characteristics of AAL-based Smart-Home, pre-elderly and elderly health care services are derived, and appropriate prices are derived through PMS analysis. | |
| Park, Sanghoo et al. (2015) Analysis of demand by age groups in their 40s, 50s, 60s, and 70s through in-depth interviews to develop healthcare services suitable for residents of AAL-based smart apartments and present services. | |
| Thomas Bock (2015) Classification and introduction of AAL programs and related building elements in Europe | |
| Lee, Jong Sun (2015) A Study on the Characteristics of Active Aging Generation preparing for healthy and vibrant old age in AAL Concept-Based Residential Space | |
| Choi, Young-Jun et al. (2016) After examining the concept of AAL as a recent trend in responding to an aged society, analyze cases to examine characteristics and derive implications for the response of an aged society in Korea. | |
(Goh et al. 2011; Park et al. 2015; Yang et al. 2018; Kim 2019), practical use (Kim, Shin, and Ryu 2012; Choi, Hwang, and Bae 2016), and evaluation of items and services (Kim 2019).

3. Materials and methods

3.1. Service and item composition of Smart-Home living-lab

The Smart Home Living Lab that is the subject of this study was opened in April 2018. It is an experience space that has realized changes in residential spaces through smart home services and items in order to present a vision of a smart home in everyday life. Table 7 shows the smart items used in this study. The living lab is designed to replicate an actual residence so that visitors can experience the space and services in the order and manner in which they would any residential space.

All of the services and items relate to the comfort, safety, and joy (in daily-life) categories of the Korean Smart Home Industry Association (Table 5). So, we have designated the three categories of services and items as 1. daily living support, 2. health maintenance, and 3. emergency and safety response, for general understanding in this study.

Due to the nature of Smart-Home Living-lab subject to this study, there is a limit to the services and items corresponding to economic life and pleasant life, that require the use of outside space or functional interaction with the outdoors.

Each item consists of the following:

First, there are daily living support services and items such as check-in/Last-check at the entrance, smart lighting/smart bed/smart curtains in the bedroom, water temperature display in the bathroom, and Countertop-height control in the kitchen. Second, for health care services and items, there is Body Composition Analysis/Smart toilet in the bathroom, Nutrition care (refrigerator) in the kitchen, and Gait Analysis in the corridor. Lastly, for Emergency, and Safety response service and items there is Auto Ventilation in the kitchen and Fall Management/Pill Reminder in the living room. Visitors to the Smart-Home Living-lab can experience the services and items in each space according to the natural order of entry and exit of the general residence.

3.2. Survey overview and respondent characteristics

To conduct this study empirically, a questionnaire survey was carried out. We questioned visitors after experiencing the Smart Home Living Lab between July 2018 and October 2019. All visitors were guided in the same direction: bedroom > bathroom > corridor > kitchen > living room > entrance. All visitors have time to experience the Living-labs in order and then freely check their services and items while wandering around the space individually. Afterward, they were asked to evaluate their preferences for each service and item with a structured questionnaire. We assumed more specific and clear results could be obtained by evaluating the services and items of the space immediately after the visit. We gathered 586 valid samples, after eliminating from the survey all insincere responses (ones providing the full 5 points for everything, etc.) and any missing value samples. The sample groups included: “youth” (20–39 years) 166 people, “middle-aged” (40–59 years) 269 people, and “elderly” (60+ years old) 151 people (Table 6). For the elderly, a trained and skilled surveyor explained each

| Table 5. Smart Home.                                      |
|----------------------------------------------------------|
| Life | Category | Service |
|------|----------|---------|
| Comfort | Daily life-support | Schedule management and provision of daily life information such as weather |
|        | Convenience management | Support for various living conditions, such as finding lost items, household chores, etc. |
|        | Health care | Video calls with family and friends |
|        | Emergency and Safety management | Providing leisure through digital devices |
|        | Safety | Lighting management etc. |
|        | Economy | Body signal detection such as blood pressure, pulse, blood sugar, etc. |
|        | Eco-friendly energy management | Health measurement and management |
|        | Joy | To identify diseases and manage diabetes through bowel analysis |
|        | Culture | Provide medication dosage and time information etc. |
|        | Leisure | Smart Door Lock and Active Emergency Response Service |
|        | | Control services for infants, the elderly and the disabled, and pets etc. |
|        | | Smart Green Home |
|        | | pro-energy power generation system |
|        | | Smarthome-based energy and management services etc. |
|        | | Smart TV Games |
|        | | bidirectional shopping |
|        | | Home Entertainment etc. |
question to improve the accuracy of the preference evaluation. A descriptive statistical analysis of collected data was performed using SPSS 25 (average, frequency, etc.) and Cronbach’s α was used to verify reliability. Also, factor analysis was conducted to draw up other research issues and perspective.

3.3. Service and item usability of Smart-Home living-lab

Another issue in this study, “usability”, can be understood as being part of equation, that is, ways of using Smart-Home technologies and items and receiving services or information are included. The usability of smart services and items relates to the form, size, and interface of the item concerning its operation method and is linked to a user’s convenience and adaptability. As technology develops, usability has gone in an easier and simpler direction. Above all, in usability, it is important that a variety of users can learn easily, and that an item can be used intuitively. Based on this premise, in this study, “input element” and “output element” were analyzed separately in the process of investigating responses of smart home residents to smart services and items. Input elements for methods used by smart home residents themselves and “output elements” as the method providing residents. Table 7 shows the contents in which residents receive services and information by operating the smart items and classifies them as visual, auditory, tactile, action (behavior, motion), and auto (sensing) according to the main methods. The behavior and motion of the action category are operation methods involving the user’s actions. With “behavior” being an unconscious daily activity, and “motion”, an intentional act to operate the device. Input (ċ) is when residents obtain services, information, etc. through smart items, such as ordering, pressing buttons, etc. Output (▲) is when a resident can receive or check a smart service or information with an LED screen or by voice.

For example, a check-in item (Figure 1) in an entrance provides a check-in/check-check audio service. When the Zimmer frame user comes into the house and places the Zimmer frame in the designated location (in the entrance), the check-in item recognizes it, activates voice guidance, and adjusts the lighting. Meanwhile, the “automatic ventilation” item of the kitchen ventilates automatically regardless of the residents’ judgment or intention, (no-input) or automatically sensing when the kitchen is used or when air pollution occurs in the detectable room.

In the case of “Fall Management” service (Figure 2), when a fall or other emergency, occurs in the residential area, the voice guidance is started immediately after detecting the impact on the floor (auto sensing). Emergency signals are sent, together with indoor video information by prior consent, linked to 119, and a release from the security system to facilitate the rescue. Through the real-time video facilitates the handling of the situation by giving outside instructions to residents related to the structure or by releasing the security system at the front door through the transmitted images. Last-check (Figure 3) “ is an item that provides the information promptly by entering the schedule and needs of the resident in advance and supports daily life. Thus each item has a different way of inputting and outputting, and in some cases, support and response to situations occur even though the residents judgment and actions are not involved. This study seeks to present a practical approach to planning smart technology application in residential spaces by conducting analysis of various operating methods together with real-world preferences for items and services.

4. Analysis of preferences and usability

4.1. Stat preparation and descriptive statistics

Reliability and mean/biased analysis:

The survey was conducted through a questionnaire evaluating the preferences of 586 visitors who experienced the services and items of the Smart-Home Living-lab. The questionnaire was in two parts. This study uses the first part, about preferences, with the second part left for a follow-up study. We devised a 5-point measurement question for 14 smart items in order to evaluate preference. As a result of verifying the reliability, the Cronbach α value was 0.896, indicating that the items were reliable.

The average score of surveys with 5-point scales is 4.23 (Table 8). The highest score was 4.55 points for body composition analysis (bathroom), followed by 4.52 points for fall management (living room) and 4.43 points for the smart toilet (bathroom). The lower scores, below average, were 4.16 points for nutrition care (refrigerator, kitchen), 4.04 points for check-in (entrance), 3.99 points for the water temperature display (bathroom), 3.97 points for gait analysis (corridor), and 3.83 points for the smart curtains. The standard deviation for each item was shown to be 0.86–1.15 or less, indicating that the deviation between visitors was not significant and that similar experiences and evaluations were generally reported.

| Categories | Number of response | Ratio |
|------------|--------------------|-------|
| total      | 586                | 100 % |
| age        |                    |       |
| 20–39      | 166                | 28 %  |
| 40–59      | 269                | 45 %  |
| 60–        | 151                | 25 %  |

Table 6. Characteristics of Visitors.
### Table 7. Smart Item in Smart-Home Living-lab.

| Location    | Item Name   | Item Contents                                                                                                                                                                                                 | Auditory | Tactile | Auto (sensing) |
|-------------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|---------|----------------|
| Entrance    | (A) Check-in | When walking aids, which are essential for the elderly, are placed in designated locations, check-in/check-out services are provided. The lights are adjusted when entering the house, and the guiding voice is heard.  | ▲        |         |                |
|             | (B) Last-check | Before leaving the house, (B) informs you of the items' location (location sensor) that you must pack on-screen in the entrance. Today's weather and major schedules can also be checked by the screen.  | ▲        |         |                |
| Bedroom     | (C) Light control | When resident fall asleep with the light on, the lights sense and turn off. When a resident goes to the bathroom during sleep, or suddenly wakes up and moves, the light is lit at a level of light that is not blinding in the dark.  | ▲        |         |                |
|             | (D) Bed control | (D) is a motion bed, which is modified to fit body shape and posture and helps sound sleep by linking with sensors on the ceiling that detect sleep.  | ▲        | /       |                |
|             | (E) Curtain control | When a resident enters the room, the curtain in the room opens as the sensor recognizes and sets it in advance.  | ▲        |         |                |
| Bathroom    | (F) Body Composition Analysis | When a resident stands in front of the sink in the bathroom, the floor sensor measures the body composition and compares (past) the data. Through smart mirrors, a resident can check information such as analyzing body composition and detects (past) the data. The sensor visually identifies the temperature with red for hot water and blue for cold water.  | ▲        | ▲       | ▲              |
|             | (G) Water temperature color | The resident can check their favorite temperature with eyes without touching the water.  | ▲        |         |                |
|             | (H) Smart toilet | The pressure sensor on the floor identifies the user and analyzes the excretion. With the information accumulated every day, changes and abnormalities in the body can be immediately identified through smart mirrors.  | ▲        |         |                |
| Kitchen     | (I) Countertop-height control | During cooking and washing dishes for a long time, the height of the countertops is adjusted to suit users by detecting floor pressure and distance from the ceiling.  | ▲        |         |                |
|             | (J) Auto Ventilation | When the hood alone lacks ventilation or the resident does not detect air pollution, (J) automatically opens the window and operates the ventilation fan.  | ▲        |         |                |
|             | (K) Nutrition care | A customized diet is recommended in consideration of nutritional conditions, ingestion conditions and food ingredients. (K) shows the nutrition and recipes of recommended menus on the screen, and helps with ideal eating habits and nutrition management.  | ▲        |         |                |
| Corridor    | (L) Gait Analysis | Pressure sensors on the floor and motion sensors on the ceiling and walls check residents' gait. Users can check information using display items. It helps prevent arthritis by checking the width, pressure, and knee angle.  | ▲        |         |                |
| Livingroom  | (M) Fall Management | (M) detects indoor falls and accidents and sends emergency rescue signals to the outside world. In case of an emergency, voice guidance on an emergency situation is started through the speakers throughout the house, and emergency call signals are sent to the outside for help. Emergency signals are sent outside together with indoor video information by prior consent, linked to 119 and released from the security system to facilitate the structure.  | ▲        | ▲       |                |
|             | (N) Pill Reminder | For proper medication management, the home informs a person of the time of the medication. Illuminates the location of the medicine bottle and guides the type of medicine by voice.  | ▲        |         |                |

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Daily-life support service and item
Health Maintenance service and item
Emergency, and Safety response service and item
Table 8. Descriptive statistics.

| Item | Value (N) | Standard deviation | Standard error |
|------|-----------|--------------------|---------------|
| (A)  | 4.04      | 1.13               | 0.05          |
| (B)  | 4.35      | 0.95               | 0.04          |
| (C)  | 4.36      | 0.95               | 0.04          |
| (D)  | 4.24      | 1.02               | 0.04          |
| (E)  | 3.83      | 1.15               | 0.05          |
| (F)  | 4.55      | 0.86               | 0.04          |
| (G)  | 3.99      | 1.16               | 0.05          |
| (H)  | 4.43      | 0.92               | 0.04          |
| (I)  | 4.35      | 1.01               | 0.04          |
| (J)  | 4.27      | 1.04               | 0.04          |
| (K)  | 4.16      | 1.13               | 0.05          |
| (L)  | 3.97      | 0.87               | 0.04          |
| (M)  | 4.52      | 0.98               | 0.04          |
| Mean | 4.23      |                    |               |

Figure 3. (B) Last-check.

Table 10. Remote system Rating Score (1-5) and Blanks.

Figure 1. (A) Check-in.

Figure 2. (M)Fall. Management.

4.2. Age group-specific preference and usability analysis

The higher scores in the Youth group between the ages of 20 and 39 were Body Composition Analysis (4.59), Fall Management (4.48), Countertop-height control (4.34), Smart toilet (4.28), and Pill reminder (4.27). Items rated below the average score of 4.11 for the Youth group were Check-in (3.74), Water Temperature display (3.65), and Gait analysis (3.6). According to the average score, the Youth group showed a high overall score due to a mix of items across the categories of health maintenance and emergency and safety response.

The higher scores in the Middle aged group between the ages of 40 and 59, were Body composition analysis (4.62), Smart toilet (4.55), Fall management (4.53) and Smart lighting (4.45). Items rated below the average score of 4.21 for the Middle age group are Nutrition care (4.21), Gait analysis (4.2), Check-in (4.14), Water Temperature display (4.14), and Smart curtains (3.36).

The higher scores among the Elderly group over 60 years were Fall management (4.55), Last-Check (4.5), Smart toilet (4.4), Smart lighting (4.39), Body composition analysis (4.39). Items rated below the average score of 4.19 for the age group were Check-in (4.18), Nutrition care (4.15), Water Temperature display (4.11), Gait analysis (3.99), and Smart Curtains (3.76).

According to the preference evaluation score for the Elderly group, the categories of Daily-living support, Health Maintenance, Emergency, and Safety response were all mixed to receive the top score. Conversely, for the Youth and the Middle age group, the three categories of items were well distinguished and health-related items received high scores. Fall Management and Smart toilet are received high marks through all age groups. The item that got the highest score in the Youth and Middle age group but was relatively lower in the Elderly group was Body Composition Analysis. The common feature of the Middle age and the Elderly group is that the blanks in the middle gray area appear together, as shown in Table 10. Items that correspond to the blanks are in a different order, but items "D/I/J/N" are common. This blank part may be as a result of the preference for the service corresponding to "D/I/J/N". But as such a blank part appears, a significant preference for the usability in a combination of visual output and behavior-automatic sensing can be expected.
Table 9. Usability in order of Preference.

| Item | V   | A   | T   | A (B/M) | A (s) |
|------|-----|-----|-----|---------|-------|
| (F)  | ▲   | ▲   | O   | O       | ▲     |
| (M)  | ▲   | ▲   |      | ▲       |       |
| (H)  | ▲   | ▲   | O   |         | ▲     |
| (C)  | ▲   | ▲   |      |         | ▲     |
| (A)  | ▲   | ▲   | O   |         |       |
| (D)  | ▲   | O   |      | ▲       |       |
| (K)  | ▲   | O   |      |         |       |
| (A)  | ▲   | ▲   | O   |         |       |
| (G)  | ▲   | ▲   | O   |         |       |
| (L)  | ▲   | ▲   | O   |         |       |
| (E)  | ▲   | O   |      | ▲       |       |
| Input: | | | | | |

4.3. Factor analysis for preference

A factor analysis was conducted to statistically derive the extent to which the characteristics of the factors were affected, assuming that the interrelationship between smart services and items is a fundamental factor for users to recognize and evaluate each item. Analysis of all items was performed based on factor loadings of 0.40 or higher. The Principal component analysis was used to extract the components, and Varimax rotation was adopted to simplify the factor loadings.

As a result, the Kaiser-Meyer-Olkin (KMO) value was 0.909, and the significant probability for Bartlett’s test of sphericity was 0.000, which can be determined to be highly appropriate for the model (Table 11). In the total variance table initially described, the loadings of rotated squares with an eigenvalue of 1 or more were classified as a total of 2 factors, and the eigenvalue of the extracted factors were shown to be 6.059 and 1.104. The commonality, which represents the proportion described by the factors contained in the variable, found that the lowest value was 0.401 (Last-check), and other items were also maintained at 0.4 or higher. The total cumulative explanatory is 51.01%, so it can be said that the explanatory power is in good order. As shown in Table 9, factor 1 according to Rotation Sums of Squared Loadings has Eigenvalues of 4.106 and 29.3% of the variance, and consisted of Body composition analysis, Pill reminder, Body composition analysis, Fall management, Gait analysis, Nutrition care (refrigerator), Factor 2 has an Eigenvalues of 3.057 and 21.8% of the variance, and consists of Smart curtains, Smart lighting, Smart bed, Check-in, Last-check, Auto ventilation, Countertop-height control, Water temperature display.

As a result, factor 1 is drawn with Health Maintenance and Emergency, and Safety response services and items together, and factor 2 is drawn with Daily-living support services and items except for auto ventilation (necessary to be more specific, classified as Emergency, and Safety response). Age group-specific factor analysis follows (Table 13).

4.3.1. The youth group

As a result of factor analysis of the Youth group, the total cumulative explanatory is 57%, factor 1 was Pill Reminder, Fall Management, Gait analysis, Nutrition
Table 10. Age group-specific preference and usability.

| Item | 20 – 39 | 40 – 59 | 60 – |
|------|---------|---------|------|
| (F)  | ▲ ▲ ○ | ○ ▲ ▲ | ○ ▲ ▲ |
| (M)  | ▲ ▲ | ○ ▲ ▲ | ○ ▲ ▲ |
| (L)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (H)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (N)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (C)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (J)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (K)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (B)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (G)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (E)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (A)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (D)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (K)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |
| (L)  | ▲ ▲ | ▲ ▲ | ▲ ▲ |

Input: ▼ Output: ▲

Table 11. KMO and Bartlett’s test.

| KMO    | 0.909 |
|--------|-------|
| Barlett chi^2 | 2899.82 |
| degree of freedom | 91 |
| Significance-P | 0.000 |

Table 12. Factorial Analysis.

| Item | Factor 1 | Factor 2 | Communality |
|------|----------|----------|-------------|
| (H)  | 0.716    | 0.260    | 0.579       |
| (N)  | 0.712    | 0.197    | 0.547       |
| (F)  | 0.701    | 0.238    | 0.545       |
| (M)  | 0.694    | 0.167    | 0.510       |
| (L)  | 0.647    | 0.263    | 0.488       |
| (K)  | 0.597    | 0.295    | 0.443       |
| (E)  | 0.084    | 0.773    | 0.605       |
| (C)  | 0.223    | 0.722    | 0.571       |
| (D)  | 0.280    | 0.651    | 0.502       |
| (A)  | 0.233    | 0.599    | 0.412       |
| (B)  | 0.276    | 0.548    | 0.401       |
| (J)  | 0.427    | 0.507    | 0.436       |
| (I)  | 0.423    | 0.482    | 0.408       |
| (G)  | 0.461    | 0.477    | 0.441       |

| Rotation Sums of Squared Loadings | % Variance | Cumulative% |
|----------------------------------|------------|-------------|
| Total                            | 4.106      | 29.326      |
|                                  | 3.057      | 21.836      |

Factor and factor 4 was drawn with Countertop-height control and Smart bed. For the Youth group, factor analysis showed that factor 1 was Emergency, and Safety response category, factor 2 as Daily-life support category, and factor 3 and 4 were the Health Maintenance services category, without interference between each item.

4.3.2. The middle age group

As a result of factor analysis of the Middle age group, the total cumulative explanatory was 60.4%, factor 1 was drawn with Body composition analysis, Smart toilet, Fall management, Pill reminder, Gait analysis, Nutrition care (refrigerator); Factor 2 was drawn with Smart Lighting, Smart bed, Smart curtains, Countertop-height control, Auto ventilation, Water temperature colour; factor 3 was Check-in, Last-check. The Middle age group recognized Health Maintenance, Emergency, and Safety response categories as having the highest scores and important factors, and the distinction between Daily-living category appeared clearly. However, exceptionally, Auto ventilation was classified as being in the same category as daily living support.

4.3.3. The elderly group

As a result of factor analysis of the Elderly group, total cumulative explanatory is 60.7%, factor 1 was drawn with Smart curtains, Smart bed, Smart lighting, Last-check, Check-in, Auto ventilation, factor 2 was drawn with Gait analysis, Countertop-height control, Pill care (refrigerator), Auto ventilation. Factor 2 was drawn with Check-in, Smart curtains, Smart lighting, Last-check, Water temperature colour. Factor 3 was drawn with Body composition analysis, Smart toilet.
Table 13. Age group-specific factor analysis.

| Item | factor1 | factor2 | factor3 | factor4 | Item | factor1 | factor2 | factor3 | Item | factor1 | factor2 | factor3 |
|------|---------|---------|---------|---------|------|---------|---------|---------|------|---------|---------|---------|
| (N)  | 0.726   | 0.013   | 0.223   | 0.048   | (H)  | 0.837   | 0.223   | 0.028   | (E)  | 0.719   | 0.210   | 0.041   |
| (M)  | 0.713   | 0.078   | 0.200   | −0.125  | (F)  | 0.719   | 0.329   | 0.122   | (D)  | 0.672   | 0.125   | 0.463   |
| (L)  | 0.633   | 0.015   | 0.230   | 0.235   | (M)  | 0.688   | 0.131   | 0.225   | (C)  | 0.659   | 0.330   | 0.210   |
| (K)  | 0.619   | 0.186   | 0.047   | 0.162   | (N)  | 0.628   | 0.293   | 0.322   | (B)  | 0.648   | 0.294   | 0.063   |
| (J)  | 0.578   | 0.250   | −0.234  | 0.383   | (L)  | 0.596   | 0.246   | 0.325   | (A)  | 0.608   | 0.084   | 0.250   |
| (E)  | 0.027   | 0.799   | 0.051   | 0.079   | (K)  | 0.542   | 0.262   | 0.323   | (J)  | 0.355   | 0.745   | 0.027   |
| (A)  | 0.361   | 0.718   | −0.032  | −0.320  | (C)  | 0.275   | 0.801   | 0.015   | (L)  | 0.107   | 0.743   | 0.294   |
| (C)  | 0.013   | 0.665   | 0.038   | 0.370   | (D)  | 0.312   | 0.769   | −0.012  | (I)  | 0.258   | 0.709   | 0.251   |
| (B)  | 0.093   | 0.512   | 0.259   | 0.177   | (E)  | 0.108   | 0.637   | 0.370   | (N)  | 0.291   | 0.498   | 0.304   |
| (G)  | 0.132   | 0.488   | 0.248   | 0.201   | (L)  | 0.228   | 0.569   | 0.319   | (M)  | 0.451   | 0.468   | 0.279   |
| (H)  | 0.138   | 0.266   | 0.797   | 0.053   | (J)  | 0.355   | 0.521   | 0.390   | (F)  | 0.279   | 0.076   | 0.886   |
| (F)  | 0.303   | 0.062   | 0.774   | 0.115   | (G)  | 0.406   | 0.421   | 0.371   | (K)  | 0.063   | 0.355   | 0.732   |
| (I)  | 0.279   | 0.091   | 0.150   | 0.708   | (A)  | 0.187   | 0.166   | 0.836   | (H)  | 0.439   | 0.342   | 0.602   |
| (D)  | 0.014   | 0.437   | 0.078   | 0.578   | (B)  | 0.252   | 0.102   | 0.800   | (G)  | 0.164   | 0.502   | 0.598   |

Daily-life support service and item
Health Maintenance service and item
Emergency, and Safety response service and item

5. Conclusion

This study presented an evaluation of preferences based on practical experience by conducting a survey among Smart-Home Living-lab visitors. The results are as follows:

First, the survey results for the entire visitor showed that the Health Maintenance and Emergency, and Safety response categories highly valued. Also, since the factor analysis results showed that these categories can be classified as one factor, accounting for 47% of the total survey results, the importance of Smart-Home services and items in the field can be inferred. In particular, the Youth and Middle aged group recognized and evaluated services and items in three categories (Daily-living support, Health Maintenance, Emergency, and Safety response) despite the lack of prior notice, and gave high scores to the Health Maintenance, Emergency, and Safety response categories. Therefore, various developments of services and items related to Health Maintenance and Emergency, and Safety response items should be actively reflected in next-generation Smart-Home plan.

Second, in particular, interest in a daily health check and body change management was high. Body composition analysis and Smart toilet have the highest scores for all ages, and it is considered that there is high interest and demand for regular body change check and change detection functions in daily life. Therefore, it is necessary to pay attention to items that can regularly check health in daily life and plan a residential space that can support them.

Third, preferences for the Elderly group, which was expected to favor Health Maintenance or Emergency, and Safety responses, were rather lower in those categories than for other age groups. For the Elderly, the classification of the three areas of Daily-living support, Health Maintenance, Emergency, and Safety response was not clear, and high scores and high explanatory skills for certain items (Last-check, Smart lighting, Auto ventilation) in the Daily-living support field. This means that there may be a difference between the needs of life felt by the elderly and the perception of life in old age held by the younger population. Among existing studies, some made similar points, such as the low demand for health care by the elderly (Kim, Shin, and Ryu 2012). It remains, nevertheless, important that the fields related to health maintenance and emergency

reminder, Fall management and factor 3 was drawn with body composition analysis, Nutrition care (refrigerator), Smart toilet, and Water temperature colour. For the Elderly group, the most explanatory factor 1 is classified as only Daily-living support category, and the remaining factor analysis items, the classifications of daily living support, health maintenance, and emergency and safety response were not clear.

The results of the factor analysis of the entire age group (Figure 4) show that 14 service and items (without prior notice) were classified, recognized, and evaluated for Daily-living support, Health Maintenance, Emergency, and Safety response categories. Also, the overall Health Maintenance and Emergency, and Safety response items received higher preference scores compared to Daily-living support category. Tables 9 and 10 show that the preference for items with an Auto-sensing function is high ranking in the usability of all items, and the items with low ranking jointly do not have an auto-sensing function. This tendency toward an auto-sensing preference is because the Elderly group is stronger than the Middle aged group, and the Youth group is the weakest.
response feature highly in the development of Smart-Home for the elderly. Therefore, follow-up research on Smart-Home for the elderly requires a multi-faceted study of practical factors and needs for these issues.

Fourth, in preference for all items, automatic sensing items that do not require a particular operation were high. Among the items, in “Health Maintenance” and “Emergency, and Safety response” categories, those with automatic sensing function scored relatively higher than those without. Items with these automatic sensing functions can be understood to mean that there is no deliberate action for the operation of these services and items, implying that no new knowledge or training is required for the operation of such services and items and the normal behavior of residents is not disturbed. In other words, in the implementation of smart spaces in the architectural field, “residence” is a space where the dweller’s natural habits and routines can emerge, and a certain amount of rejection of the unfamiliar is to be expected. That resistance to change will have been reflected in the preference assessment. Moreover, that the Youth and Middle age group who are relatively familiar with smart technology and device operation, also had a high preference for automatic sensing. This suggests that the development of the smart home should incorporate minimal change in the normal behaviors of residents. This is because, even with high-tech services, residential spaces that require residents to change their daily lives will not facilitate them to settle down and could lead to the same drifts away from the smart home concept witnessed by smart spaces in earlier times.

This study is meaningful as a basic study of specific smart space plans in that it includes practical experience and evaluation of Smart-Home with new smart services and items that have not yet become common. It is also expected to provide a more specific and practical understanding of smart services or items by analysing them, including the recorded experience and usability, rather than assessment through pure text and assumption. In future studies, it is necessary to understand the preferences and needs of prospective residents by observing users’ behavior over a longer period, and considering the interior and exterior of the house together. In addition, for resident-oriented Smart-Home systems and space planning, a comparative study is required on items that purport to offer the same function or service but may ultimately have different levels of usability.

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