

# A Study on Affordance Dimensions of Digital Services for the Elderly through the Analysis of Senior Adults' Daily Activities

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## Abstract

Designing environments for the elderly includes studying changes in the elderly themselves, changes in their environment, and changes in the intercommunication between the elderly and their environment. The purpose of this study is to provide guidelines for a ubiquitous environment in which seniors can "age in place," using an environment-behavioral approach. 305 subjects aged 45 to 78 take part in the survey research. Temporal sequence (age groups) and behavior (daily activities) are considered as the significant variables to design digital services for the elderly in the perspective of an environment-behavioral approach. Several conclusions can be made. (1) The characteristics of subjects in the over-65 age group shows that they manage an independent lifestyle even if they realize some body functions deteriorate as they age. (2) Over-65 age group is more engaged in healthcare and pastime activities. The male subjects of it are most inactive. (3) The IDA (importance of daily activities) and FDA (frequency of daily activities) are classified by five to six factors in each group. The IDA and FDA of the group aged over 65 differ from other age groups. (4) Five affordance dimensions of digital services for the elderly are proposed: Healthcare, Domesticity, Mobility & Security, Network, and Recreation & Pastime. These affordance dimensions will help research groups or companies design ubiquitous environments to enhance the quality of life of seniors.

*Keywords : Elderly, Affordance dimensions, Digital Services, Environment-Behavioral Approach, Aging in place*

## 1. INTRODUCTION

One out of every ten persons is now 65 years old or older; by 2026, it is estimated that one out of five will be 65 years old or older<sup>1</sup>. The Aging Index<sup>2</sup> was determined to be 55.1 in 2007 and estimates say will be 100.7 in 2016, such that the older population will overtake the younger population. The older population itself is also aging. The expected life span of people over 65 years old has grown from 15.4 years in 1995 to 18.2 years in 2005. People over 65 years old, as of 2005, have to manage their lives until the age of 83.2. As society ages increasingly<sup>3</sup>, maintaining an independent lifestyle at home becomes an important issue for older people. The elderly themselves demand maintaining an independent lifestyle despite their health status and living arrangements.

In recent decades, digital technology has been attempting to modify our environment to be "smarter" and to support our daily lives in various ways. For example, a room can recognize who is present and provides a proper environmental atmosphere with embedded sensors, a networking system, and so forth. It is expected that the elderly, who constitute an increasing percentage of the population, will be able to function independently and maintain a desirable quality of life in ubiquitous environments planned under a digital infrastructure basis.

Ubiquitous environments, described as responsive or interactive environments, have to be more concerned with

interaction between humans and environment. Ubiquitous design which overlooks users' behavior does not satisfy them and used permanently. Few researchers interested in ubiquitous design have been concerned with human behavior, despite an increasing interest in searching the well-designed examples and inferring their usage for special context. In this respect, it is meaningful to explore behavioral aspects for ubiquitous design.

The purpose of this study is to provide guidelines for a ubiquitous environment in which seniors can "age in place" through an environment-behavioral approach. In line with this purpose, (1) the environmental gerontology theory and representative research projects of available digital services for the elderly are reviewed; then, (2) the senior adults'<sup>4</sup> daily activities are analyzed and classified into behavior factors to propose the affordance dimensions for digital services.

## 2. METHODS

This research is undertaken with two differentiated processes.

One is re-examination of available data from diverse sources, including project groups of universities, companies, and the consortium. Their research processes and results include the concerns regarding how technologies contribute to assisting the physical limitations of the aged, the memory and learning of an older adult, as well as the interpersonal relationship between seniors and other family members. The results not only technological appliances but also the publications presenting research methods and processes are reviewed.

The other is the comprehensive survey and the analysis

<sup>1</sup> Korean National Statistics Office (2007) reported that the population of over-65-year-old people in Korea has reached 4,810 (9.9%) in July 2007 and estimates that it will reach 20.8% in 2026.

<sup>2</sup> The population of over-65-year-olds over 0~14-year-olds

<sup>3</sup> An aging society is one where the population of over-65-year-olds is 7~14%, 14~20% for an aged society, and over 21% for an ultra-aged society.

<sup>4</sup> Middle- and advanced-aged people

of the seniors' daily activities. Over-45-year-old, healthy adults answered a questionnaire during May 2006. The subjects were categorized into six groups according to age and gender (Table 1). 305 questionnaires from more than 348 were used for analysis. The rest were omitted due to large amounts of missing information. Frequency, one-way ANOVA, and factor analysis were conducted by SPSS win 12.0.

Table 1. The Sampling Groups

Age	Over 65(O)	55-64(M)	45-54(Y)	Total
Male	G <sub>om</sub> 49(50.0)	G <sub>mm</sub> 53(52.0)	G <sub>ym</sub> 52(49.5)	154(50.5)
Female	G <sub>of</sub> 49(50.0)	G <sub>mf</sub> 49(48.0)	G <sub>yf</sub> 53(50.5)	151(49.5)
Total	98(32.1)	102(33.4)	105(34.4)	305(100.0)

### 3. ENVIRONMENT BEHAVIORAL APPROACH

Carp (1987, p.334) stated that "architects or planners turned to behavioral scientists for information to guide their work." The information such as the impact of new environments on old people was regarded as the foundation of the planning houses for the elderly in those days. They were concerned with which specific features of a building, if any, were favorable for older tenants, and how the old assessed whether a facility was "successful".

#### (1) Environmental Gerontology

Theoretical approaches to explain elderly behavior in the context have developed both the psychological and the planning fields. Such a theoretical tradition, stretching back to the classic ecology of the environmental psychology of Barker (1968), and Lawton's environmental press in the 1970s (Kending, 2003, p.612), has established environmental gerontology. Many of them started with the concern of people and environment fit, which includes Murray's, Lewin's, and Carp's environmental psychology theory.

Environmental gerontology is concerned with the variety of private housing arrangements available to older people in terms of household composition, ownership, housing standards, time of residency, and residential satisfaction (Wahl & Weisman, 2003, p.617). From the perspective of the environmental press model, it focuses on the active and intentioned dimensions of older people as they "use, manipulate, or perform tasks in their environment."

These environmental aspects or environmental context of aging facilitate the building of conceptual bridges across disciplines, which emphasize the substantial role that the environment plays in supporting the "quality of life" in old age. Theories and findings of environmental gerontology have been applied at multiple scales ranging from evidence-based housing design to institutional living, from the micro level of home modifications to the macro level of recommendation for "age-friendly" communities or even countries (Wahl & Weisman, 2003, p.616).

#### (2) Home Environment for the Elderly

The home environment is central to healthy aging and well-being in old age, and the study of home environments has long been an important research domain within the field of environmental gerontology. However, there is a scarcity of adequate theoretical foundations and appropriate methodology for this kind of research (Gitlin, 2003).<sup>5</sup>

The literature on environmental change in the field of gerontology falls into two major categories. A significant portion of that literature is derived from studies conducted on institutionalized elderly samples and the remainder is based on studies of older people living in relatively conventional community settings. However, quantitative analysis of empirical literature published between 1989 and 2000 (Wahl e al., 2003, p.619) showed that interest in private home environments has grown since the mid 1990s. The decrease of planned environment research and the increase of residential decision research support the idea that besides relocation from home to institution and intra-institutional relocation, home-to-home relocation has grown in recent years as a psychological challenge and as a means to improve one's person-to-environment fit while aging.

Actually, the majority of the old population is living in ordinary houses and apartments. Gitlin (2003, p.698) argues that "most individuals grow old in their primary, long-term, community-based residence (rented or owned); and "staying put" or aging in place at home is the consistently expressed desire of both older adults and family caregivers." He also explained the rationale for the study of home environments as follows (2003, p.629):

1. *The subjective appraisal by elderly people as to the importance of the home to life quality and the consensual preference and commitment of informal caregivers to helping aging family members stay at home indicate that the aspiration to age in place has been consistently documented in gerontological literature. The vast majority of time spent by older people is inside the home.*
2. *Home environment itself takes a role of retrieval. The home environment may buttress daily functional abilities as well as buffer the threat of loss to personal autonomy and control, two important contributors to well-being.*
3. *Home of old people is increasingly becoming the context for long-term care. The home has also become the primary setting for short- and long-term unpaid informal caregiving provided chiefly by families and secondarily by friends or neighbors.*

#### (3) Time and Behavior

Older people have experienced changes in various aspects such as physical environment, health status, body functions, and the interpersonal relationship. Even when older people do not move from their current residence, dwellings may become older and fall into disrepair or the population and land use characteristics of their neighborhoods and communities may change. They are often forced

<sup>5</sup> Iwarsson, S., A long-term perspective on person-environment fit and ADL dependence among older Swedish adults, *The Gerontologist*, Jun 2005, 45(3), p. 327.

to use their dwellings differently, because of chronic health problems or behavioral competence deficiencies. They will also behaviorally adapt differently to changes in the contents of their residential setting in temporal perspective, and they will not similarly reassess the desirability and functionality of their current actions and behaviors (Golant, 2003, pp.638-639).

The environmental behavior or activity patterns offer a tangible indicator with which to distinguish the environmental content of a setting that is most relevant to its older person and likely to evoke their responses (Scheidt & Windley, 1985)<sup>6</sup>. People's experience of a current environment are influenced by the context and meaning of their past environments, as well as by their anticipation of the future. Furthermore, the same environmental features of changes can have either a positive or negative impact on older individuals and on their sense of self. Indeed, the meaning and use of home can be inseparable from life continuity and identity. Finally, personal changes in the competencies and other characteristics of older people both influence and interact with environments and their consequences (Kending, 2003, p.613). As a result of it, the behavior and activity of older people can often be predictive of whether their needs are met, whether they are positively assessing their setting's qualities, and whether they have a positive self-concept.

In these aspects, it is necessary to understand the complex time and space interaction or interface between persons and their environment. This study focused on behavioral patterns of older individuals by analyzing daily activities from the middle-age to the advanced-age in temporal perspective. The information such as the distinctive activity patterns will give an insight into planning the environment where older people remain independent longer.

#### 4. DIGITAL SERVICES FOR THE ELDERLY

##### (1) Ubiquitous Environment and Digital Services

Ubiquitous Environment (UE) is a concept that grew out of "ubiquitous computing (Weiser, M., 1988)," that is, creating a vision of people and environments augmented with computational resources that provide information and services whenever and wherever desired (Abowd, G. D. et al., 2002). Creating a UE is not only concerned with technology, but also with users managing their daily lives in such a situation. As of late, researchers creating UEs are forced to examine what people expect from a UE (Intell, S. S. et al., 2003; S.S. Intille, 2006). A UE functions under various requisite infrastructures. Digital services are one of fundamental infra structures, which communicates with a user directly. It is a current topic of discussion which and how digital services are developed and adapted for quality of life.

Digital services can fall into several categories, such as

home networks, digital green electronic appliances, and healthcare services. The Ministry of Construction and Transportation (2001) defined six digital systems: Home automation for the intelligent apartment, safety and security systems, indoor environmental control systems, house chore support systems, culture and healthcare systems, apartment maintenance systems, and automatic control systems. In empirical research of mid- and advanced-aged digital home design, Park (2006) analyzed six categories of digital systems: Safety and security systems, healthcare systems, convenience systems, management systems, entertainment systems, and relationship systems. The subjects preferred healthcare digital services, as well as safety and security services, more so than those of comfort and entertainment. Additionally, they required digital services that contributed to their social and emotional relationships and healthcare.

##### (2) Research Groups

There are several groups researching digital services for the elderly: The Aware Home Research Initiative (Georgia Institute of Technology), the Gator-Tech Smart House (University of Florida's Mobile and Pervasive Computer Laboratory), the interLiving (The Royal Institute of Technology in Stockholm), the PlaceLab (MIT House\_n + TIAX initiative), the Smart Medical Home (University of Rochester Medical Center), and so on. Among them, the Aware Home Research Initiative and the Gator-Tech Smart House are the prominent research groups working on various digital services for the elderly.

The Aware Home Research Initiative (AHRI) is an interdisciplinary research endeavor aimed at addressing the fundamental technical, design, and social challenges in providing services to its residents to enhance their quality of life, or to help them maintain independence as they age<sup>7</sup>. The AHRI has been devoted to the multidisciplinary exploration of emerging technologies and services based in the home since 1988. Research areas cover chronic care management in the home, future tools for the home, and digital entertainment and media. The major projects for helping elderly in each research area are shown in table 2.

Table 2. The projects of the AHRI

Chronic Care Management in the Home*	Future Tools for the Home**	Digital Entertainment and Media
<ul style="list-style-type: none"> <li>• Fetch</li> <li>• Cook's collage</li> <li>• Digital family portrait</li> <li>• Dude's magic box &amp; grandma's lap desk</li> <li>• The technology coach</li> <li>• Super Assistants</li> <li>• Living Memory Box</li> </ul>	<ul style="list-style-type: none"> <li>• Tangible UIs for networking</li> <li>• iCAM</li> <li>• The tableaux machine at the aware home/ Alien Presence</li> <li>• Privacy in an Aware Home</li> </ul>	<ul style="list-style-type: none"> <li>• Gesture pendant</li> <li>• Videotater: Video segmentation and tagging</li> <li>• Photo collage/ Collaginator</li> <li>• Family Video Archive</li> <li>• Exergaming</li> </ul>

\* Three projects among eleven not related to the elderly life are excluded.

\*\* Nine projects dealing with home networking infrastructure and four projects not related to the elderly life are excluded.

<sup>6</sup> Golant, S. M. (2003), Conceptualizing Time and Behavior in Environmental Gerontology: A Pair of Old Issues Deserving New Thought, *The Gerontologist* 43(5), p.639.

<sup>7</sup> <http://awarehome.imtc.gatech.edu/>

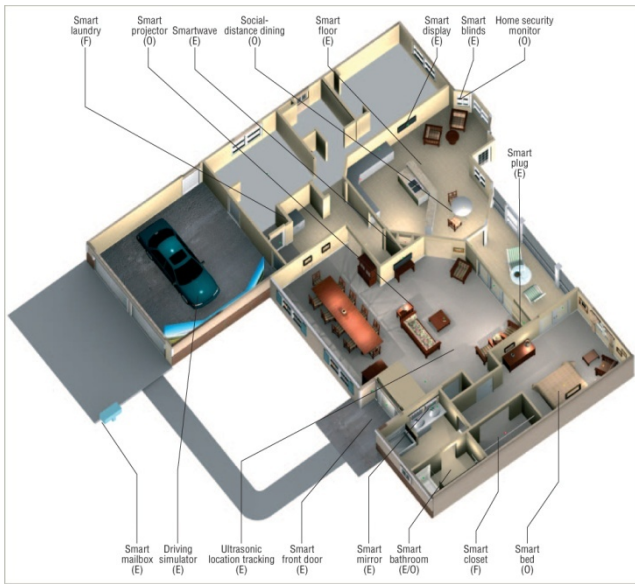


Figure 1. Gator-Tech Smart House. The project feature numerous existing (E), ongoing (O), or future (F) "hot spots" located throughout the premises (Heral et al., 2005, p.65).

The Gator-Tech Smart House is a programmable space designed for elderly and disabled people<sup>8</sup>. The project's goal is to create an assistive environment that can sense itself and the residents to provide remote monitoring and intervention services. Figure 1 shows most of the "hot spots" that are currently active or under development in the Gator Tech Smart House (Helal et al, 2005).

Besides, the interLiving project aims to develop new methodologies for designing technologies that can contribute to bringing family members together through an ethnographic approach. The PlaceLab is an apartment-scale 'living laboratory' designed to test design concepts and new technologies in a real home setting. It has been designed to study proactive healthcare activities of daily living, as well as biometric monitoring and indoor air quality. Also, it has been designed to understand and find solutions to issues like privacy and trust (Satpathy, 2006. p.67)<sup>9</sup>. Finally, the Smart Medical Home aims to develop an integrated Personal Health System which allows consumers, in the privacy of their own homes, to maintain health, detect the onset of disease, and manage disease.

## 5. RESULTS

### (1) Characteristics of Samples

The subjects' socio-demographic status and dwelling arrangements are measured by a set of seven questions as shown in Table 3.

There are differences between the over-65 age group and other groups, as well as between the male and female subjects with respect to educational and occupational status. From among the over-65 group, 64.3% of the  $G_{om}$

group graduated from high school and 36.7% from university, while 86.4% of the  $G_{of}$  group graduated from high school. 37% of the  $G_{om}$  group are still working as professionals, managers or businessmen. Their monthly income ranges from 0.5 to 4 million won. More than half of the  $G_{om}$  and the  $G_{of}$  groups (56.5%) earn 2,000~3,000 won. It amounts to the average monthly income of Korean households of over sixties although it comes up to that of under sixties<sup>10</sup>. 62.2% of the  $G_{om}$  and  $G_{of}$  groups live with their spouses, 28.6% with their children, and only 9.2% live alone. More than half of subjects (58.6%) live in an apartment, which is one of the representative urban housing types in Korea, and 25.3% live in a detached house. 40.5% of the subjects live in a 66-98m<sup>2</sup> sized dwelling, the other 27.8% of the subjects live in a dwelling of 99-131m<sup>2</sup>. A large portion (88.4%) shares their dwelling.

Table 3. The subjects' socio-demographic status and dwelling arrangements

Status	Groups	Over 65 Year-Old		55-64 Year-Old		45-54 Year-Old		Total
		M/ $G_{om}$	F/ $G_{of}$	M/ $G_{om}$	F/ $G_{of}$	M/ $G_{ym}$	F/ $G_{yf}$	
Education	Under High school	31(63.3)	38(86.4)	20(38.5)	29(63.0)	14(28.0)	31(60.8)	163(55.8)
	University	18(36.7)	6(13.6)	32(61.5)	17(37.0)	36(72.0)	20(39.2)	129(44.2)
Occupation	Total	49(100.0)	44(100.0)	52(100.0)	46(100.0)	50(100.0)	51(100.0)	292(100.0)
	Unemployed	29(63.0)	45(91.8)	17(32.1)	38(79.2)	2(3.8)	33(62.3)	164(54.5)
	Employed	17(37.0)	4(8.2)	36(67.9)	10(20.8)	50(96.2)	20(37.7)	137(45.5)
Monthly Income (thousand won)	Total	46(100.0)	49(100.0)	53(100.0)	48(100.0)	52(100.0)	53(100.0)	301(100.0)
	Under 2,000	14(30.4)	7(15.2)	4(8.0)	9(20.5)	1(2.0)	0(0.0)	35(12.1)
	2,000~2,999	23(50.0)	29(63.0)	21(42.0)	26(59.1)	15(29.4)	18(34.0)	132(45.5)
	3,000~3,999	7(15.2)	6(13.0)	11(22.0)	2(4.5)	15(29.4)	16(30.2)	57(19.7)
Type of Family	Over 4,000	2(4.4)	4(8.8)	14(28.0)	7(15.9)	18(39.2)	19(35.8)	66(22.7)
	Total	46(100.0)	46(100.0)	50(100.0)	44(100.0)	51(100.0)	53(100.0)	290(100.0)
	Single	2(4.1)	7(14.3)	2(4.0)	6(12.2)	1(1.9)	0(0.0)	18(6.0)
	Couple	33(67.3)	28(57.1)	18(36.0)	23(46.9)	4(7.8)	9(17.0)	115(38.1)
	Multi-Generation	14(28.6)	14(28.6)	30(60.0)	20(40.9)	47(90.3)	44(83.0)	169(55.9)
Type of House	Total	49(100.0)	49(100.0)	50(100.0)	49(100.0)	52(100.0)	53(100.0)	302(100.0)
	Apartment	30(61.2)	28(57.1)	32(61.5)	31(63.3)	29(55.8)	28(52.8)	178(58.6)
	Detached	12(24.5)	17(34.7)	17(32.8)	11(22.4)	8(15.4)	12(22.6)	77(25.3)
	Others	7(14.3)	4(8.2)	3(5.7)	7(14.3)	15(28.8)	13(24.6)	49(16.1)
Dwelling Size	Total	49(100.0)	49(100.0)	52(100.0)	49(100.0)	52(100.0)	53(100.0)	304(100.0)
	Under 65 m <sup>2</sup>	4(8.5)	6(12.8)	4(8.2)	5(10.2)	1(2.0)	1(2.0)	21(7.2)
	66-98 m <sup>2</sup>	12(25.5)	21(44.7)	15(30.6)	21(42.9)	27(54.0)	22(44.9)	118(40.5)
	99-131 m <sup>2</sup>	21(44.7)	12(25.5)	12(24.5)	12(24.5)	13(26.0)	11(22.4)	81(27.8)
	Over 132 m <sup>2</sup>	10(21.3)	8(17.0)	18(36.7)	11(22.4)	9(18.0)	15(30.7)	71(24.5)
Ownership	Total	47(100.0)	47(100.0)	49(100.0)	49(100.0)	50(100.0)	49(100.0)	291(100.0)
	Owner	44(89.8)	39(83.0)	49(92.5)	46(93.9)	42(80.8)	48(90.6)	268(88.4)
	Others	5(10.2)	8(17.0)	4(7.5)	3(6.1)	10(19.2)	5(9.4)	35(11.6)

Larger than Total Mean Value (%)

Therefore it is expected that the advanced-age people like over-65 manage their lives differently from under-64.

<sup>8</sup> <http://www.icta.ufl.edu/gt.htm>

<sup>9</sup> [http://architecture.mit.edu/house\\_n/placelab.html](http://architecture.mit.edu/house_n/placelab.html)

<sup>10</sup> Korean households' average monthly income during the second quarter of 2006 was 3,056,825 won and that of over sixties was 2,225,310 won.

(2) Subjective Personal Competency

Before studying the elderly and their environment, the physical status and functional capacity of seniors has to be understood. For this, the subjects' "subjective physical status," and "subjective functional capacity" are analyzed.

The assessment of physical status (figure 2) shows that a few subjects evaluate their physical status as "bad (1.0%)" or "very bad (9.9%)" and most subjects evaluate it as "normal (56.0%)" or "good (27.5%)." This is due, in part, to the fact that the subjects were sampled from a healthy and active senior adults group, and reflects that, generally, people are aging with normal or good health.

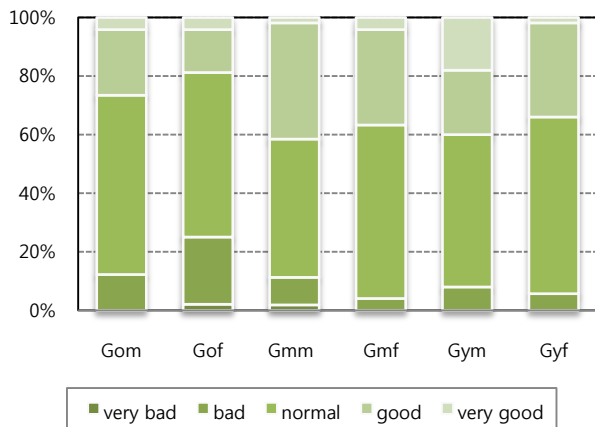


Figure 2. Assessment of Physical Status

The analysis of sensible, kinetic, cognitive, and social functions (figure 3) shows that most subjects have slight problems with eyesight and slight problems with speaking and mingling with friends and relatives. The mean values of the  $G_{om}$  and the  $G_{of}$  group shows that they have some difficulty standing ( $G_{om}$ :  $M=3.1$ ,  $S.D.=0.9$ ,  $G_{of}$ :  $M=3.5$ ,  $S.D.=0.9$ ), bending/kneeling, walking ( $G_{om}$ :  $M=3.1$ ,  $S.D.=0.8$ ;  $G_{of}$ :  $M=3.0$ ,  $S.D.=0.9$ ), and learning  $G_{om}$ :  $M=3.1$ ,  $S.D.=0.7$ ,  $G_{of}$ :  $M=3.1$ ,  $S.D.=1.0$ ). Also, the  $G_{om}$  group's

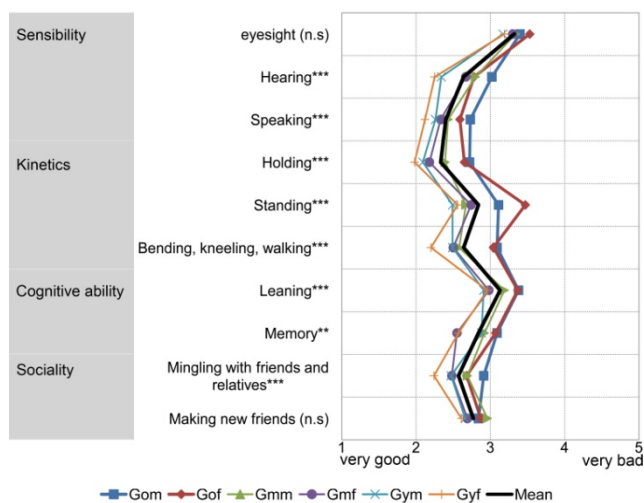


Figure 3. The Functional Capacity

mean value of mingling with friends and relatives was lower than that of others. It seems that even though most subjects feel their physical status is adequate, they realize some body functions deteriorate as they age.

(2) The Importance and Frequency of Daily Activities

The importance and frequency of daily activities (IDA, FDA) are measured by a set of 20 activities, 10 of which are indoors and 10 outdoors, rated on a scale of 1 to 5. Representative activities of the elderly are selected from previous research results (Chang& Lee, 2001; Sung et al., 2005). Each group's IDA and FDA are compared by means of One-way ANOVA analysis.

The analysis of IDA shows that the mean values of all indoor and outdoor activities except 'going to movies or exhibitions' ( $M=2.9$ ,  $S.D.=0.9$ ) are over 3.0 (3.0~3.9). The mean values of healthcare activities such as 'indoor excise' ( $M=3.9$ ,  $S.D.=0.9$ ) among indoor activities and 'outdoor exercise' ( $M=3.8$ ,  $S.D.=0.9$ ) and 'taking a walk & hiking' ( $M=3.7$ ,  $S.D.=0.8$ ) among outdoor activities are the highest items in each category without significant differences between the groups. Among indoor activities, the mean values of recreational activities like 'watching TV' ( $M=3.7$ ,  $S.D.=0.8$ ), 'family talks & pastime' ( $M=3.8$ ,  $S.D.=0.8$ ), 'reading' ( $M=3.7$ ,  $S.D.=0.8$ ), and house chores like 'housekeeping & cleaning' ( $M=3.7$ ,  $S.D.=0.8$ ) and 'cooking & meal preparation ( $M=3.6$ ,  $S.D.=0.9$ )' are higher than those of other activities. The mean value of 'listening the radio' ( $M=3.0$ ,  $S.D.=0.8$ ) is the lowest from among the indoor activities. The mean values of social activities such as 'mingling with friends' ( $M=3.6$ ,  $S.D.=0.8$ ), 'convivial meetings' ( $M=3.5$ ,  $S.D.=0.7$ ), and 'joining the club' ( $M=3.5$ ,  $S.D.=0.8$ ) are higher than those of other outdoor activities.

The analysis of each group's IDA shows that the mean values of 'family talks & pastime' are differed by three:  $G_{mf}$  and  $G_{yf}$  groups' are highest, then  $G_{of}$ ,  $G_{mm}$ , and  $G_{ym}$  groups' and  $G_{om}$  group's follow them ( $p<0.01$ ). Those of house chores such as 'cooking & meal preparation,' 'housekeeping & cleaning,' 'laundry & clothing,' 'home decorating,' and 'gardening' are differed in each group ( $p<0.01$ ).The mean values of women groups' are over the mean value of total and those of men groups' are under it. Among outdoor activities, the mean values of 'mingling with friends' are ordered  $G_{mf}$ ,  $G_{yf}$ ,  $G_{mm}$  and  $G_{ym}$  groups',  $G_{of}$  group's, then  $G_{om}$  group's ( $p<0.01$ ). Those of 'joining the club' are ordered  $G_{of}$ ,  $G_{mf}$ , and  $G_{yf}$  groups',  $G_{mm}$  and  $G_{ym}$  groups', and  $G_{om}$  group's ( $p<0.01$ ). Women groups' mean values of 'going to market' are higher than those of men groups ( $p<0.01$ ), while the mean values of 'shopping' are ordered  $G_{of}$  group's,  $G_{mf}$  and  $G_{yf}$  groups',  $G_{mm}$  and  $G_{ym}$  groups', and  $G_{om}$  group's ( $p<0.01$ ). Prominently, the  $G_{om}$  group's mean values of social activities such as family talks, mingling with friends, and joining the club are the lowest ones of all the groups.

The over-65 age group regards healthcare activities (indoor and outdoor exercises), house chores (cooking and cleaning), and social interaction and pastime activities

(watching TV, family talks, mingling with friends, and joining to the club) as more important activities than others. Female groups weigh house chores and the old male group shows a lower interest in social activities than other groups.

The analysis of FDA shows that the mean value of 'watching TV' (M=3.7, S.D.=0.9) is the highest one and 'reading' (M=3.4, S.D.=0.9), 'family talks & pastime' (M=3.3, S.D.=0.8), 'indoor exercise' (M=3.3, S.D.=1.0), 'preparing meals & cooking' (M=3.3, S.D.=1.2), and 'housekeeping and cleaning' (M=3.3, S.D.=1.0) are over 3.0 among indoor activities. Among outdoor activities, healthcare activities like 'outdoor exercise' (M=3.3, S.D.=1.0) and 'taking a walk & hiking' (M=3.2, S.D.=1.0), and social activities like 'mingling with friends' (M=3.2, S.D.=0.9), 'convivial meetings' (M=3.2, S.D.=0.9), 'joining the club' (M=3.1, S.D.=1.0) and 'going to market' (M=3.0, S.D.=1.0) are over 3.0.

The analysis of each group's FDA shows that the  $G_{of}$  group's mean value of 'watching TV' (M=4.1, S.D.=0.8) is highest and  $G_{om}$  group's is the lowest (M=3.5, S.D.=0.7) ( $p<0.01$ ). This result differs from the commonly accepted statement that old people spend more time watching TV than the young in Korea. Gender accounts for a large difference in the mean values of 'cooking and preparing meals:' the mean value of the  $G_{of}$ ,  $G_{mf}$ , and  $G_{yf}$  groups is higher than that of the  $G_{om}$ ,  $G_{mm}$ , and  $G_{ym}$  groups ( $p<0.01$ ). Other house chore activities like 'housekeeping & cleaning' and 'laundry,' 'going to the market' and 'shopping' among outdoor activities are significantly different in each group ( $p<0.01$ ), with gender inclination as like the result of IDA.

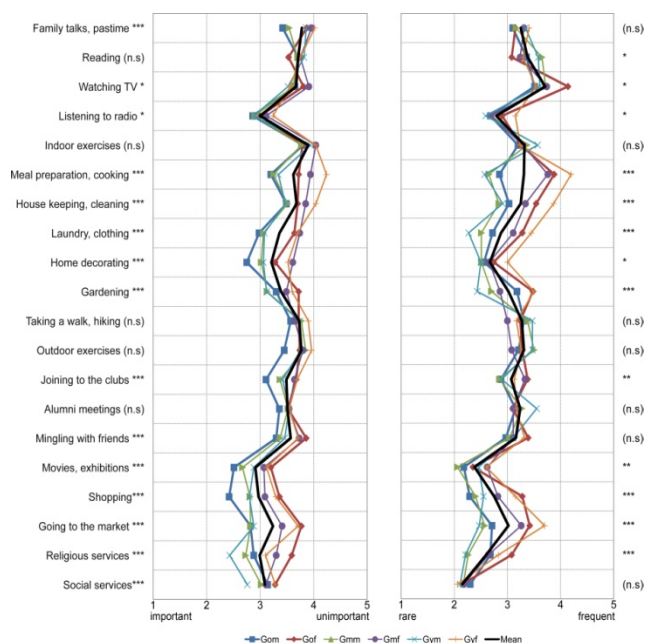


Figure 4. Importance and Frequency of Daily Activity

Over-65 age group are more engaged in healthcare and pastime activities such as exercising and hiking, watching TV, family talks, and convivial meetings. The female

groups' active participation in house chores verifies that most domestic duties are still women's role in all age groups. The notable fact is that old males are considered the most inactive, even in pastime activities like watching TV.

### (3) Factor analysis of Daily Activity

Factor analysis is a multivariate statistical method for reducing large numbers of variables to fewer underlying dimensions. It was originally developed to test the relationship between concepts to see if putative relationships or underlying dimensions (Watson & Thompson, 2006).

In this research, factor analysis is used to find underlying dimensions of seniors' behavior in order to understand how the behavior changes as time goes by and, moreover, what the main character of older people's behavior is. In line with this purpose, factors are extracted from four groups: three aged groups (45-54 ( $G_y$ ), 55-64 ( $G_m$ ), and over 65 ( $G_o$ )), as well as from the entire sample<sup>11</sup>.

Through the analysis of the twenty IDA items, five factors are extracted from the entire sample and from each age group (table 4). The IDA factors of the entire sample are defined as follows:

Factor 1: The activities of this factor are related to house chores aimed at maintaining daily life. It also includes home decorating and gardening as extensive activities involved in housekeeping. It is named "the domestic behavior factor."

Factor 2: The activities of this factor include outdoor activities, such as devoting one's effort to religious and social services, going to the movies or to exhibitions, shopping, and going to the market. These activities can be carried out alone or with companions to make use of spare time. Therefore, it is named "the outgoing behavior factor"

Factor 3: The activities of this factor, such as convivial activity, mingling with friends, and joining the club, can be characterized by sociability. Therefore, it is named "the social behavior factor."

Factor 4: The activities of this factor, such as indoor and outdoor exercise, walking, and hiking can be characterized by a desire for good health. Therefore, it is named "the healthcare behavior factor."

Factor 5: The activities of this factor include indoor pastime or rest activities, such as reading, family talks, watching TV, and listening to the radio. It is named "the recreational behavior factor."

<sup>11</sup> The factor analysis is driven by 'principal components analysis (PCA)' method of extraction and 'VARIMAX' orthogonal method of rotation. The number of factors is determined by the Eigenvalues (over 1.0) and the factor loadings (about 60%).



The factors of each age group are named the same as the factor names of the entire sample (see figure 5). The IDA factors of the 45-54 group are named “factor 1-the domestic behavior factor,” “factor 2-the outgoing behavior factor,” “factor 3-the social behavior factor,” “factor 4-the healthcare behavior factor,” and “factor 5- the recreational behavior factor.” The IDA factors of 55-64 group are named “factor 1-the domestic behavior factor,” “factor 2- the outgoing behavior factor,” “factor 3-the healthcare behavior factor,” “factor 4- the recreational behavior factor,” and “factor 5- the social behavior factor.” The IDA factors of the over-65 group are named “factor 1- the social behavior factor,” “factor 2- the domestic behavior factor,” “factor 3-the healthcare behavior factor,” “factor 4-the recreational behavior factor,” and “factor 5- the service behavior factors.”

The composition of factors is varied in each age group. While the factor composition of the 45-54 group is the same as that of the entire sample, those of the 55-64 group and the over-65 group are different from it. In the 55-64 group, indoor exercise is combined with the domestic behavior factor, and joining the club with the healthcare behavior factor. The factor composition of the over-65 group shows different results. Activities in the outgoing behavior factor are split and absorbed into the social behavior factor, the domestic behavior factor, and the “service behavior factor.” Watching TV is combined with the domestic behavior factor, and convivial meetings with the recreational behavior factor.

Through the analysis of the twenty FDA items, five factors are extracted from the entire sample, as well as from the 45-54 and the 55-64 groups. Six factors are also extracted from the over-65 group (Table 5). Compared to IDA factors, the composition of FDA factors shows that activities in the outgoing behavior factor are split and absorbed into the other factors, such as domestic behavior, social behavior, and service behavior. The FDA factors of the entire sample are defined as follows.

Factor 1: The activities of this factor are related to house chores aimed at maintaining daily life. It also includes home decorating, gardening, going to the market, and even shopping as an extensive activity of housekeeping. Therefore, it is named “the domestic behavior factor.”

Factor 2: The activities of this factor, such as indoor and outdoor exercise, walking, and hiking can be characterized by a desire for good health. It also includes the activity of joining the club. Therefore, it is named “the healthcare behavior factor.”

Factor 3: Convivial activity and mingling with friends are combined with going to the movies or to exhibitions. Therefore, it is named “the social behavior factor.”

Factor 4: Unlike the IDA factors, social and religious activities are distributed into an independent factor, named “the service behavior factor.”

Factor 5: The activities of this factor include indoor pastime or rest activities, such as reading, family talks, watching TV, and listening to the radio. Therefore, it is named “the recreational behavior factor.”

The factors of each age group are named as to the factor names of the entire sample (see figure 6). The FDA factors of the 45-54 group are named “factor 1-the domestic behavior factor,” “factor 2-the healthcare behavior factor,” “factor 3- the social behavior factor,” “factor 4- the service behavior factor,” and “factor 5-the recreational behavior factor.” The FDA factors of the 55-64 group are named “factor 1-domestic behavior factor,” “factor 2-the healthcare behavior factor,” “factor 3-the recreational behavior factor,” “factor 4-the service behavior factor,” and “factor 5- the social behavior factor.” The FDA factors of the over-65 group are named “factor 1-the healthcare and social behavior factor,” “factor 2-the domestic behavior factor,” “factor 3-the outgoing behavior factor,” “factor 4-the service behavior factors,” “factor 5-the recreational behavior factor,” and “factor 6-the pastime behavior factor.”

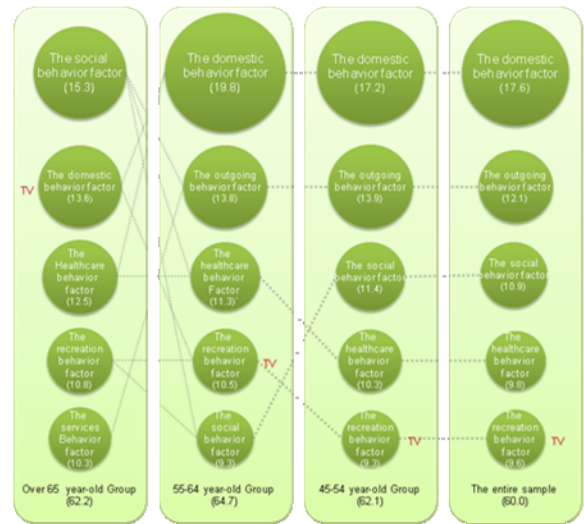


Figure 5. The IDA Factor Composition

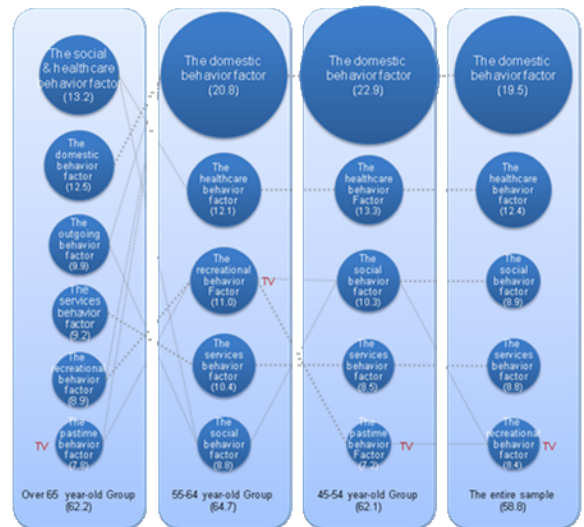


Figure 6. The FDA Factor Composition



The composition of FDA factors of each age group also presents remarkable trends. In the 45-54 group, only two activities, watching TV and reading, remain in the recreational behavior factor. Therefore it is named "the pastime behavior factor." Family talks and pastime are moved to the social behavior factor. The factor composition of the 55-64 group is similar to that of the entire sample, except that the social behavior factor includes activities with familiar company. The over-65 group has the unique factor composition of all groups. Though healthcare is regarded as an important factor in old people's daily life, the healthcare behavior factor is not established independently, but instead joined to the social behavior factor. The activities previously belonging to the domestic behavior factor are divided into the house chore behavior factor (factor 2) and the outgoing behavior factor (factor 3).

The prominent difference between IDA and FDA factor composition is that activities belonging to the outgoing behavior factor are distributed into either the social behavior factor or the recreational behavior factor, and the social and the religious services of the FDA consist of the service behavior factor alone. It seems that even though people think service activities are as important as social or recreational behavior, in fact, the subject are not frequently engaged in those activities. The remarkable behavioral features of the over-65 group, as shown in Figures 5 and 6, are the percentage % of variance of the domestic behavior factor is reduced even it is the first factor in other two groups. The factor composition of FDA shows that the advanced-aged group does not regard healthcare and social behaviors as an individual factor, while they might think the importance of healthcare behavior is different from that of social behavior. Older people's daily activities are distinguished from the younger ones', in that they tend to be more engaged in social, healthcare, and outgoing behaviors than younger people.

#### (4) Affordance Dimensions and Digital Services

From the general characteristics and the analysis of senior adults' daily activities, several affordance dimensions of digital services for the elderly can be proposed as to the IDA and the FDA factor composition of the advanced aged-group over 65

The "Healthcare" dimension is fundamental to enable other behaviors. The over-65 group does not consider healthcare an independent factor. They include it with recreation or pastime factor in IDA and with social activities in FDA. However, it is an independent second or third factor in other age groups.

The "Domesticity" dimension is necessary to reduce the seniors' essential house chores such as cooking, cleaning and laundry.

The "Mobility & Security" dimension supports seniors going out and keeps their shelters safe and calm. It is important for the elderly to go out and mingle with companions within their community, thus preventing alienation.

The "Network" dimension satisfies seniors' needs to take part in social or religious services whenever they want. It

is desirable for society to make use of human resources and for the elderly to enhance their social role.

The "Recreation & Pastime" dimension is necessary to promote seniors' daily living. It supports all the leisure and pastime activities, including family talks and social exchanges.

Table 6 shows five dimensions of digital services for the elderly and distributions of each project under process in AHRI and GTSH. Beyond the projects of these two groups, Smart Medical Home's "a medication advisor" and Placelab's "longitudinal home health monitoring" can be categorized into the healthcare dimension and interLiving's "massage prove/videoprove" into the recreation & pastime dimension.

Table 6. The Affordance Dimension of Digital Services

Affordance	The Aware Home	The Gator-Tech Smart Home
Healthcare	Technology coach Super Assist	· Smart bed · Smart bathroom
Domesticity	Cook's collage	· Smart microwave · Smart refrigerator
Mobility & Security	Gesture Pendant	· Smart front door · Driving simulator · Smart camera
Network	Tangible UIs for networking	· Smart mirror
Recreation & Pastime	Digital Family Portrait dude's magic box & grandma's lap desk Living Memory Box The tableaux machine Videotater Photo collage Family video archive	· Smart-distant dining · Smart blind · Smart-distant dining · Smart phone

## 6. CONCLUSIONS

The purpose of this study is to provide guidelines for a ubiquitous environment in which seniors can "age in place," using an environment-behavioral approach. 305 subjects aged 45 to 78 take part in the survey research. Environmental gerontology theory and representative research projects of available digital services for the elderly are reviewed and the senior adults' daily activities are compared and classified. Temporal sequence (age groups) and behavior (daily activities) are considered as the significant variables in adapting the environment-behavioral approach to ubiquitous environmental design for the elderly. Several conclusions can be made.

First, over-65 groups' socio-demographic status, such as education, employment, and income level, is lower than those of the younger groups, but their dwelling arrangements, such as dwelling size and home ownership, are better than or similar to those of younger groups. Over-65 groups also seem to manage an independent lifestyle even if they realize some body functions deteriorate as they age.

Second, the over-65 groups are more engaged in healthcare and pastime activities, such as exercise and

hiking, watching TV, family talks, and convivial meetings. Female groups are more frequently engaged in house chores. The old male group is the most inactive, even in pastime activities such as watching TV. It seems necessary to support the advanced-age subjects' healthcare and domestic activities and especially to improve the advanced-age male people's leisure activity.

Third, the IDA (importance of daily activities) and FDA (frequency of daily activities) are classified by five to six factors. The IDA and FDA of the over-65 group also differed from other age groups', in that the healthcare behavior factor is combined with social or recreational factors and the domestic behavior is combined with essential house chores. The factor compositions of the IDA and FAD demonstrate behavioral sequence from middle-age to advanced-age as well as distinctive activity patterns of advanced-age.

Forth, five affordance dimensions of digital services for the elderly are proposed through the comparison of all the age groups: Healthcare, Domesticity, Mobility & Security, Network, and Recreation & Pastime. The affordance dimensions will help research groups or companies design ubiquitous environments that will enhance the quality of life of seniors.

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