ANALYZING NEEDS OF SMART HOMES FOR OLDER ADULTS

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Abstract

As the proportion of younger adults taking care of older adults decrease, caregiving for older adults will be increasingly difficult. Smart homes hold enormous potential to replace much of caregivers work and fulfill needs of older adults. What smart homes can provide for the older adults, however, is uncertain. Literature review in human factors, gerontology, and psychology has identified older adults needs, including: spirituality, productive aging, anti-aging, dependency avoidance, and nurturance seeking.

Projective tests with older adults above sixty years old were used to identify seven functions in smart homes to support older adults. These are: mobility, communication, safety, health, outdoor activities, housework, and mental activities. Subsequently, information was solicited using storytelling with students with older kins. This methodology identified in particular the need to support communication and mobility among older adults. Data collected through projective and storytelling tests were used to conceptualize smart home features, which were rated in a survey. The ratings were analyzed with factor and cluster analyses. The needs structure of older adults was found to comprise of three domains: personal needs, household needs, and active aging needs. In addition, tools for personal safety, household security, mobility, and communication, and transgenerational design, and usability issues are identified as promising areas for research and development.

Keywords: Smart home, Older adults, Needs, Projective test, Storytelling.

Executive Summary

An early literature review pointed to additional needs requiring attention, such as spirituality, active aging, anti-aging, dependency avoidance, and nurturance seeking (Kow and Helander, 2003b). These needs may be conceptualized in three dimensions: (1) maturity, (2) independence, and (3) anti-aging. Chapter 2 reviewed these findings by pointing out problems faced by aging individuals and needs that emerged at old age.

Few researchers seem to understand the needs of older adults that can be fulfilled by smart homes. A conventional viewpoint is that older adults desire "independence." Nisbett (2003) argued that the Western value of independency was quite different from the Eastern value of interdependency. A holistic needs structure of older adults can reconcile both positions and construct a value structure that can be useful to design. Concurrently, the process of investigating needs structure also provides an opportunity to look into new methods and procedures.

In this study, an interview was conducted using principles of projective testing. This technique was discussed in Chapter 3 and 5.

User needs might also be uncovered from scientific methods and procedures such as interviews and ethnographic studies (Carroll, 1997; Bayer and Holtzblatt, 1998). These methods and some theoretical concerns were raised in Chapter 4.

Opinions about desirable smart home functions were collected using projective tests. These were sorted into seven basic functions namely (1) health, (2) mobility, (3)

outdoor activities, (4) housework, (5) communication, (6) mental activities, and (7) safety. It was observed that communication and mobility functions were necessary to fulfill many of the other usage scenarios. Thus, a survey was conducted to investigate any correlational relationship between the seven functions. It was found that communication and mobility were of overriding importance in fulfilling their daily needs, see chapter 6.

Based on literature reviews and interviews, the evaluation of the scenarios collected was mapped into product design solutions. These solutions were translated into drawings and statements that were cluster and factor analyzed according to positive feelings of the users. This process was explained in chapter 7. Finally, the needs structure of the older adults and implications of this research were discussed in chapter 8.

Chapter 1 Introduction

1.1 Problems Faced by Singapore's Aging Population

Currently, older adults above sixty-five comprise of six to fifteen percent of each country's population (Fisk et al., 2004). In 2030, the figure will rise to twelve to twenty-four percent (Fisk et al., 2004). The main problem is the retirement of the baby-boomers (Dychtwald, 1999). This group of people was born from 1946-1964 and is the largest age group in many developed countries. As such, the strain on future youth is increasing. At present, most caregivers are spouses, children, and children-in-law of the elders. Of the older adults, 30.5% suffered in terms of social life, 22.5% experienced a decrement in health, 19.9% held some kind of resentment, and 27.2% were depressed (Advisory Council on the Aged, 1989). They are living longer, becoming more active, and stay at home longer before joining an assisted living facility (Fisk et al., 2004).

In addition, future youth may be holding multiple jobs and working harder than their seniors (Dychtwald, 1999). The future youth will then have less time for their parents, but this is only part of the problem. They are also likely to engage more in caregiving. A study conducted in UK showed that the middle aged (between 40-54) were more willing to assume responsibility in caring for the old than the younger persons (between 25-39) (Parker and Clarke, 1997). It is possible that the future youth will rather negotiate and pay for health care aids that keep their parents independent than to take care of them personally. Signs are already emerging in China where a phenomena known as a 4-2-1 family is increasingly common (BBC New Online, 1998; 2000b; 2002c). This is the scenario whereby one person is tasked to take care of two parents and four grandparents. Many of the older adults will rather stay in nursing

home because their children are not spending enough time with them. To solve these problems, Singapore government recognized the need of older adults to stay independent. Programs were conducted to encourage them to stay active. Singapore supported the Asian tradition that the primary responsibility for care of the older adults lie with the family (Inter-Ministerial Committee, 1999). This is different from the Western counterpart where the state assumes basic responsibilities (Parker and Clarke, 1997). Due to such demands, family members in Singapore may engage services, such as smart homes, to bestow greater independence to the older adults.

Smart homes are developed around the world to prepare for older adults needs. However, what to provide is not certain. There has been no study to show what older adults need and how smart homes can fulfill these needs. It is thus important to conduct surveys to identify these needs.

1.2 Present Smart Homes Development

Pessimistically, an aging population is threatening to a nation's economic health. But optimistically, these people will become a dominant consumer force. As such, there is commercial value to understand their specific needs and design appropriate products. Presently, many companies are developing smart homes for the older adults. These include Honeywell, Accenture CSTaR, Hewlett-Packard, Intel, Motorola Lab, Lockheed Martin Company, and Matsushita Electric Works (Sanders, 2000; Warren et al., 1999; emWare, 2002). Many new developments place great emphasis on safety and health of the older adults. In fact, there is a paralleled effort of both companies and government bodies in promoting safety and health in caring for the older adults.

Smart homes development is at an infancy and only a few ideas have been tested in the market. These ideas can mean a change in life pattern, and users may not be willing to accept. Resistance to change has been a pervasive problem in any technical innovation, and it is one of the causes of product failure in the market place (Mackie and Wylie, 1988). Among the factors that reduce such resistance to change are the initial awareness, needs for improvement, level of interest, and perceived features and perceived needs (Rogers and Shoemaker, 1971). Initial awareness is how much the users understood the technology. This will depend on any knowledge about the system the users may know. The users should also be aware of the needs for improvement, which was a function of one's own experiences.

The users' level of interest is also important for the success of an innovation. According to Rogers and Shoemakers (1971):

"Generally, individuals tend to expose themselves to those ideas which are in accord with their interests, needs, or existing attitudes … an individual may (also) develop a need when he learns that an improved method, and innovation exists."

As such, needs were important in driving the success of an innovation, and they might be latent until an innovation exists. Finally, whether the innovation was perceived favorably would depend on how features were in accordance with the user's view of operational problems and needs for improvement.

These issues can be evaluated before smart homes were physically conceived. Initially, a needs structure for the older adults is required to understand what needs might motivate the older adults to adopt these innovations. Another matter of concern are the dissatisfiers (Jordan, 2000). While some needs motivate smart home usage,

other aspects of smart homes such as poor usability can make smart homes undesirable. These were discussed in chapter 4.

1.3 Scope

Smart homes are houses and institutions that contained technological tools for people to use. As such, any technology fitted into a home could make it smart. Many of these home technologies were discussed in chapter 3. Being at the infancy of these developments, which technology will fail and which will succeed remain unclear. As such, it will only be fair to provide a sufficient representation of all the developments today. As this number is large, it is not possible to represent them all. Nonetheless, many of these developments share similar functions. For example, telemedicine of various diseases, or sensing technology for monitoring health and safety. At the very least, each of these functions should be researched and discussed with association to needs of older adults.

1.4 Objectives

The spectrum of needs of older adults is not completely covered by current smart homes development. It is also not understood holistically. As a basis for design, there must be holistic understanding. The purpose of this thesis is to identify the needs structure of the older adults. Emphasis will be placed on needs that had direct implications to design of smart homes.

Due to evolution of technology, there may be additional important needs that smart homes may address in the future. In addition, as technology becomes available, new needs may be generated. Unsatisfied needs present a challenge to designers.

Assuming that smart home products are the means to needs satisfaction, unsatisfied needs will represent a challenge in design, that can be fixed with better design solutions (Kow and Helander, 2003a). Thus, needs are not static, they are dynamic and change in accordance with changes in users' needs and preferences, see figure 3.2.

Figure 3.2 Dynamic states of needs in design

There is no precise understanding as to when innovation, needs, or design may begin. Innovations arise as solutions to user needs come from choices of how users solve their problems. The converse is also true that users' choices depend on availability of innovations. When innovations become inefficient, new needs arise. Therefore, needs do not stay the same but evolve with technology. We shall attempt to identify needs supported by smart homes for the older adults only within the present context of technological development.

The objectives of this research are: (1) to identify the needs of older adults that are satisfied by smart homes, (2) to classify these needs into a clear taxonomy; and (3) suggest the structure of this taxonomy through identifying any relationships that exist between them.

Chapter 2 Literature Review of Aging Needs

2.1 Definition of Older Adults

In 'Designing for Older Adults,' Fisk et al. argued that the term 'older adults' is arbitrary. If forced to define, older adults would be people above the age of 60 (Fisk et al., 2004). But in reality, different effects of aging begin at different age. For example, threshold for range of hearing decline at 60, visual accommodation decline at 65, and visual acuity decline at 40. Although chronological age is just a convenient index to measure age, it does not separate the difference between younger adults and older adults very well. Further more, there is a great individual difference between older adults themselves (Fisk et al., 2004). At best, aging should be seen as a continuum where aging effects take place at different point in time.

2.2 Difficulties of Aging

Different difficulties emerge at various stages of growing up. According to Erikson (1997), some of these stages were from toddler to teenager – where learning to trust others and identity building were vital, and from young adults to matured adults - where career and relationship were important. Becoming old covered some of the last of these stages. Some of these difficulties were triggered by physical, and cognitive changes. Section 2.1.1 and 2.1.2 will discuss these issues.

2.2.1 Physical Difficulties

The greatest changes in senses of the older adults lied in vision and hearing (Welford, 1980). The ability to see under poor lighting or low contrast diminishes at old age, admitting only one third of light admitted by younger adults (Welford, 1980; Fisk et

al., 2004). This might be related to loss of visual acuity (the ability to focus on details) (Stuart-Hamilton, 1994). This could be helped by increasing luminance in a room. There was also a decline in tolerance of glare, making night driving dangerous for older people (Welford, 1980). At the same time, adaptation to the dark became more difficult (Welford, 1980; Stuart-Hamilton, 1994). For a smart home, it was important not to leave the room of an older person completely dark at night to facilitate walking between brighter and darker areas. Nonetheless, an older adult had a higher visual threshold and was able to see less dim lights (Stuart-Hamilton, 1994).

An older person might not see objects located in the peripheral visual field well (Welford, 1980). This problem was more serious above the age of 75 (Stuart-Hamilton, 1994). Objects located at the peripheral field should therefore be large enough to be noticeable. There was a problem of accommodation, in adjusting the focus to different distances (Welford, 1980; Stuart-Hamilton, 1994). This was because aging made the eye lens rigid. It was important that older people were supplied with reading glasses or magnifying glasses. To a person above 80 years, the world could appear “yellower” (Stuart-Hamilton, 1994). Such an older adult would find it easier to detect yellow and harder to distinguish between green, blue, and purple. Additionally, 7% of 65-74 years old and 16% of 75 years old and above were blind or had severe visual handicaps (Stuart-Hamilton, 1994).

Older people had problems in hearing sounds at the low range and at the high range of the hearing (Welford, 1980). These impaired normal conversational ability in 50% of males and 30% of females above age sixty-five (Fisk et al., 2004). Some of these difficulties might be overcome by hearing aids. However, hearing aids were limited

help because they could not provide clear indication of the directions of voices and sounds (Welford, 1980). Older adults with Presbycusis could find higher pitch sound louder than normal (Stuart-Hamilton, 1994). Lower pitch sounds below a thousand hertz were clearer and more comforting (Fisk et al., 2004). At the same time, high pitch sound beyond eight thousand hertz was almost incomprehensible even at ninety decibel (Fisk et al., 2004). Male voices were preferred for spoken announcement (Fisk et al., 2004). Older adults had lesser capacity in identifying sound signals against a background of noise (Stuart-Hamilton, 1994). By understanding this and other problems, hearing difficulties for older adults could be minimized by providing good listening conditions in housing (Welford, 1980).

In the sixties, older adults might experience a gradual loss of sense of taste, particularly salty flavors (Fisk et al., 2004). It might be accompanied by the loss of sense of smell. These might reduce the older adults efficacy in tasks such as cooking.

With older age, there was a reduction of muscle mass and strength (Stuart-Hamilton, 1994). At the same time, the lungs could not circulate as much blood while hardening and shrinking of arteries made it more difficult to pump blood. The result was a reduction of cardiac output. Between 30 and 70 years of age the cardiac output was reduced by 30% (Stuart-Hamilton, 1994). Additionally, physical weakness of older adults resulted in slower action time and less accurate movement (Fisk et al., 2004)

Reduction of muscle mass and strength was accompanied with poor control of balance and gait. This led to one of the most serious problem of old age – fall accidents (Simoneau and Leibowitz, 1996). Reports of falls in institutions estimated an annual

rate of 668 per 1000 older adults (Simoneau and Leibowitz, 1996). Poor balance, impaired somatic sensitivity, inaccurate movement planning, and inappropriate motor response were the main reasons (Simoneau and Leibowitz, 1996; Fisk et al., 2004). In fact, standing itself was a challenge to some older adults. Standing was an unstable position that required constant balancing of the body mass characterized by constant sway. Older adults with large sway were more liable to fall while standing than other older adults (Simoneau and Leibowitz, 1996). Others might fall by tripping. Gait pattern of older people was different from younger people. Most commonly reported differences include: decrease in gait velocity, increase in double support stance (standing with both feet on the ground), decrease in gait length, and larger stride width (Simoneau and Leibowitz, 1996). Weakened muscles also resulted in lower push-off power, which might be the cause of many older adults leaning forward while walking. A survey done in Sweden found that 25 % of 79 years old and above required walking assistance and they could not walk faster than 1.4 m/s, which interestingly was the minimum required speed for pedestrian to cross the road before signals change (Lundgren-Lindquist et al., 1983).

2.2.2 Cognitive Difficulties

Many older adults found it difficult to learn new skills. Many cognitive processes suffered decline, including: attention, working-memory capacity, discourse comprehension, inference formation and interpretation, and encoding and retrieval processes. Some cognitive resources showed little or no change. These include: semantic priming, picture recognition, implicit memory, and prospective memory (Park, 1992).

Due to reduction of cognitive resources, working memory in older adults was reduced (Fisk et al., 2004). They made use of smaller chunks of memory and had to do more frequent integration of what they just read (Fisk et al., 2004). If one could make use of resources that were less affected by aging, one could reduce aging difficulties. One way was by providing contextual or environmental cues that supported the failing memory (Park, 1992; Fisk et al., 2004). It was because semantic memory and event-based prospective memory did not declined significantly at old age (Fisk et al., 2004). Thus, information embedded in pictorial form would be helpful (Park, 1992). Also reuse of texts, labels, and providing explicit relationships between concepts would be helpful (Fisk et al., 2004.

Older adults required more time to process information and to shift attention from one thing to another (Park, 1992; Fisk et al, 2004). Thus, designers must consider providing more time for older adults to react in complex situations. A method to reduce processing time of an older person was to orientate the attention of an older person before passing on the information. For example, one could alert an older adult in a conversation before making a remark (Welford, 1980). One could say “Listen to this,” and wait for the response before continuing. Also, it was critical to make sure older adults have the least number of objects to search through to perform a task (Fisk et al., 2004)

Guidelines for improving medication adherence might be useful. Park (1992) emphasized: (1) the design of instructions to facilitate the development of a mental model for taking medicine, (2) standardized labels, (3) using mixed (verbal/pictorial) labels, (4) external reminders, and (5) training. Fisk et al (2004) advocated making

use of event based prospective memory to help older adults remember taking of medicine. This could be accomplished by the usage of associated visual or audio cues.

Older people found it harder to detect figures embedded in a larger picture (Welford, 1980). It was important to provide only essential information without confusing details or clutters (Welford, 1980). A problem similar to this was the difficulty in visual integration of separate parts into a whole.

Positive aspects of aging did exist. Older adults might rival their younger counterparts in typing, bridge playing, and chess playing (Park, 1992). Another advantage an older adult had over one's younger peers was in hearing the correct words. When words of similar pronunciation were repeated, older adults were able to hear the words more correctly the younger people (Welford, 1980). This might be due to a different memory system in implicit memory capacities thus aiding procedural tasks development. One explanation was that intelligence can be divided into two types – crystallized or fluid (Stuart-Hamilton, 1994). The former represented a collection of knowledge over a lifetime and the latter were thinking skills over novel situations. While many older adults were lower than younger adults in fluid intelligence, they scored evenly on crystallized intelligence (Fisk et al., 2004). As such, it might be helpful to design tasks that older adults could make use of actions they already know (Fisk et al., 2004).

2.3 Needs of Older Adults

Besides physical and cognitive difficulties, an aging person must adapt psychological. A retiree would experience a loss of status and control of his environment (Langer, 1983b). One also faced loss of friends and family members through death or

experienced a limited choice of activities due to physical and cognitive limitations. These would result in a need for adjustment in habits and thinking. For example, it was a cultural norm that a Chinese family was headed by the oldest family member (Xu, 2001). In the past, the children would learn to manage their father's business and inherited the fortune when the father died. Thus, the oldest member became the controller of both family decision and wealth. Today, the younger generation took over the burden of supporting the family. This shift of control of wealth within a family induced a shift of power from older to younger family members (Xu, 2001). The following sections discussed on the potential behaviors of older adults due to adjustments in aging.

2.3.1 Spirituality Needs

Spirituality needs had been discussed by many researchers (Lieff, 1984; Peck, 1968; Erikson, 1968; 1997; Maslow, 1968). This concept applied to the situation where individuals were doing away with self-centered pursuits of life. One example was to overcome the desire to live, and the fear of death. Lieff (1984) explained Jung's concept as follows:

"*…the older adult's task on late life was to foster this inward orientation by coming into harmony with the collective unconscious, religious ideals, and the approach of and preparation for death.*"

This inward orientation to come to terms with one's inner struggle, and thus surpass these concerns, was termed spirituality. It was a freedom from further pursuits of status, acceptance, adequacy, and self-esteem (Lieff, 1980). The freedom from pursuit, being a struggle, had a close relationship with psychological wellbeing, or eudaimonism. It touched the deepest needs, strivings, goals, ideals, and competencies

of a person (Averill and More, 2000). The reason why spirituality was akin to eudaimonism was that its main objective was to come to terms with biological principles, consisting of survival instinct such as the desire to live. The aim was to achieve a more socially orientated attitude to life and play a role benefiting others (Averill and More, 2000).

So it could be assumed that an older adult with a spirituality need would be interested in the activities of children and their needs. There could be volunteer opportunities in the community to help the more unfortunate. Communication devices connected with such places would be welcome by these people. One might use an “always-on” video channel and see what was happening at one’s children home. This provided an electronic window to keep in touch with one’s close friends without having to travel the distance.

Studies in hedonism showed that one third of persons with disabilities were somewhat less satisfied with their life (Fiske, 1980). Among the rest, there was a combination of “positive” and “negative” attributes which seemed to enhance satisfaction. Thus, there was a ground for the consideration of both eudaimonism as well as hedonism in the study of wellbeing (Ryan and Deci, 2001). This was especially so since older persons have a decreasing capacity to enjoy life based on hedonism.

Spirituality might be difficult to achieve. Culturally, older adults living in the city were conditioned to feel the need to remain productive and dominant (Lieff, 1980). This was also demonstrated in comparative studies in China and America (Kaplan, 1979). In China, it was reported that life became easier as one gets older. An older

adult was able to exercise more control and do things that were more meaningful. One was not willing to retire. There was a feeling that it was a responsibility to pass down the cultural heritage. On the other hand, in America, older adults participated less in intellectual activities. They were flattered when someone said that they did not look or act their age. Additionally, they were also likely to believe that success belonged to the young. Due to these reasons, it was likely that people in the city were facing a greater struggle to gain independence from self image. As these studies were done in the 1970s, circumstances might now have changed. It was more likely that China, being in the midst of globalization, was gradually moving towards an American aging culture (BBC News Online, 1998; 2000b; 2002c).

Many older adults were facing inner struggle, which could be drawn from the greater rate of introspection and reflection (Lieff, 1984). This might have direct relationship to the conflict between diminishing efficacies versus cultured belief in the pursuit of status, acceptance, adequacy, and self-esteem. This inner struggle might manifest itself as an emotional ambivalence between two contradictory self-images: one that was efficient and productive, and one that understood one's limitations. For a man, this often meant looking for a self worth beyond working; for a woman, it entailed looking for a self worth beyond motherhood (Peck, 1968).

Being healthy and thus efficient and effective until the point of death might avoid this struggle. However, no matter what precaution was taken, an older adult would face the need for physical dependence after 80 (Erikson, 1997). This biological finitude was an inescapable fact and the only escape was perhaps in spirituality or self-

actualization. Peck (1968) thus defined the most constructive way of living in late old age as:

"*To live so generously and unselfishly that the prospect of personal death … looks and feel less important.*"

Spirituality did not mean being detached from socially defined activities. Rather, it had to do with finding meaning beyond self-benefits in these activities. This phase of life started from an average age of 63.8 years old (Frenkel-Brunswik, 1968). Plaguing a person were anticipation of death, complains of loneliness, and religious questions. Religions, philosophies, sciences, or other ways that helped transposing a suitable attitude towards life were important at this point of time.

While ritualistic religious behavior outside the home diminished with age, religious feelings and attitudes tend to increase (Moberg, 1968). This was not to say that an older person felt that it was unnecessary to ritualize a belief. Rather, the opportunities for ritualization diminished. This pointed to the need for resources that maintained their efficacy for ritualization. For example, an elder might need to attend a religious ceremony. Although one could not move around, there could be means of transportation, public transport, and others. Alternatively, a tele-conference of the ceremony might also work.

Other persons of spiritual inclination might disengage themselves from the society and retired in the countryside (Neugarten, Havighurst, and Tobin, 1968; Erikson, 1997). Although disengaged from the routines in a city, there might still be a need to contact people who could offer advice on spirituality. It might be a monk, a

psychiatrist, a priest, or similar people. To keep in touch, a person could use teleconferencing, emailing, or Internet.

It was a common stereotype that older persons were not receptive to technological gadgets. However, Czaja (1997) concluded that although older people were less confident with technology than younger people, those who had experience with these technological devices had more positive attitudes and greater confidence. BBC News Online (2002c) reported that many retirees, mostly women, surfed the net on a regular basis. Thus, the possibility of mixing technology and the older adults should not be overlooked.

2.3.2 Productive Aging Needs

The focus of some older adults was the creative use of dependency (Baltes et al., 1999). This kind of dependency took wisdom (Lieff, 1984). An earlier example of denial of one's limitations was to carry a long umbrella as a cane. The courage of using a cane for the sake of one's real needs required wisdom. While younger people focused on self-knowledge, competence, and self-esteem, older persons were better off learning to adapt (Ryan and Deci, 2001). One way was to use positive reliance. One who came to term with his own dependencies did not suppress his sickness. Instead, one aimed to maximize gains and minimize losses. Such adaptation processes often started within careful *selection* of meaningful activities, *optimization* of these activities, for example by putting in more time, and *compensation* for irreplaceable deficits (Baltes et al., 1999). A person would be able to assume a new role, regains sense of usefulness and confidence, formulates new problem solving strategies, and maintains some activities in life. Although such elders valued independence, physical

independence was now translated into a pride in autonomy and concern for the freedom of others (Clark, 1968).

An older adult with a positive outlook was arguably more receptive to aids such as a cane, a wheel chair, or a memory aid. One might be looking forward to new tools that could help him/her remain relevant to others. For example, mobility devices (e.g. the motorized wheelchair), electronic memory aids, home appliances (e.g. the microwave ovens for fast meals), and other home automation that freed one's time for more meaningful activities (e.g. taking care of grandchildren, doing volunteer work, and so forth).

As such, the differences between universal design or accessible design might not matter anymore. Since these individuals had realized their declining state and focus on adaptation, products that were not explicitly "designed for all," which were likely to be more expensive, might not be acceptable. They might take on the challenge of using products that culturally belong to the domain of younger people, including computers, PDAs, and computer games! They might be early adopters of technological innovations that were conceived for the older adults.

2.3.3 Active Aging Needs

A person living in the city had to follow legislations that benefited the economy. Among these was mandatory retirement at 60 years old (the current norm in Singapore). So deep was this social schema, that it was often seen as the beginning of old age (Fiske, 1980). A person after 60, although he or she often enjoyed good health, was recognized as "passed one's prime." This was evident from the re-hiring

of these people at lower status, pay, and benefits. These losses often prompted older adults to long for the “good old days.”

Many tried to maintain their level of activities from middle age (Neugarten, Havighurst, and Tobin, 1968). One example was from the older married women. This group was normally in less demand economically and socially than their husbands. In order not to fall into the undignified status of widowhood, they became increasingly preoccupied with the state of their husbands’ health (Fiske, 1980). This was particularly important to subjective wellbeing since perception of happiness came by comparing their life to *standards* (Diener and Lucas, 2000; Averill and More, 2000). These standards might be created from observing people around them or comparing with what they were like in the past.

However, it was difficult to maintain a person’s activity level (Fiske, 1980). In general, when the amount of activities decreased, subjective wellbeing decreased (Havighurst, et al., 1968). Cognitive defenses might then set in to minimize the effect of losses. One way was to distance oneself from some identities (Howard, 2000). For example, 86% of persons in their eighties feel younger compared to only 54% of people in their forties. In general, greater self-esteem was associated with feeling younger. Data suggested that life satisfaction was lower and stress was higher for those who saw themselves as old (Howard, 2000). The previous point, that old people in America were flattered by comments that they did not look like their age, reinforced this view (Kaplan, 1979).

There was a tendency for people to hide their age. Products that avoided stigmatizing due to aging were preferred (Hirsch et al., 2000). An example was an observation of the author that many older people in Singapore often carry a long umbrella as a cane. Many of them had a real cane, which they refused to use, at home,.

Recent developments in *inclusive design*, *universal design*, or *universal access* aimed at providing a design approach for everybody, thereby avoiding discrimination due to age (Coleman, 1998; Jordan, 1998; Stephanidis and Savidis, 2001). This possibly required some form of adaptation to changing user's skills. In contrast, specific design schemes for people with difficulties might sometimes strengthen their sense of inferiority.

It was also likely that people who were keen to avoid growing old would continue to make use of health and beauty care products offered at beauty saloons, and so forth. Transportations and information technologies might thus appeal.

Smart homes might be designed such that a perception of youth might be bestowed upon the older adults through aesthetics. It might be highly plausible that human attribute life to inanimate objects (Freud, 2001). Some people in the past made use of effigies to bestow curse unto the enemies. Some people burnt flags. One of the author's friend claimed that eating *Tiramisu*, a kind of cake, gave her a sense of "keeping it up," same as the meaning of tiramisu in Japanese. The idea was to convey meanings beyond the intended functions of the object. Perhaps the quality of youth could be conveyed through aesthetics in a smart home. The actual carrying out of this idea might require many design iterations and confirmation using affective test such

as Kansei Engineering (Nagamachi, 1996). The latent variable or Kansei word here would be “youthful,” as being the quality of interest.

Another interesting observation was that older women tend to worry about their husbands’ health. This came from the observation that older women, upon relieved of duties as a mother to take care of their children, turned their attention towards well being of the their husbands. Gradually, these obsessions became frustrations toward their husbands’ disregard for a healthy life (Fiske, 1980). Women might therefore become more interested in health care products. Furthermore, as women often outlived their husbands; it was expected that the loss of purpose in caring for her husband, coupled with the earlier loss of motherhood, would enhance the need for social activities to renew and reaffirm her life goals (Fiske, 1980). One smart home solution might be an Internet group of like-minded people, who supported each other and assisted in creating a sense of identity. This might bestow a feeling of “you are not alone” in combating the belief of indignity.

2.3.4 Dependency Avoidance Needs

Some older adults rejected all forms of aids (Lieff, 1984). According to Clark (1968), this might be a way to free oneself from danger out of fear and mistrust of others.

A frequent manifestation of this protectionism was the reluctance to be institutionalized. Many older adults were successful in achieving a status of “social invisibility.” They avoided the attention of potentially responsible or decision-making people (Fiske, 1980). Brown and Lieff (1984) implemented a home psychiatric treatment program to help such older adults. The illnesses suffered by their patients

were not trivial: chronic illnesses, social withdrawal, depression, alcohol abuse, nutritional problems, and difficulties with activities of daily living. Many were also in need of help in housework, preparation of meals, and care during illnesses. In one study, Brown and Lieff (1984) found that 96% of a group of older adults were in fact liable to institutionalization.

While it was important to intervene into the life of the older adults to keep them safe, an inappropriate intervention might be harmful. Several studies concluded that those who received the most services had highest rate of institutionalization and death (Burnside, 1980). The higher death rate might have more to do with excessive control of the older adults, which was against their will, and had little to do with excessive care. In comparison, studies had shown that inducing responsibilities to take care of themselves in a new living environment improved their health significantly (Langer, 1983b; Carp, 1968). Another theory stated that only self-endorsed goals enhanced wellbeing (Ryan and Deci, 2001). Many health care institutions had a rigid lifestyle, which discouraged personal initiatives, and lowered the wellbeing among occupants. Thus, the best strategy to provide health care might be to design products that were home based and could be used with minimal intervention.

Today, most electronic home products were designed for the use of younger adults. Products such as computers, VCR recorders, and microwave ovens might not be compatible with the mental model of older adults. A kind of TV-radio known as Tivo was one example of a user-friendly machine for technologically incompetent home owners (BBC Online, 2001). It made educated guesses as to what users would like to watch on TV and could record hundreds of hours of movies automatically. There was

no need to program a VCR: a frustrating and difficult task. It was believed that enhanced usability would allow some older adults to maintain their self-esteem by avoiding seeking help from others.

Older adults with strong disdain for dependency might not want to visit hospitals. Thus, medical needs normally provided in hospitals could be provided at home. These services might include video monitoring, measuring pulse, oxygen levels, blood pressure, blood glucose level, ECG, body weight, tracking of medication adherence, and use of short interviews and questionnaires through video-conferencing. These services might provide feedback for medical conditions including injuries, mental health of patient and caregivers, cardiac care, diabetic care, HIV, coronary artery disease, asthma, and hypertension (Risk and Rayne, 2002). Doctors and nurses could observe the health status at a distance, check on the condition of their patients and give advice. This kind of tele-medicine required communication infrastructure, such as broadband connection with an “always on” Internet access. It was a reasonable assumption that a patient who shunted dependency would at least be able to take care of him/her own basic needs.

2.3.5 Nurturance Seeking Needs

Many older adults needed emotional support and approval from others. They perceived themselves as powerless and ineffectual, and tend to be anxious and fearful (Bornstein, 1998). They might become resentful, demanding, and hostile to people who failed to meet their demands (Lieff, 1984). One possible explanation came from observing collective culture. Among the collective identities, compensation was often provided for subordinate status that sustains a system of inequalities (Howard, 2000).

For example, people who win on the lottery or get promoted were often expected to give a treat to the others who were in a “less fortunate” position. As a result, there were signs that people of lower social status translating a coercive relationship into dependency by forcing their “oppressors” into accepting obligations towards them. But ironically, in the case of overly dependent older adults, the more successful they were, the more dependent they became.

Older adults were forced into subordination for many reasons. One reason was the branding of old people as a homogenous group with terms such as senile, older adults, Golden Ager, and so forth. Studies had shown that simple labels of subordinate status (such as “worker” versus “boss”) reduce performance dramatically (Langer and Benevento, 1983). Many older adults believed in such labels (Kaplan, 1979). Another reason for the subordinate status wa loss of housing, and income. Lindstrom (1997) argued that a home address was a marker of socioeconomic position. Retirement income was also an indirect sign of buying power. These “labels” might lead older adults to sense a loss of personal control and competence, critically undermining a desire to live independently. Searle et al. (1995) argued that perceiving oneself as independent (being in control and competent) was to behave accordingly. The opposite effect, known as self-induced dependency, the case where one gave up taking actions due to a perceived futility of responses, or randomness of outcome.

Following this line of argument, dependency had a strong relationship to perceived sense of lack of control due to assumption of a subordinate role. A person with self-induced dependency believed that one was not expected to nor should they perform

any role in a household. Instead, people who were "superior," in this case the children, would take on the various chores and needs.

There were at least two different approaches to meet the needs of these older adults: (1) To acknowledge their desire to be nurtured and to provide what they wanted; and (2) To provide tools that might recover their autonomy.

For the first approach, it was recognized that caregivers had to put in much effort to provide for the older person. According to Neugarten et al. (1968), this group of older adults (termed *succorance-seeking*) could maintain medium levels of activities and life satisfaction, as long as they had one or two other persons who could satisfy their emotional needs. The caregiver would likely be the main user of any devices conceptualized for the needs of the older person. It was known that a person with a higher dependency falls ill more frequently; common illnesses include ulcer, asthma, and heart diseases (Bornstein, 1998). Thus, it was reasonable to assume that dependent older adults needed more medical attention. Their medical needs, coupled with their dependency, pointed to the use of simple medical devices. The usability of these devices might also benefit the caregiver. One example was the NovoPen (Novo Nordisk, 2001). It was a pen-like insulin injection device. Users could dial the dose and inject the needle easily. The enhanced usability accounted for its wide acceptance.

Caregivers of older adults took care of many house chores included shopping (56.7%), laundry (55.1%), cleaning the house (55.4%), bathing, feeding, and toileting (NACFA, 1995). Older adults who could walk can also bathe without aids. However, once they required some form of walking aid, walking, bathing, feeding, and toileting

needs increase by 20% to 80%. Caregivers often suffered in social life, health, and mental depression, and feel resentments against family members who did not offer help (Inter-Ministerial Committee, 1999). In principle, caregivers needed assistance in shopping, laundry, and house cleaning. In these aspects, information appliances for purchase of groceries, food, and services would be ideal. Similar to the previous example on Tivo, usability might be the key to the success of these appliances. Additionally, in looking to the side effects on caregivers, they might often be isolated from others due to the need to constantly supervise the older adults. This could be taken care of by an always-on video channel that connected the patient to other locations, such as the home of family members or friends.

From the second perspective, older adults could be given tasks so that they might recover and rediscover a "sense of independence!" Langer and Rodin (1976) showed that it was possible to revoke dependency by giving responsibilities to the older adults. This led to a sense of control since one's action affected the probability of the outcome. Other ways of creating a sense of control might be the introduction of choice and active involvement in daily chores (Langer, 1983a).

First, older adults should be able to choose and buy their products themselves, rather than the caregivers. Such a simple choice might increase the acceptance and use of the product (Langer, 1983a, Yen and Woolley, 2001). Designers should, accordingly, be tasked to design product that older adults could accept and understand.

Second, the product interface and feedback should be familiar. Familiarity, being a usability principle, was also a control psychology principle (Langer, 1983a). Some

older adults might spend very little time on technological gadgets. As such, feedback such as like flashing leds and highlighted icons might not make any sense. These features might capture the attention of younger users but discouraged the older people. It was important to understand the usability concepts for older adults.

Third, older adults should be encouraged to use the products themselves. This meant designing gadgets were exceedingly easy to use, so that there would be no penalty in using them.

Chapter 3 Review of Present Smart Home Development and Inadequate Coverage of User Needs

Smart homes were developed for many purposes. Design goals included: peace of mind of carers, safety, security, independence, cognitive assistance, tele-medical care, mobility, slowing down of age associated changes, tele-shopping, and transgenerational design. These concepts were explained below. On one hand, the coverage of needs was enlarged. On the other hand, there were few guidelines for what older adults needed in a smart home. Many of the current developments were ad-hoc studies without a holistic investigation of the problem space of older adults. Needs were important motivators of users acceptance of technology; smart home development could benefit from examining needs of older adults before taking on these development.

3.1 Current Smart Homes Development

Many smart home projects were being developed. Each of these projects aimed to achieve a certain objective, and they were described below.

3.1.1 Aware Home

Aware Home was initiated by Georgia Institute of Technology to create an environment that was able to know information about itself, who were the inhabitants and what they were doing (Kidd et al., 1999). There was an existing prototype of the Aware Home. This served as a test bed for the sensors used to accomplish the intended tasks. Sensors implemented by 1999 included ultrasonic sensors, RF technology and video, floor sensors, and vision technology.

In the long-term, the project aimed to build a home whereby the context of users' communication could be made known. Also, user information might be taped with sensors in the home and wearable computers wore by the users. Additionally, a smart floor system was being tested to identify users. Another useful research direction was to develop a system to find lost objects such as keys. This might be useful for the older adults with memory impairment.

One of Aware Home initiatives, known as "Aging in Place" aimed to make use of some of these technology to enable the older adults to stay in their own home for as long as possible (Sanders, 2000). The purpose of Aging in Place was to make use of ubiquitous computing to allow the older adults to perform basic activities of daily living, instrumental activities of daily living, and enhanced activities of daily living (EADLs). This would not only ensure that older adults continue independent life, but also active life (Mynatt et al., 2000). Generally, the system aimed to address three key problems facing the older adults: possible crisis, everyday cognition, and daily life and long-term trends. Crisis included possibility of fall and injury. Everyday cognition was required to perform task such as tooth brushing and finding keys. Daily life and long-term trends included simple things in life that would affect the wellbeing of the older adults in a long run, such as keeping in touch with family members.

3.1.2 Assisted Cognition Project

The Assisted Cognition Project was carried out by University of Washington and Alzheimer's Disease Research Centre of the United States (Kautz et al., 2002). The purpose was to make use of ubiquitous computing and artificial intelligence to

substitute memory loss and problem solving abilities of Alzheimer's patients. An Alzheimer's patient often relied on a familiar environment to provide cognitive cues to perform basic tasks. When placed in a novel environment, one might not be able to perform as effectively. To solve this problem, the project directed the development of two systems: The Activity Compass and the Adaptive Prompter.

The Activity Compass was a hand held device. The screen showed a large arrow that pointed to where the user intended to go. The intended destination was calculated from data of the user's activity, collected by GPS technology. The system had to decide if a drift from normal activity pattern warranted an intervention. The system was designed to learn from its own experience for such matter.

The Activity Prompter was designed to prompt the user in case one had forgotten the steps in performing a sequential activity. This might happen to Alzheimer's patients who might forget to brush their teeth. When the sensors "sensed" that an activity (tooth brushing) had "stalled," the prompter would remind the user to pick up the toothbrush.

3.1.3 Intelligent Health Care Technology

Other than crisis detection and environmental support, ubiquitous computing might also be useful in health care of the future. Sandia National Laboratory was developing "intelligent health care technology" (Warren et al., 1999). The aim of this initiative was to deliver highly automated, intelligent health care in the home while reducing the cost of care. Several needs were addressed included: physical security,

entertainment, communications, lighting, heating/cooling efficiency, and voice-activated environmental control.

To achieve the objectives, sensors planted around the house would pick up various information about the user and the home. These included: heart rate and blood pressure, humidity, temperature, carbon monoxide level, viruses, bacteria, and chemical/biological agents. Smart toilets might also analyse urine specimens (Warren et al., 1999). Through this information, it would be possible to analyse and make appropriate suggestions to the user.

3.1.4 CARE System and Other Healthcare Systems

Matsushita Electric Works (MEW) Ltd had developed a simple system called CARE to monitor the safety of older adults in nursing homes using a video camera (emWare, 2002). Rather than sending “live” pictures of older adults, the system used sensors to detect whether the person was in the bathroom, bedroom, standing up, lying down, sleeping, or agitated sleep. This enabled nursing home staff to monitor every patient at once.

Several other healthcare systems were developed. These included: lifelong electronic personal healthcare record, portable pulse, oxygen, and blood pressure monitoring equipment, home monitoring equipment for cardiac, HIV, coronary artery disease, hypertension, diabetes, and asthma patients, teleconferencing social and psychological support services (Risk and Rayne, 2002).

3.1.5 Accessibility for Impaired Mobility

Besides ubiquitous environment and healthcare technology, efforts were also underway to design products that blended into a smart home environment. One such effort was known as Accessibility for Impaired Mobility (AIM) (Edwards et al., 2001). A device was attached to a wheelchair and enabled navigation around the neighbourhood. While wheelchair users were presently able to access most places, they still required some assistance. AIM aims to relieve these users from help and bestowing them full independence to move from one place to another. This required a combination of technology and ergonomics in wheelchair design and environment modification. Environments being studied included shopping malls, public buildings, transports, and street environment. Some improvements to these infrastructures were suggested. For example, provision of more ramps, automatic doors, lower shelving, convenient lift buttons, and low-floor buses.

3.1.6 Ergonomics for Slowing Down Age Associated Changes

Some ergonomists were investigating products that might slow down “age-associated changes.” It was believed that death rates might be altered considerably by environmental influences. Kristjuhan (2000) estimated health depends 20% on the environment and 50% on lifestyle. He suggested reducing ultraviolet radiation, skin soiling, smoking, pollution, muscle activity, and noise.

3.1.7 Tele-shopping

Hautala et al. (2000) presented a form of home tele-shopping service that allowed older adults to use the telephone to order groceries by leaving a voice message. The message was played back to confirm the order. Sixty seven percent of the subjects

evaluated themselves as capable of using the system. Otherwise caregivers found that the system allowed them to spend more time on other chores around the house.

3.1.8 ELDer Project

The ELDer project was initiated by Hirsch et al. (2000). The purpose was to study the psychological and social factors of design with respect to elder's technologies. An interesting observation was that some devices caused users to feel ashamed and powerless, known as stigmatizing aesthetic. This led to the widespread use of motorized scooters. Although they had similar functions compared to a wheelchair, they reduced stigmatizing effects.

3.2 Inadequate Understanding of Needs of Older Adults in Smart Homes

Many of the above mentioned projects were carried out to solve one or two problems encountered by older adults. This might be acceptable since smart homes and other technologies being designed were at an early stage. In the past, technological gadgets were used mainly by the younger generations. Today, many older adults were beginning to understand the opportunities that technology presented. As a result, many needs of older adults were not yet fulfilled by new technology. As more and more companies entered the market, competition would become more intense and knowing what needs to target would become important.

Many needs of the older adults were mentioned in chapter 2. They were formulated at a high abstraction level: spirituality, productive aging, active-aging, dependency avoidance, and nurturance seeking. They arise from the domain of psychology and

gerontology and lacked design prospects. However, they could provide many opportunities in expanding the area of needs coverage by technology. For example, many older adults had a strong desire to understand religious view points. One might support this by providing information using voice or video. One might argue that a company only needed to provide a basic technology, such as mobility and communication, and users will would for themselves how to use it. However, understanding the underlying needs allow awareness of several ways in which the needs may be satisfied. Different design options can then be compared. For example, safety might be enhanced by faster communication between older adults and their caregivers or by remote monitoring through a security system. Once the purpose of the design was understood, the cost-benefits of both methods could be compared.

These high level needs could be interpreted so that one could propose means for satisfying the needs. For example, being a widow might be disgraceful from a social point of view (Fiske, 1980). As a result, many women paid much attention to the health of their husband (Fiske, 1980). Health products for the male were therefore in demand for several reasons, and some were bought by the wives.

An interesting cultural observation was that, while an independent person was seen as normal in the west, interdependence was seen as normal in the east (Nisbett, 2003). There was a difference between the values of easterners and westerners. The philosophical foundation of the easterners placed emphasis on the holism of thoughts (Nisbett, 2003). They believed that all objects were interdependent and no individual category existed. Thus, more emphasis was placed on relationships. On the other hand, according to Nisbett (2003) Westerners' frame of thoughts came from the

Greek philosophy, which emphasized a fragmentation of objects into independent groups. Thus, Westerners saw people as independent, and encouraged development of personalities and independent functions. Thus, in the east, older people were expected to be more dependent on their children (Nisbett, 2003). It was because while parents first took care of their young, these children in turn grew up to take care of their parents.

The emphasis on independent living was therefore in conflict with other cultural values. However, many companies and government agencies equated well being with independency. As such, products were developed to support older adults living alone: a conflicting proposition to some adults.

Thus, there were several scenarios. People with spirituality and dependency avoidance needs might desire disengagement from people and society. Others with productive aging and nurturance seeking needs would look for help in the form of tools and caregivers, see table 3.1.

Table 3.1 Two dimensions of needs of the older adults (Kow and Helander, 2003b)

	Independent	**Dependent**
More matured	Spirituality	Productive aging
Less matured	Dependency avoidance	Nurturance seeking

Table 3.1 was derived from a review of needs of the older adults from research articles covering human factors, gerontology, and psychology. Many different issues

were brought up and it was useful to classify them. To do so, three dimensions were chosen: maturity, independence, and acceptance of aging.

Maturity dimension was represented from Erikson's (1963; 1997) findings that different types of conflicts had to be resolved at different age. As a result, he developed a total of eight conflicts from childhood to adulthood. Peck (1968) drew from Erikson's findings and argued that three main conflicts have to be resolved in old age: work-role preoccupation, decline in health status, and death. Resolution of each amount to growth in maturity, which was not represented by intellectual capacities, but wisdom. This wisdom was the ability to make judgments by the use of perception and imagination (Peck, 1968). Thus resolving work-role preoccupation led to 'ego differentiation' - finding self worth beyond the 'job.' Resolving preoccupation in health decline led to 'body transcendent' - finding pleasure not in body comfort but in mental activities. Resolving preoccupation in death led to 'ego transcendence' – to live so generously and selflessly that personal death seemed unimportant. Dependency avoidance and nurturance seeking needs were the results of inability to come to terms with ones decline in work status and health. Therefore, these people went to the extreme of disregarding care or became totally reliant on others. Older adults who were more matured would develop new activities and deeper understanding which were in line with spirituality and productive aging needs.

Independence is one of the most touted reasons for providing welfare for the older adults. It is also possible that some older adults are only able to achieve life satisfaction through dependency (Neugarten, 1968). Designers have to consider both

requirements before conceptualizing designs. Therefore, smart homes for the older adults should not be designed solely for the older adults but also for the caregivers.

With respect to the needs of older adults mentioned in this chapter, many of these needs can be fulfilled if smart homes provide access to Activities of Daily Living (ADLs) and Instrumental Activities of Daily Living (IADLs) for the older adults. ADLs consist of (1) Bathing with sponge, bath, or shower, (2) Dressing, (3) Toilet Use, (4) Transferring (in and out of bed or chair), (5) Urine and Bowel Continence, and (6) Eating. These are functions to satisfy many of Murray's viscerogenic needs. These functions are so basic that they are fundamental to the normal functioning of a human being. Instrumental Activities of Daily Living (IADL) consist of seven activities: (1) Use of the telephone (look up numbers, dial, answer), (2) Traveling via car or public transportation, (3) Food or clothes shopping (regardless of transport), (4) Meal preparation, (5) Housework, (6) Medication use (Preparing and taking correct dose), and (7) Management of money (write checks, pays bills). They are able to support higher level needs beyond just surviving. For example, going out for social gathering.

In order for older adults to be fully independent, or if the caregivers are to manage the dependency of the older persons, smart homes have to support users carrying out ADLs and IADLs. For example, for older adults to fulfill spirituality needs, they may have to keep in touch with their spiritual community. IADLs including traveling and telephone use would come into usefulness. If older adults are unable to perform these tasks, they would encounter a loss of efficacy for spirituality fulfillment. Examples of IADLs activities that support each need were shown in table 3.2.

Table 3.2 Examples of IADLs Supporting Needs of Older Adults

IADLs	***Spirituality***	***Productive Aging***	***Dependency Avoidance***	***Nurturance Seeking***
Use of the telephone (look up numbers, dial, answer),	Calling religious friends for support.	Calling children to find out if they need help.	Calling for aid only when one is injured or very ill.	Calling children for help where the person is physically healthy enough to handle it.
Traveling via car or public transportation,	Going to religious retreats.	Going to community club to perform voluntary duties.	Carry on driving even when she vision has declined.	Making her children drive her out to the hospital, refusing to consider taking a cab, even when they are not free.
Food or clothes shopping (regardless of transport),	-	Going shopping and walking in the mall for oneself and family.	Buying clothes and shopping for oneself.	Insisting caregiver to go shopping with her even when it is safe not to do so.
Meal preparation,	Preparing food for the religious community.	Preparing meals for oneself and family.	Preparing meals for oneself	Refusal to buy food or prepare meals when one is physically capable.
Housework,	Performing house duties at the church.	Doing housework for the family.	Carry heavy objects without asking for help.	Refusing even to do the simplest of task, e.g. washing clothes, even when one is able to do so.
Medication use (Preparing and taking correct dose),	Taking medicine to remain healthy.	Finding medicine organizers and reminder to manage medications.	Unwilling to take medications for minor illnesses and symptoms.	Insisting that caregiver preparing medicine for her.
Management of money (write checks, pays bills)	Making donations to the church.	Learning to use Internet banking for payments.	Managing own private savings.	-

In table 3.2, examples of how needs can be satisfied by IADLs are given. People of different needs may handle each IADL differently. For example, people seeking spiritual growth may pay more attention to church activities. For people who wish to

remain productive, there will be a higher tendency for them to volunteer at their children's home or at the community services. While IADL activities define the function older adults need to perform, needs of older adults decide how to carry out function. For example, nurturance seeking person needing medications would prefer that her children or caregiver take care of them. As such, devices designed for older adults have to fit into the older adults' needs by incorporating the right features. For example, if a device is primarily in use by younger caregivers, small fonts and buttons would become more acceptable.

Chapter 4 Literature Review of Needs Elicitation

4.1 Characteristics of User Needs

The word "needs" was often used in product design and development to describe customer motives for buying products. Customer needs had become a buzzword to show that the design was "on track" and would please the users. There were several approaches to analyze needs.

Maslow (1994) postulated that innate needs directed human behavior. These needs formed the functions, effects, purposes, or goals of the behaviors. They were largely subconscious. However, whenever a need was "active," it altered the individual's behavior: a hungry person seeked food. Maslow classified human needs into five levels: (1) physiological; (2) safety; (3) love; (4) self-esteem; and (5) self-actualization needs.

Murray (1938), on the other hand, proposed that humans had consistent behaviors that evolved over years of aging, and accumulation of experience. This was the way which people learnt and integrated schemas of reactions towards situations, and people were likely to behave the same way according to the schemas. This was the driving force that Murray considered as needs. His definition of needs consisted of the following:

"A need is a hypothetical process, the occurrence of which is imagined in order to account for certain objective and subjective facts."

"…is an invisible link (between the stimulus situation and the resulting action)."

"…refer to an organic potentiality or readiness to respond in a certain way under given situation."

"…need is defined as a disequilibrium which stresses toward equilibrium." Murray's needs included: achievement, deference, order, exhibition, autonomy, affiliation, intraception, succorance, dominance, abasement, nurturance, change, endurance, heterosexuality, and aggression (Edwards, 1959). The needs were behavioral oriented. What he explained was a set of behavioral tendencies that human would exhibit in most situations.

Both Maslow and Murray took needs as causes of resulting actions. In Maslow's (1994) case, needs were goals to be accomplished. In Murray's (1938) case, needs were the reactions to problems. In both cases, needs were motivators, and the source of behaviors. In this research, the ultimate measure of behavior would be product purchase. As such, we would define needs as, "Meaningful functions, effects, purposes, or goals that motivate consumers to buy a design product and resulted in user satisfaction."

4.1.1 Decision Making in Purchase

A very common measure of product appeal was customer attitudes. It could be measured by using one or several affective or evaluative dimensions (Fishbein and Ajzen, 1975). Attitudes were learned from positive and negative feedback a person gets from an object. It could not be observed directly, but could be inferred from consistency in a person's behavior. Osgood (1957) suggested using bipolar dichotomies as good-bad, clean-dirty, and beautiful-ugly to evaluate attitudes.

There were few difference between affect and attitude. In fact, Fishbein and Ajzen (1975) reserved the term "attitude" for "affect," as distinctive from cognition. Affect

consisted of many psychology reactions. Parrott (2001) defined affect as “any psychological state that is felt and in some way is evaluative or valenced.” Emotion as defined as a subset of affect, which was “an ongoing state of mind that was marked by mental, bodily, or behavioral symptom.”

There were six “basic emotions:” anguish, fear, sadness, disgust, surprise, and happiness (Parrott, 2001). They were hypothesized to root in the limbic system. Other “secondary emotions” were formed as combinations of two or more basic emotions (Ekman and Friesen, 1971). These emotions might be elicited from facial expressions. Fridja (2001) suggested that these emotions:

1. Arise in response to the meaning of a situation.
2. Arise in response to situations that are important to the individual’s goals, motives, or concerns.
3. Arise in response to situations perceived as real. And the intensity of the emotions corresponds to this degree of this realism.
4. Arise out of actual or expected changes in favorable or unfavorable conditions.
5. Intensity of emotions depends on the comparative advantage or disadvantage of the new condition in relation with some frame of reference.
6. Whenever possible, a person would view a situation from a perspective that minimizes negative emotional load.
7. Whenever possible, a person would view a situation from a perspective that maximizes positive emotional gain.

In fact, we were beginning to understand that emotions were mechanisms that set a person’s highest-level goals (Pinker, 1997). They altered thinking and behavior,

directed attention, and rearranged priorities (Parrott, 2001). We were coming to understand that emotions were integral to the processes of reasoning and decision-making. Patients who were unable to feel emotions could exercise perfect logical thinking. However, they were unable make rational personal and social decisions (Damasio, 1999).

Emotions were perceived quickly and easily, making a person more efficient. In Asch (1946) words, “We look at a person and immediately certain impression of his character forms itself in us. A glance, a few spoken words are sufficient to tell us a story about a highly complex matter.”
A single twist in a descriptor about a person was enough to create a completely different picture (Asch, 1946). Thus, users’ emotions were capable of affecting users’ intention about product purchase.

Consumer who made decisions to adopt a smart home go through three levels of decision - needs recognition, pre-purchase search, and evaluation of alternatives (Schiffman et al., 2001). Needs recognition, according to needs theory, was aroused by the development of a tension. This tension was the result of the difference between a desired situation and the current situation. Pre-purchase search began when the consumer believed that one’s needs could be satisfied by a product.

Personal attitude and social norm appeared to have a strong relation with emotional processing and social schemas (Fishbein and Ajzen, 1975). If a person was happy with a product, he would have a positive attitude towards it. Social norm was related to subjective norm or what should normally be done. The strength of the social norm

depended on the expectation of other people, known as referents. Based on these two factors, the intentional strength could be derived by the following equation (Fishbein and Ajzen, 1975):

$$B \sim I = (A_B)\, w_1 + (SN)\, w_2$$

B was the behavior; I was the intention to perform behavior B; B ~ I was the intentional strength; A_B was the attitude to perform B; SN was the subjective norm; w_1 and w_2 were the weights which could be obtained through regression techniques.

4.1.2 Decoupling between Likes and Wants

In human factors, users were seen as physical and cognitive processors (Green and Jordan, 1998). It was now important to recognize affect. People think more rationally when emotions are available as a guide (Damasio, 1999). Guidance by emotions took place subconsciously, as reactants to events that unfold to the perception.

Evaluation had never been a fully conscious process. Many times, people were not always conscious of themselves acting (Sartre, 2002; Leont'ye, 1978). When one chose to buy a product on a shelf, one might not understand what led to that decision.

Since affect could be subconscious, it might be more ideal to see reasoning and affect as separate but concurrent processes. Damasio (1999) provided an interesting model of life regulation that illustrates this in figure 4.2.

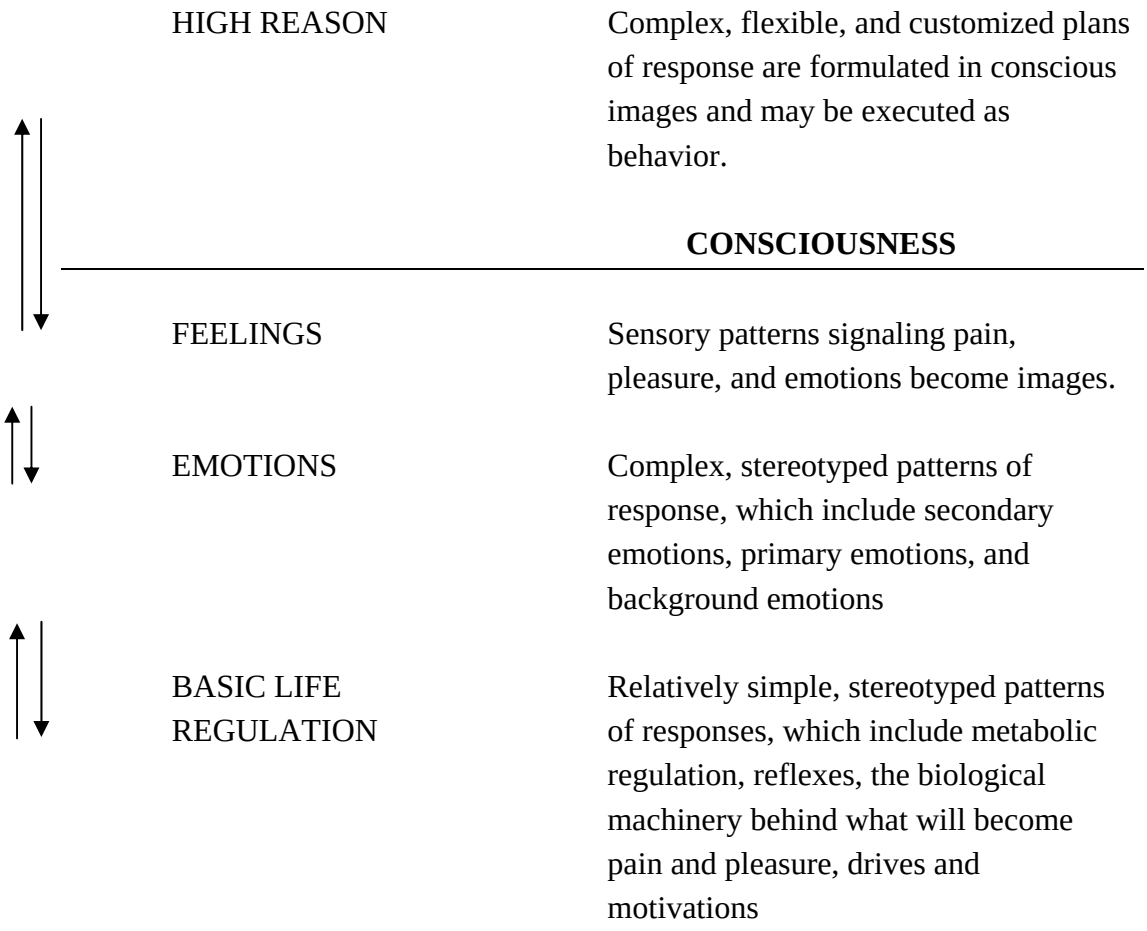


Figure 4.2 Levels of life regulation (Damasio, 1999)

Damasio (1999) broke down the mechanisms that allowed human to function properly into four levels. The most basic one was basic life regulation followed by the emotions. The most basic forms of emotions were pain and pleasure (Damasio, 1999). Both of these work separately as two different systems. Pain was caused by the perception of a sensory representation of local living-tissue dysfunction. On the other hand, pleasure was initiated by a visceral imbalance. It began with a search process, in anticipation of the actual goal to restore this imbalance, and increased when the goal was met. Lower level forms of emotions were the primary emotions. Primary emotions associated with pain were anguish, fear, sadness, and disgust (Ekman and Friesen, 1971). The primary emotion associated with pleasure was happiness.

After emotions, feelings might evolve. According to Damasio (1999), feelings consisted of mental images. This process alerted the person to the problem that the emotion was attending to. In high reason, feelings allowed emotions to permeate into the thought process. It was the part that allowed any object to be known to the person and allowed response to be made to his/her environment. Thus feelings enhanced the person's ability to response to his/her needs. In this model, high reason constantly monitors one's feelings although it might be difficult to maintain full awareness of them.

With subconscious processing, it was also possible that a human would exhibit contrasting preferences for a product (Berridge, 1999; Cacioppo, and Gardner, 1999). He might like a product because it was beautiful and futuristic but dislike it because it was too expensive and the sales staff were unfriendly.

Human factors had also demonstrated that positive and negative feelings about a product were in fact the result of different factors. Helander and Zhang (2001) categorized feelings about chairs into two sets of factors – comfort and discomfort. Comfort factors comprised of affective feelings, whereas discomfort factors comprised of biomechanical sensations.

Poor usability issues were dissatisfiers. If usability was poor, users would be dissatisfied; but if it was good, user do not feel happier. Users expected usability but were unwilling to pay for it. Some products developers found that PC consumers pay more attention to internal drive triggered by new products (status, fun, applications)

(Waarts et al., 2002). When products matured and features became similar across different designs, consumers refocused their attention to factors such as usability and cost (Waarts et al., 2002). From the point of view of needs hierarchy, this seemed to place usability and cost as higher needs. But it might simply be due to users' familiarity with the product and knew what to look for.

A possible result of focusing on needs was that users might express "liking" for a product without "wanting" it (Berridge, 1999)! For example, a retiree who likes watching movies would not go to the cinema unless one could spend less time traveling. The former was a satisfier (watching movie) and latter iswas a dissatisfier (traveling time). Similarly, while one might like the product aesthetics, factors such as price, usability, convenience, and system compatibility might make it undesirable. Knowing that users had different expectations and trade-offs, designers needed to offer various products with differential appeal. Taking the example of blue tooth. It was touted as a novel product to satisfy the needs of hassle free connectivity. Yet to set up the connections take very long time and spoilt the pleasure (Jenson, 2003).

While poor usability were mostly dissatisfier, it might not always remain so. Referring to our definition of needs as "meaningful functions, expectations, or goals that motivate consumers to buy a design product and result in user satisfaction," usability would become a need when it served as a "meaningful function, expectation, or goal" of the user. For example, usability was always an important consideration in aircraft and factory space design. These were areas where good usability would improve safety, quality, and efficiency which were the desires of the users. On the other hand, the main purpose of consumer products was usually not to accomplish

work quickly or safely. Rather, they might serve other purposes such as prestige and entertainment.

Thus, it was expected that depending on context and user needs, a different set of satisfiers and dissatisfiers would emerge. It was thus arguably impossible to generate the same set of needs for all products. Although when products were similar, such as kitchen appliances, needs might also be similar.

4.2 Methods of Needs Elicitation

Product should be designed so that it had merits that users could appreciate (Rogers and Shoemaker, 1971). These merits should be based on users' needs and they might have to be identified before design concepts could be developed.

But if a product was truly innovative, it was difficult to know what the important needs were since there was no prior sales and no prior user experience. As such, identifying user needs was difficult. What designers identified as reasons to design a product might be based on their attitudes and believes, and true needs might be overlooked. In addition, some potential users might not be aware of that they have certain needs, and such needs would not be reflected when questioned. Lastly, innovations could lead to new needs and vice versa (Rogers and Shoemaker, 1971). These issues confound innovation design, which was hence a challenging problem.

Some methods provided partial answers to these issues, including SBD (scenario-based design), and *ethnographically-informed design* (Carroll, 1997).

4.2.1 Scenario-Based Design and Ethnographically-Informed Design

SBD used stories to illustrate scenarios of use (Carroll et al., 1994). According to Carroll (1997):

"The defining property of a scenario was that it projected a concrete narrative description of activity that the user engaged in when performing a specific task, a description sufficiently detailed so that design implications could be inferred and reasoned about."

In an illustration, Rosson and Carroll (2002) used field observations to gather users' data for scenario construction. This included interviews, observations, and study of artifacts related to tasks. The data was then translated into statements and *themes* that were categorized. In the scenario writing, categorized statements and *themes* were used to construct stories representative of problems with the activities. Carroll and Rosson (1992) noted that theories of user needs could also be used as information and assumptions to what future scenarios might be.

There were several similar methods. *Ethnographically-Informed Design* involves detailed observations of behavior in real situations (Carroll, 1997). One type was Contextual Design, which aims at matching design with users' system and ways of working (Bayer and Holtzblatt, 1998). Contextual design was particularly useful for product design. User needs were identified using the framework of "contextual inquiry." The researcher began with detailed observations of user's work and then clarified these observations with users. Users thereby made use of intuitive knowledge that otherwise would be hard to articulate. Given the opportunity they could articulate details that they otherwise did not pay much attention to (Bayer and Holtzblatt, 1998).

Although *ethnographically-informed design*, such as contextual design, could be used to understand the user's system and ways of working, it was difficult to use for innovative products. One could not observe the system in-use for innovations since there were no experienced users.

Scenario-based design used various sources of data including self-reporting of users. However, latent knowledge was difficult to articulate often due to habituation and social undesirability (Larsen and Fredrickson, 1999; Klein, 1999; Teglasi, 2001). For example, people overestimated their willpower, underestimated their desire to spend, underestimated their vulnerability to social pressure, and underestimated their sexual desire (Loewenstein and Schkade, 1999). Social or personal undesirability meant that the respondents would reply in manners that create positive impression of themselves (Larsen and Fredrickson, 1999). They would deny negative attributes and endorse positive attributes. This might be done to appease the investigator or just to avoid being seen as negative.

4.2.2 Projective Test

Projective testing could potentially provide an insight into the above issues. It comprised comprise a wide range of techniques aimed at eliciting feelings that a user was not aware of, or knowingly or unknowingly was trying to hide. These included word association, sentence completion, third person technique, and TAT (Thematic Apperception Test) (Schiffman et al., 2001). They depended on understanding how users hide, or suppress, or became unsure of their own feelings and behavior (Schiffman, et al., 2001; Willis, 2002). Projective tests had evolved from an ambiguous psychoanalytic foundation. Despite the origin, many of the theories had

stood the test of time and were still widely used by marketers as well as clinical psychologists (Willis, 2002; Teglasi, 2001; Freud, 1946).

The fundamental theory supporting projective techniques was the *projective hypothesis*. Subsequently, other established psychological theories had been added to support specific tests such as the TAT (Teglasi, 2001). These included schema theory and dual theory of information processing, which were similar to tacit knowledge and recognition-primed decision making.

Projective hypotheses stated that stimuli from the environment were perceived and organized by the individual's specific needs, motives, feelings, perceptual sets, and cognitive structures, and that in large part this process occurred automatically and outside of awareness (Frank, 1948). Rorschach (1942) showed that a person might project feelings from looking at ambiguous stimuli. He showed inkblots to subjects and asked them to identify the "objects." In one study, a client undergoing psychotherapy insisted that he saw "sex" on inkblots. The client insisted that the therapist showed him dirty images, which were merely manifestation of some of his desires. Rorschach (1942) proposed that these interpretations had to come from the person and revealed certain aspects of his personality.

People responded to familiar circumstances with autonomic reactions. Preset responses to a situation was known as a "schema," which was defined as "a basic unit of knowledge that develops from past experiences, provides a framework for judging future experiences, and influences how you perceive and react to people and events (Asch, 1946)." Schemas might be applied to social norms, including – identity

construction, conformity to group pressure, stereotyping, and adjustment (Markus and Kitayama, 2001). Additionally, there could be stereotypical identities associated with groups, such as information about social positions and stratification statuses, such as gender, race, age, or class (Howard, 2000).

Schema theory had similarities with RPD (recognition primed decision making) in human factors. Humans used intuition in what they were doing well (Bayer and Holtzblatt, 1998). Klein (1999) further explained that intuition allowed experienced firefighters to see a new situation as typical, thus automatically generating a course of action. This was unlike inexperienced firefighters, who might be lost when facing new situations.

In third-person techniques, schemas might be elicited by asking subjects circumstances surrounding a context (Schiffman et al., 2001). In one study, a picture of cheap cosmetic was perceived as “greasy and oily” and a costlier cosmetic was viewed as making the skin “clear, refreshed and young-looking.” In another study in the 1950s, a housewife who used instant coffee was viewed as “lazy” while another housewife using ground coffee was “thrifty.” This impression disappeared in a replicated study in 1970s.

Humans process information using both rational and experiential systems of thought (Epstein, 1994). The rational system was deliberate, effortful, and analytical, while the experiential system was emotional, autonomous, and subconscious (Teglasi, 2001). This predicted that a person might only report what she had rationalized herself

to be, but not what she had experienced. This was similar to evidence in hedonic psychology that a person might "like" without "wanting" an object (Berridge, 1999).

In TAT, it was believed that self-report techniques of interview tend to elicit "wants" accountable to social values and self-attributed needs (Teglasi. 2001). On the other hand, narratives could be used to assess implicit needs or "likes" through indirect reporting.

Murray (1938) noted that a great deal would be known about people if they were asked to tell a story about drawings. This technique was later known as TAT or Thematic Apperception Test. He defined *perception* as the recognition of an object based on sensory impression, and *apperception* as the addition of meaning to what was perceived (Murray, 1938b). The idea behind TAT was that people could interpret the behaviors of other people in pictures by judging from the clues given. However, if some clues were omitted, the narrator would fill in the missing links by projecting his own tendencies (Murray, 1938a). According to Murray (1938b), these were driven by needs which aimed to "transform an existing, unsatisfying situation."

TAT had also been performed with the older adults. Neugarten and Gutmann (1968) explored the use of this technique in understanding the different types of roles played in a family with older people. 131 subjects were asked to describe figures in a picture. The picture contained one older male, one older female, one younger male, and one younger female. The descriptions were grouped on similarity basis and compared. Younger respondents saw the older male as authoritative while the older respondents

saw the same figure as submissive. The younger and older female were also found to having personal conflict.

Chapter 5 Survey 1: Identifying User Needs using Projective Test

5.1 Identifying Uses of Smart Homes Based on Known Needs of Older Adults

Products should be designed so that it had merits that users could appreciate (Rogers and Shoemaker, 1971). These merits should be based on user needs and had to be identified before design concepts could be developed. Many needs of older adults were identified in chapter 2. These needs were formulated at a very high abstraction level. This chapter explained the methodology used for identifying needs of older adults' in smart homes. Preparations included setting scope, tools, figure, social environment, and questionnaires.

To understand the problem domain, documented needs of the older adults were reviewed mostly from the human factors and gerontology literature (Kow and Helander, 2003b). The result was a hypothetical framework shown in table 5.1.

High or low maturity illustrated the different stages of growth in a lifespan of a person (Erikson, 1997). In dependency avoidance, anti-aging, and nurturance needs, there was a sense of disdain of dependency, loss of status, and isolation respectively. Such people despised their present status and desired extreme dependency or independency (Bornstein, 1998; Fiske, 1980; Diener and Lucas, 2000; Averill and More, 2000). In spirituality and productive aging needs, the theme centered on agreement with one's decline. These older adults had shifted their concerns from self-centeredness to spirituality and productive aging (Baltes et al., 1999; Averill and More, 2000).

Table 5.1 Hypothetical Framework of Needs of the Older Adults

	Independent Needs		**Dependent Needs**
High Maturity	Spirituality Needs Desire for religious activities. To lead a simple life. To help others. To take care of oneself in retirement.		Productive Aging Needs Desire for self-improvement courses. To use tools to reduce effect of aging. To pursue hobbies. To take care of grandchildren. To do housework, to participate in social work. To keep in touch with society. To maintain health
Low Maturity	Dependency Avoidance Needs Desire to secure belongings. To avoid meeting decision making people. To do *everything* independently	Active Aging Needs Desire to lead an active life. To remain youthful. To maintain spouse's health. To avoid identification with the aged. To affirm social identity.	Nurturance Needs Desire to ask caregivers for guidance, support, and approval. Need for support group. To assuage anger. To reassure of caregivers' faithfulness. To call for help as and when necessary. Need medical aids for frequent monitoring and advisory for assessing need to attend hospital.

The purpose of the tests was to investigate which of these needs could be applied to the context of smart homes.

5.2 Hypothesizing Features of Smart Homes for Projective Testing

In order to make use of projective test to elicit needs, pictures portraying smart homes were required. Features of smart homes were collected from a wide variety of sources including the five needs of older adults, Murray's Vicerogenic Needs (chapter 3), and smart homes development (chapter 4). The following sections described how features

were designed by breaking down older adults needs and using Murray's Vicerogenic Needs.

5.2.1 Transforming Older adults Needs and Murray's Vicerogenic Needs into Higher Level Needs and Smart Home Features

Table 5.2 broke down needs and personalities of older adults as discussed in chapter 2.

Table 5.2 Summary of elders' needs and personalities

Personalities and related needs →	**Detailed needs to be supported by products**	**Behavior**
Spirituality	1. Ability to see/experience religious activities 2. To lead a simple life 3. To help others 4. To help family members 5. To take care of oneself in retirement	• to be less self-centered • socially oriented • seeks self worth in meaning • attend church/ temple ceremonies • retirement in suburb
Anti-aging	1. To lead an active life 2. To remain youthful 3. To maintain spouse's health 4. To avoid identification with the aged 5. To affirm social identity	• maintain activities from mid-age • preoccupied with husband's health • comparison with others • avoid abandonment by society • avoid identification with aged
Dependency Avoidance	1. To secure belongings 2. Avoid meeting decision making people 3. Do everything independently	• avoid help from others • strongly protects own belongings • avoid decision making

		people
Productive Aging	1. Attend self-improvement courses 2. Efficient tools to reduce effect of aging and need not consider ageism 3. Pursuance of hobbies 4. Take care of grandchildren 5. Housekeeping 6. Participation in social work 7. To keep in touch with society to continue ability in making decision 8. Maintenance of health	• learning to adapt to age • maximise gains, minimise losses • does not suppress age • selection of meaningful activities • to maintain autonomy
Nurturance Seeking	1. Devices to pull caregivers closer for guidance, support, and approval 2. Support group 3. Devices to help “blowing off steam” 4. To feel the faithfulness of caregivers in using the product 5. To call for help as and when necessary 6. Home medical aids for frequent monitoring and assessing need to attend hospital	• seeks guidance, support and approval from others • resentful, demanding, and hostile • fearful of being abandoned • dependent on one or two caregivers • seeks compensation from others • falls ill more frequently

5.2.2 Hypothesized Features of Smart Homes

In this section, features of the smart homes were hypothesized as resources to support the needs of the older adults. The detailed needs from table 5.2 were translated into higher level needs. The higher level needs had greater specificity and were used to conceptualize products. The superscripts beside the features referred to the features as described in the next section.

Table 5.3 Hypothetical smart home features

SPIRITUALITY NEEDS		
Needs	**Higher Level Needs**	**Smart Home Features**
Ability to see/experience religious activities	Information devices	[1]"Remote rooms"
		[2]"Written text transmitter"
	Mobility aids	[3]All purpose wheelchair with environmental modification
To lead a simple life	Like objects that instill simplicity	[4]"Simple" aesthetics
To help others	Information devices	[2]"Written text transmitter"
		[8]Information channel
	Mobility aids	[3]All purpose wheelchair with environmental modification
	Working aids	[5]Multimedia information system
	Communication devices	[6]"Cyber tunnel" (home/ portable)
To help family members	Information devices	[2]"Written text transmitter"
		[8]Information channel
	Mobility aids	[3]All purpose wheelchair with environmental modification
	Working tools	[5]Multimedia information system
	Communication devices	[6]"Cyber tunnel" (home/ portable)
To take care of oneself in retirement	Mobility aids	[3]All purpose wheelchair with environmental modification
	Working aids	[5]Multimedia information system
	Communication devices	[6]"Cyber tunnel" (home/ portable)

ANTI-AGING NEEDS		
Needs	**Higher Level Needs**	**Smart Home Features**
To lead an active life	Traveling assistance	[7]Remote shopping
		[8]Information channel
	Working aids	[5]Multimedia information system
		[9]"Micro carrier"
	Socializing assistance	[9]"Micro carrier"
		[8]Information channel
To remain youthful	Anti-aging information	[8]Information channel
		[26]Nutritional advisor
		[7]Remote shopping
	Exercise equipment	[10]Bed, body massage/ assistive movements

		[11]Chair for body massage and assistive movements
		[12]"Health scorer"
	Anti-aging technology	[13]UV filter
		[14]Air purifier
		[15]Noise filter
To maintain spouse's health	Family health information	[8]Information channel
		[7]Remote shopping
To avoid identification with the aged	Objects that do not convey ageism	[16]"Transgenerational" aesthetics
To reaffirm social identity	Device to keep in touch with support groups	[6]"Cyber tunnel" (home/ portable)

DEPENDENCY AVOIDANCE NEEDS		
Needs	**Higher Level Needs**	**Smart Home Features**
To secure belongings	Security devices	[17]Security camera
		[18]Intruder alert
		[19]Police alert
Avoid meeting decision making people	Home care medical devices	[20]Monitoring, advisory, with prescription delivery to home
Do everything independently	Adjustable home ware	[21]Electronic self-adjusting shelf, bed, and chair
	Working aids	[5]Multimedia information system
	Mobility aids	[3]All purpose wheelchair with environmental modification

PRODUCTIVE AGING NEEDS		
Needs	**Higher Level Needs**	**Smart Home Features**
Self-improvement courses (e.g. hobbies, know about social work, improvement courses)	Information devices	[8]Information channel
	Communication devices	[6]"Cyber tunnel" (home/ portable)
Efficient tools to reduce effect of aging	Adjustable home ware	[21]Electronic self-adjusting stove, shelf, bed, chair, and table.
	Working aids	[5]Multimedia information system
		[22]Event alarm
Pursuance of hobbies	Mobility aids	[3]All purpose wheelchair with environmental modification
	Communication devices	[6]"Cyber tunnel" (home/ portable)
	Information devices	[8]Information channel
Take care of grandchildren	Mobility aids	[3]All purpose wheelchair with environmental modification

		[27]Movable phone
	Working aids	[5]Multimedia information system
Housekeeping	Mobility aids	[3]All purpose wheelchair with environmental modification
	Working aids	[5]Multimedia information system
	Shopping aids	[7]Remote shopping
Participation in social work	Mobility aids	[3]All purpose wheelchair with environmental modification
To keep in touch with society to continue ability in making decision	Mobility aids	[3]All purpose wheelchair with environmental modification
	Information devices	[8]Information channel
		[28]Computer
	Communication devices	[6]"Cyber tunnel" (home/ portable)
		[2]"Written text transmitter"
Maintenance of health	Information devices	[8]Information channel
		[26]Nutritional advisor

NURTURANCE SEEKING NEEDS		
Needs	**Higher Level Needs**	**Smart Home Features**
Devices to pull caregivers closer for guidance, support, and approval	Communication devices	[6]"Cyber tunnel" (home/ portable)
		[2]"Written text transmitter"
Support group	Communication devices	[6]"Cyber tunnel" (home/ portable)
Devices to help "blowing off steam"	Mobility devices	[3]All purpose wheelchair with environmental modification
To feel the faithfulness of caregivers in using the product	Product to convey the quality of filial piety	[23]"Filial" aesthetic/ caregiver control device
To call for help as and when necessary	"Calling" devices for any form of help	[24]Portable help calling device
Home medical aids for frequent monitoring and assessing need to attend hospital	Home care medical devices	[20]Monitoring, advisory, with prescription delivery to home
		[25]Medication reminder

The personalities mentioned in table 5.3 indicated the various ways elders might differ from one another in the way they coped with problems. It might appear that only differences were emphasized. However, certain needs were common but

essential to all older adults. For example, both older adults of transcendent orientation or anti-aging orientation might see “harm avoidance” as important. These would be the most fundamental needs resulting from biological need. Murray (1938) suggested a list of such Vicerogenic needs. They were air, water, food, sex, lactation, urination, defecation, harmavoidance (to avoid harm), noxavoidance (to get ride of noxious substances), heatavoidance (to avoid heat), coldavoidance (to avoid cold), and sentience (to need to taste and touch). These needs, although essential for needs investigation and common to all human beings, were unable to account for difference between older adults. A table of vicerogenic needs and implications for needs as resources were given in table 5.4. Table 5.5 shows how these implications might be translated into smart home features.

Table 5.4 Vicerogenic concerns and implications for needs

Vicerogenic needs	Resources required to support needs
Air, water, food, sex, lactation, urination, defecation, harmavoidance, noxavoidance, heatavoidance, coldavoidance, and sentience.	Device that fetches food and water (food and water needs) Air freshener that keeps the room smelling good (Noxavoidance) Temperature control system (heat/coldavoidance) Mechanical pets (sentience) Chemical analysis on urine samples (harmavoidance) Device that detect air-born viruses (harmavoidance) Fall alert (harmavoidance)

Table 5.5 Translating implications of needs into smart home features.

MURRAY'S VICEROGENIC NEEDS		
Needs	**Higher Level Needs**	**Smart Home Features**
Food and water	Device that fetches food and water	[29]Food and beverages robots
Noxavoidance	Air freshener that keeps the room smelling good	[30]Self regulatory air freshener
Heatavoidance and coldavoidance	Temperature control system	[31]Self regulatory temperature control system
Sentience	Mechanical pets	[32]Smart pets
Harmavoidance	Chemical analysis on urine samples	[33]Smart toilets
	Fall alert	[35]Fall detection vision system

5.2.3 Presentation of Design Features

All smart home features discussed in this section are presented as follows with the number according to the superscripts provided in tables 5.3 and 5.5.

1 "Remote rooms"

An older adults may want to participate in religious ceremonies, but is unable to do so. He/she may join many others who will come together to convenient rooms located remotely from the actual venues of religious events. Online conferencing or recorded video of the religious events will be shown on a large screen.

Remote rooms can also be used for holding classes that the user may not be able to attend due to immobility.

2 "Auto text transmitter"

An older adults may wish to communicate with someone else but unable to use the computer or talk over the phone due to poor listening. It may then be possible to write

a note on a piece of paper and send it to the other person. The note is fed into the transmitter and the same note will appear on the other person's transmitter.

3 All purpose wheelchair with environmental modification

To support an older adult who wishes to move around inside or outside the house. A motorized wheelchair can be used. Modifications to the indoor and outdoor environmental may be necessary to ensure that the wheelchair can move freely.

4 "Simple" aesthetics

Aesthetics in this case is defined as stimuli that elicit qualities about the products. An example is the "dark blue" of IBM - a symbol of corporate professionalism. Some older adults may like to simplify his/her life and thus tend towards the quality of simplicity. "Simple" aesthetics is to design products that convey this quality. In this case, the aesthetics should convey simple life style, such as minimalist design or Zen design.

5 Multimedia information system

An older adults may be hard of hearing, and may not hear the door bell while cooking in the kitchen. Multimedia information system can transmit sounds from other parts of the house to where the older adults is. Video can also be transmitted to a local screen. Thereby, he or she will be able to look after a grandchildren while cooking, look at who is pressing the door bell without having to reach the door, and hear water boiling while watching the television.

6 "Cyber tunnel"

An older adults not be living with his/her children may wonder how they are doing. Similarly, the children may be worried about their parents. A “cyber tunnel” is a screen connecting the two homes with video and audio. It is as if the two homes are unified.

A “cyber tunnel” may also allow an older adults to attend classes at home which otherwise would be impossible.

7 Remote shopping

An older adults may find it difficult to walk long distances. Remote shopping allows him or her to select daily items to purchase and deliver to home. He or she may also meet a sales assistant via video and asks questions.

8 Information channel

An older adults may wish to find out about the news, weather, community activities, or traveling. It may also be a skill such as language, computer skill, childcare, or hobby. The information channel makes it possible to select information and view it on a screen. It works like a television with a one-way transmission.

9 Micro carrier

This is similar to the all-purpose wheelchair. However, a wheelchair conveys the stigma of immobility. A “micro carrier” looks more aesthetic and conveys the quality of a carrier.

10 Bed, body massage/ assistive movements

A person may have aches and pains, but the capacity for exercising is limited. A bed that provides massage and assistive movements, such as turning, raising of legs can relieve some discomfort.

11 Chair for body massage and assistive movements

Although this is functionally same as 10, but it is in a form of a chair.

12 “Health scorer”

An older adults may wish to exercise to stay healthy. Yet it is difficult to know how much is enough. “Health scorer” keeps track of the pulse rate, converts exercise sufficiency into “scores.”

12 UV filter

UV light may harm the body in some ways (Kristjuhan, 2000). A UV filter installed to cover the window keeps out harmful sunlight and keeps the skin healthy.

13 Air purifier

An older adults may want to minimize the effect of aging. But polluted air may be working against this (Kristjuhan, 2000). An air purifier reduces harmful chemical and particles in the air that may cause aging.

14 Noise filter

Noise may have harmful effect and worsen hearing for an older adults (Kristjuhan, 2000). A noise filter reduces environmental noise and increases wellbeing for the older adults.

15 Transgenerational aesthetics

Older adults may dislike objects that are identified with the aged, such as walking cane, wheel chair, and thick glasses. Transgenerational aesthetics do not convey such identity. Instead, the aesthetics is acceptable to people of all ages. For example, many televisions and air-conditioners are aesthetically neutral and are found in the living room.

16 Security camera

Some older adults live alone independently and may fear the lost of property. The fact that they may be unable to earn a living anymore may compound such fear. A security camera informs the older adults of movements in the corridor or other parts of the house by showing them on a screen.

17 Intruder alert

As in 16. But intruder alert further identifies abnormal movements and trigger on an alarm to alert the older adults.

18 Police alert

The older adults may not feel safe after leaving the house. Police alert informs the police of abnormal movements in the house and call them automatically.

19 Monitoring, advisory, with prescription delivery to home

Some adults may not feel comfortable visiting doctors as they avoid decision making people. Others may fall sick so often that it is very inconvenient to keep visiting the hospital. Monitoring, advisory system keeps track of prolonged illness such as asthma, diabetes, and high blood pressure. The result of the monitoring is fed back to the hospital and the prescription may be delivered to the older adults.

20 Electronic self-adjusting shelf, bed, and chair.

Many older adults have difficulties bending, leaning, reaching objects, and standing up from low seat (Rohles, 1978). Self-adjusting shelves, beds, and chairs adjust to the need of the older adults.

21 Event alarm

An older adults may have problems remembering things. It may be the time to take medicine, or pick up his/her grandchild from school. An event alarm acts as an extra sensory cue so that the older adults may be able to remember what to do next.

22 Filial aesthetic/ caregiver control devices

Some older adults rely on one or two persons for support in their daily life, and may be afraid of losing these people. Filial aesthetic implies product forms that convey the quality of filial piety and faithfulness. Since these older adults are also highly dependent, devices made for these older adults may target the caregivers as users.

23 Portable help calling device

An older adults may need to call for someone to help with shopping, food, toileting, bathing, medication, or social duties. Yet the caregiver may not be available. A portable help call device can be carried by the older adults and call for his/her caregiver as and when necessary. The caregiver may pick up these calls from SMS or paging services.

24 Medication reminder

Older adults frequently miss medication. A medication reminder acts as a device that stores medicines in separate compartments. Whenever it is time to take a certain medicine, a compartment will light up. After the compartment is opened, the light is turned off.

25 Nutritional advisor

Some older adults may wish to remain youthful and others may wish to remain healthy. If the older adults wish to know if they have been eating healthily, they may key in the food that they have been eating and the nutrition level will be reflected. Daily score and appropriate advice will be given by the advisor.

26 Movable phone

Rushing to answer the telephone may be a chore to many older adults. This is also dangerous as they may fall down as a result. Movable phone is mounted on a platform that will find its way to the older adults when the phone starts ringing.

27 Customized computer

Many older adults have little confidence in using a computer. However, they may be optimistic about its usefulness. If they can make the first move, many of them may ultimately adopt them (Czaja, 1997). However, the main obstacle may be the low usability of computer. If computer may be modified so that the interface and mental concepts required to operate it is simplified, older adults may benefit from it (Czaja et al., 1993).

29 Food and beverage robot

Older adults may fall sick often. When they are ill and no one is around to take care of their meals, a food and beverages robot helps to heat up food and bring it to the bedside. It can also carry drinks.

28 Self-regulatory air freshener

Self-regulatory air freshener help freshen the air regularly. It has a sensor that detects the amount of particles that keep the air fresh. When particle counts run too low, it sprays air freshener.

31 Self regulatory temperature control system

An older adults may not tolerate large temperature variations. It can be a chore to use remote controls for air conditioners. Self-regulatory temperature control system has multiple sensors that connect to some conditioning units. It regulates the temperature within tight limits adjustable by the older adults.

32 Smart pets

Older adults may need to communicate with objects by touch and feel. Smart pets move around the house and come when the older adults call them. They wag, scratch, pant, sleep, yawn, and play like real pets. They are an affective replacement for real pets.

33 Smart toilet

Smart toilets detect urine and keep track of the older adults' health by analysis of urine samples. They are able to warn of emerging illnesses such as diabetes.

35 Fall detection vision system

Falling is the most common accident at home and 45% of all older adults fall at least once per year (Simouneau and Leibowitz, 1996). Although most falls do not lead to critical injuries, some can be fatal or serious. Fall detection vision systems monitor the older adults and inform caregivers when falls are detected and injuries are suspected.

Not all features presented here are used in the data collection. This is due to practicality of presentation of concepts and also time constrain in interviewing the older adults. Actual features and descriptions used in the data collection are presented in Appendix F.

5.3 Deciding the Scope

It would be ideal if stimuli representing every aspects of older adults' life and every possible technology could be used. This would cover all areas that technologies could

be found useful. However, this was not possible due to time and resource constraints. Stimuli, such as Figure 5.1, were chosen to represent existing technologies.

5.3.1 Smart Home Features

One concern in deciding the features to represent a smart home was face validity (Teglasi, 2001). Face validity was whether the appearance of the test seemed consistent with what it was supposed to measure. To maintain good face validity, tools were taken from existing technologies and fitted in a smart home environment. These tools were labeled in Figure 5.1. The labels were not shown in the survey.

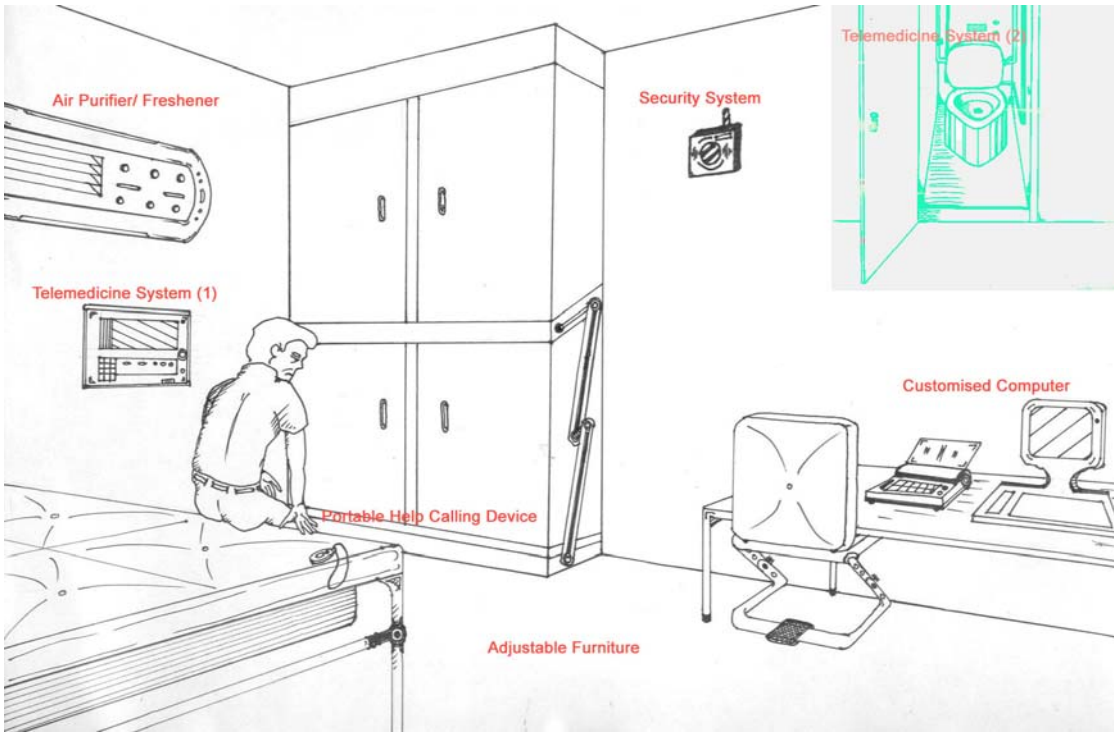


Figure 5.1 Illustrations of stimuli used in the projective tests

There were eighteen features: air purifier, telemedicine device, security system, customized computer, portable help calling device, adjustable furniture, massage chair, teleshopping device, teleconferencing device, multimedia-environmental monitoring device, event reminder, robot helper, fall-detection vision system, mini

scooter, smart wheelchair, smart pets, and movable phone. They were chosen to fulfill the various needs in table 5.1 and biological needs found in Murray's (1938) Vicerogenic Needs listed include: air, water, food, sex, lactation, urination, defecation, harm avoidance, noxious air avoidance, heat avoidance, cold avoidance, and sentience (to touch and feel) needs.

5.3.2 Figure and Social Environment

Content validity was whether there were sufficient types of relationships, emotions, and situation to capture the existing array of needs (Teglasi, 2001). Due to resource constraint, there were limitations in the number of pictures that could be administrated. As such, all pictures only depicted a single male figure. Pictures of male cards were known to elicit richer and more complex narratives (Teglasi, 2001). Also, the researchers decided that the pictures should depict slight negative facial expression. This should provide an advantage since if there were needs to be satisfied, there would also be emotional disturbances (Teglasi, 2001).

5.3.3 Stimuli

Ambiguous pictures typically generated more motives in response (Teglasi, 2001). For example, the person was not shown to be doing anything in particular. However, the disadvantage was that when few clues were available, the users might also find it difficult to react. It was thought that ambiguity was preferred in exploratory research, so that users would not be drawn towards any particular type of responds.

Elements not relevant to smart homes might also interfere with the apperception of the pictures. Therefore, any unnecessary elements that were normally found at home, such as television and flowerpots were not shown so as to avoid creating any extraneous impressions on the drawings.

Pictures that represent relatively universal situations were more suitable across age groups (Teglasi, 2001). Thus the pictures depicted homes similar to the layout in common housing in Singapore.

The male figure was placed near the center of the picture. This was to draw prominence to the figure in the narratives (Teglasi, 2001). Similarly, the tools were placed in the background as subsidiary objects.

The eighteen features were placed separately in four locations around the house, namely living room, bedroom, kitchen, and corridor. Six drawings were used to depict these four locations.

5.4 Step 1: Extracting Needs of Older Adults Using Projective Tests

5.4.1 Method

Stories made up by the users would elicit rich set of needs and behaviors relevant to smart homes. However, pilot tests showed that some older adults were not able to do so (which did not happen to younger users, see discussion in this chapter). Alternative, a question and answer type approach, while may reduce the degree of freedom of response, was more structure and easier for older adults to comprehend. The structure could extract two types of information: (1) Projected needs, and (2) Projected circumstances, meaning objects, persons, or conditions, that were associated with these needs. Circumstances must come from the users' own perceptions.

It was important to establish standard structure, encouragements, and prompts (Teglasi, 2001). This was to ensure that no additional cues would be incidentally made to prompt the users what to say. Anything that the users commented must come from the picture or themselves. As such, standard descriptions of each smart home feature were prepared. Descriptions explained what the tools do. These focused on how the tools work, not the user tasks. For example, the robot was described as such, "This robot is a food and beverages servant. It will go to the kitchen on his behalf and heat up food and drinks. Then it will bring the food and water to him."

After the investigator described every feature, referring to the man in the picture, he should then ask a standard question, "How does he find this useful?" This question prompted the users to think about cases within their own experiences that would fit into the usage of the feature. Taking a motorized wheelchair as an example, they could project the device into a scene where they needed to purchase groceries but their family members were not around. Having a weak pair of legs, they would find the device useful. This would assume that the users had no way of making up a usage other than relying on scene they had encountered before.

It was not impossible that the usage example made up came from a movie or magazine the users read (Teglasi, 2001). When the usage was not typical, the investigator would need to verify the source with the users. For example, it would be suspicious if a user envisaged in details how a robot single handedly took care of a paralyzed man's needs. First, there were not many paralyzed patients. Second, no robot in the consumer market could do that yet. Further probing could reveal that the users had seen a documentary about robotic science.

Users needed encouragement to project (Teglasi, 2001; Murray, 1943). This was because projection required guess work which required and friendly and assuring environment. If the users thought that they would be shamed for making inappropriate statements, their projections would be highly distorted. Users had to be continuingly comforted that they were doing well (Murray, 1943). Additionally, encouragements should not contain any information that the user would not otherwise know. For example, saying "I see" would be an acknowledgement of users' response without adding additional information into the projection. On the other hand, "You are right" provided new information that what the users said was the truth and any attempt by their consciousness to include conflicting information may be suppressed.

Prompts led the users to project on different aspects of the pictures. Without prompts, users might say too much, or went on to unimportant aspects. Prompts kept the users on the right track. However, the investigator and the users should not get involve in discussing how to go about a prompt (Murray, 1943). For example, the investigator might prompt, "Who is the man?" Users may comment, "I don't know. Any clue?" At this point, the investigator should encourage the users instead to letting it lead to a discussion. Standard prompts to be used in the test were such as, "Who is he," "how old is he," "why does he use it in this way," and/or (if it is a transport) "where is he going?" Within a scene, these prompts revealed the circumstances that a designer should consider. These were: (1) the user's characteristics – sex, age, role, and (2) the user's goal. "Who is he" may be sufficient for some users to comment about everything they assumed about the person in the picture. Otherwise, "how old is he" may be asked to obtain age information which was often an important design variable.

"Why does he use it in this way" asked the users to elaborate about an earlier claim to complete the projection. For example, it would not suffice if the user just commented that "the man called his children using the information display." The 'why' question probed the real intents of the man calling his children. Similarly, it was not sufficient to know that "the man was going out using his wheelchair." Rather, we need to know what his intents were.

5.4.2 Sample Population

The sample was chosen from one of the six studio apartments in Singapore. The studio apartments were built by Singapore government for older adults above 55 years old to purchase. The purpose of the studio apartment is for older adults to move into a smaller home when their children have moved out. This way, they can realize the cash value of their old house and live comfortably. Each studio apartment has capacity for about 150 families.

The residents have to be adults above the age of 55. However, they may stay with a child or spouse below 55. They had to make a one time payment of approximately S$60'000 to stay there for 30 years. The apartment building was new and residents had stayed for less than a year. It had many facilities that are providing older adults with a safer and more accessible environment. These include: puller cord for help calling purposes, hand rails, glass walls for transmitting lights into home at night, large doorbells, large corridors within home to accommodate wheelchair, anti-slip floor tiles, and a club house.

Most of the older adults are healthy with no visibly signs of disabilities. Many kept in touch with their children who might give them allowances periodically. Some

employed a maid who acted as a caregiver and stayed with them. As shown in table 5.6, their ages ranged between 55 and 90 years old (mode lies between 65 to 69). 12.5% are below 60, 56.3% between 60 to 75, and 31.2 % above 75 years old. Ten were married (62.5 %), four were single (25.0%), and two were divorced or spouse had passed away (12.5%). Twelve of the subjects were working (75.0%), and four were not working (25.0%). Of the sixteen subjects, five has no formal education (31.2%), nine has primary or secondary level education (56.3%), and two has above high school level education (12.5%). Only two were staying with a child or a maid. As shown in table 5.7, the interviews were conducted in various languages including English (12.5%), Mandarin (62.5%), and Chinese dialects: Mixture (6.3%), Hokkien (6.3%), and Cantonese (12.5%).

Table 5.6 Breakdown of age of subjects

Age	**50-54**	**55-59**	**60-64**	**65-69**	**70-74**	**75-79**	**80-84**	**85+**
Number of subjects	1	1	1	6	2	3	1	1

Table 5.7 Breakdown of languages used in interviews

Language	**Mandarin**	**English**	**Cantonese**	**Hokkien**	**Mixture**
Number of Subjects	10	2	2	1	1

The subjects were informed by post one week in advance. Forty apartments were visited at the studio apartment over the period. Nineteen of them agreed to the interview. The respond rate is 47.5%. Each interview lasted approximately forty-five minutes with no longer than an hour. At the end of the interview, $10 was given as a token of appreciation.

Of the nineteen interviews, one was a pilot subject interviewed with Thematic Apperception Test. This interview showed that these older adults had difficulties making up stories using the pictures. She commented that the task was very difficult and she did not know understand what to do. The test was subsequently restructured to a question and answer format.

Another subject who initially agreed to the interview withdrawn when the interview was half-done. The reason given was that he was not rich and thus had no comments regarding the devices. His reaction may be caused by misunderstanding that the investigator was a sales person attempting to sell him the devices.

A third subject was considered an outlier for his unresponsiveness to the questions. He remained silent for long period of time throughout the test. When prompted to proceed, he gave vague answers such as, “I don’t know,” or just “good” and “bad” without additional details. The data collected from this user was not useful. His inability to produce speech may be due to dementia (Stuart-Hamilton, 1996). However, no screen was used to filter the subjects because many of the older adults are not accustomed to such interviews and it was possible that additional formalities would deter the subjects from participation.

5.4.3 Procedure

Sixteen users were interviewed at their home. This arrangement was made despite possibilities of distractions such as phone calls. The advantage was the higher possibility of obtaining a wide variety of users.

To reduce the users' anxiety, the interview began with a casual conversation. This was to break down any barrier of defense between the user and interviewer (Teglasi, 2001). The interviewer began with an introduction of himself. But care was taken not to expose the projective nature of the test. The interviewer would also listen intently while the user was speaking so as to encourage an exchange.

Each tool was first introduced to the user. This was followed by a question of "how is the man using the device?" It was deemed that each "use" could be associated with one or more needs that the user may not be aware of. The introduction of each tool was repeated exactly in the same way to all the users. This was to establish consistency. Additionally, if there were questions regarding the tools, the interviewer replied to these questions without leading or prompting the user to any possible tasks.

The tests were conducted in a relaxed atmosphere. The conversations were recorded for transcription so that the interviewer could focus on its development during the interview.

It was found that some users look at the interviewer and do not pay attention to the stimuli. The interviewer reacted by avoiding eye contact with the users when they were narrating. One way of doing so was to lead by example by looking at the pictures intently.

Sometimes users commented that the tools resembled something and ask for verification. The interviewer would then only encourage the users to comment on "how the man is using it." Such prompts were made only when necessary, and the

interviewers tried to encourage the user by phrases such as “carry on,” “what do you think,” “maybe,” “okay,” and so forth.

If the users kept quiet, the interviewer would repeat the question once. This was to avoid pressing the users into saying things not representative of their schemas.

After the users had provided a few examples of using a tool, it was sometimes possible to probe the projected objects, persons, or characteristics of which came with their conclusions. Questions asked included: “Who is he,” “What kind of person is he,” “what sickness does he have,” “where is he going,” “how old is he,” and “why does he use it in this way?”

5.4.4 Analysis of Interviews

The interviews were transcribed verbatim. Within the transcriptions, needs were abstracted and paraphrased into proper and standardized English (Weller and Romney, 1988). Proper English included correct grammar and speech. Standardization included making each sentence clear and autonomous so that each sentence could be read on its own. Finally, specific words such as “Mercedes” and specific terms were generalized into categories such as “car.”

Needs abstracted and paraphrased were only those that were associated with the features. For example, one of the needs abstracted was “to use a *robot* so as to do without a maid” but not “to join a volunteer group in the apartment.” The latter made no reference to any smart home feature.

The data with sixteen subjects was consolidated. Analysis of the method used showed some consistency with the theories (Murray, 1938). These included:

- Subjects projected their own schemas into the stimuli. For example, they projected several objects into the picture such as saying the ‘man’ was sick or the ‘man’ was educated.
- Responses came from a variety of experiences including irrelevant sources such as television programs. For example, when questioned, one user revealed that she obtained ideas from science documentaries.
- Schemas resisted change. For example, when the subjects felt that the ‘man’ was sick, they would think so for the rest of the interview.

Analysis of the content showed a variety of data. These could be divided into three portions – smart home functions, usability issues, and projected needs.

A total of 314 functions were collected. Out of which, 188 were not repetitive. A repetition was considered when one device contained two similar responses. Based on the trend of the number of non-repetitive needs collected, regression analysis, and probability analysis, 188 was estimated to have covered 82% of existing needs in the population. The method to achieve this was shown in Appendix E.

From the interviews, many needs of the older adults were noted but not associated with smart homes. These included engaging in religious activities and living alone. These needs were not associated with technologies but were clearly important to the older adults. In many cases, while they claimed to be active in the temple since such

activities will increase their chance of having a good afterlife, they did not associate them with technology. As such, these needs could only be discussed separately.

Needs associated with dependency avoidance might not be readily recorded in interviews. In one case, the interviewer came to one older adult who was disillusioned and made much recollection of his past. He urged the interviewer to remain and listen to him recalling his past, yet he refused to participate in the test stating that he had "seen too much." He seemed to be avoiding attention from authority. Many older adults who declined to be interviewed might display the same tendency (Fiske, 1980).

There were other data that could be used for design purposes. Two categories of these data were observed: (1) usability concerns and (2) projected needs. Usability concerns were elements that would enable the products to be more accessible. These were features such as "to be used by children," "fear of using due to lack of knowledge," "to use without being literate," "using conversation to communicate (with sales assistant in teleshopping)," and "to pay (the tools) by installment."

There were frequent projections of needs. These were objects, persons, or characteristics of which users associated with the products in order to come to their conclusions. For example, "(the teleconferencing system) is costly and not for family," "person (who uses teleshopping) is old and uses cane," "(customized computers) are for young people," "doctors may not be able to cope with (telemedicine system)," and "(portable help calling device) is for people with early stages of memory loss." These needs were not part of the descriptions of the tools but were improvised by the users. They could have implications for design such as how to

support the users' thought process, remove stigmatization of help calling device, or convince users that doctors were able to respond quickly to emergency in telemedicine system.

Interesting, the categories of smart home functions, usability issues, and projected needs formed different components of product design. While they are different when it comes to identifying design requirements, fulfilling each of them are equally important. Smart home functions are user goals. They are "what users want to achieve with the product." It has to do with fitting products into the general activities users are working on. It has to deliver a desired outcome. For example, "Can this carrier help me to go shopping?" or "Can I use this computer to find my long lost friend?"

Usability issues were issues pertaining to "what problems would the user face when using the product." It arises when users are actually using the product. It requires designing the products to meet the level of effectiveness, efficiency, safety, and user satisfaction required by the users. For example, "I will like to bring this carrier outside my house." Or "I need to know how to get this repaired." To meet usability requirements require careful scenario testing and design consideration.

Projected needs were new to design. They involved dimensions users 'see' in the product although they may not exist. For example, "The device looks expensive," "Only educated people use these," or "it deprives a person of walking." Consumers do not spend a lot of time checking out usability or functional issues when evaluating a product. Thus, perceptions are important in deciding if they are going to make a purchase. It is important to address projected needs to change or enhance users'

perception so that they would favor making the purchase. However, address projected needs extend beyond design the physical product. It includes coordinating with packaging, marketing, industrial designers, and sales representatives to deliver a coherent and acceptable user experience.

5.5 Step 2: Categorizing Needs of Older Adults Using Pile Sorting

Projective tests were useful in aiding the subjects in participating in smart home usage and capturing the activities likely to take place in such environment. The data obtained was massive. With regards to usage examples, there were one hundred and eighty six. Presently, they were grouped into usage relevant to different smart home features. In order to make sense of the structure within the data, they have to be categorized.

The data were in four main categories (1) needs associated with tools, (2) needs not associated with tools, (3) usability concerns, and (4) projections. We are primarily interested in needs that are associated with tools. The rest of the needs will only be discussed.

Several replicated needs associated with tools were combined. They were shown in Appendix A. However, there were still one hundred and eighty six of them and they needed reduction. This number was too large for pair or triadic comparison. As such, pile sorting was used for categorization purposes (Meister, 1985; Weller and Romney, 1988).

In order to maintain validity of the categories, two human factors experts were selected for pile sorting. They had PhD in human factors with twenty five years of experience. Each item was written on a white card (80 gram white printed paper) approximately seven centimeters by seven centimeters. Therefore, there are one hundred and eighty six cards altogether. The task included sorting the items into as many or as few piles as they liked and each pile could contain as many or as few items. At the end of the task, the expert would label each pile with a posit note with brief descriptions. After which, the investigator examined the piles for similarity and possible structure.

Table 5.8 Needs sorted by two experts

	Expert 1	**Expert 2**	**Possible category**
1	Coping with illness	Physical health	
2	Boredom (due to illness)	Mental health	
3	Awareness of health status	Medical emergency contact	
4	Stress relief	Medical monitoring	
5	Air quality	Medical information for diagnosis	
6	Health maintenance	Good air for health purposes	
7	Health assurance		
8	Medical help		Health
9	Fear of missing call	Communication	
10	Social contact		
11	Contact caregivers in mishaps		Communication
12	Security by visual feedback	Monitoring of home	
13	Controlling access to self	Monitoring of door	
14		Calling for help	
15		To be informed of burglary	
16		To prevent burglary	Safety
17	Constraints due to mobility	Finding direction	
18		Buying things	Mobility
19	Active lifestyle of the mind	Learning	Mental activities
20	Physical activity	Robot servant	Housework
21		Handling things at high places	

22		Adjusting bed		
23		Reminders	Outdoor activities	
24		Buying things		
25		*Prestige*	*Prestige*	
26	*Independence*		*Independence*	
27	*Dependence*		*Dependence*	

Needs sorted by the experts were shown in table 5.8. The columns under expert 1 and 2 included the labels of the piles written down by the experts. The columns under possible category showed the needs as classified by the authors. It was obvious that while there were many resembling elements between the two experts, some were unique, such as prestige, independence, and dependence.

The possible categories appeared to relay a different structure as hypothesized earlier from the literature. The literature expressed needs that were more basic and fundamental. For example, biological needs such as inability to walk fast, and psychological needs such as dependency. These needs were of higher levels and they were expressed in a different form when related in the form of user activities. Thus, in order to go faster from one place to another, users might develop a liking for motorized transport or communication devices to call someone to fetch them. Hence of and for the sake of clarity, these lower level needs will be termed smart home functions. Table 5.9 suggested a possible link between the six needs and the smart home functions.

Table 5.9 Association between smart homes functions and the five needs from literatures

Five Needs (Higher level needs)	**Smart Home Functions (Lower level needs)**
Spirituality	Health, communication, housework.

Active Aging	Health, communication, mental activities, physical outdoor activities, housework.
Anti-aging	Health, communication, physical outdoor activities, prestige.
Dependency avoidance	Safety, independence.
Nurturance seeking	Health, communication, dependence.

Some examples of findings were discussed in the next section.

5.6 Results

Some of our results from projective tests and sorted needs were discussed in this section.

5.6.1 Smart Home Function - Health

Health function served an array of needs related to the importance of health. Many older adults were aware of their deteriorating body and actively try to maintain their health. They tried to stroll frequently while they were still healthy, kept the air fresh, and massaged their body for better blood circulation and vibrancy. It was interesting to note that many older adults believed that massaging was a replacement for exercise. These steps were taken to slow down or prevent the eminent weakening of their body. Besides the physical body, older adults were also aware of the dangers of dementia. Many of them attempted to keep up with their mental activities through learning and remembering things.

Despite these preventive measures, older adults were realistic about possibilities of sudden illnesses. Many of them sought confidence that in the event that they had heart attack, giddiness, or fall, help was imminent. For emergency, help could come in

many ways, such as family, police, volunteers, hospital, neighbors, doctors, or even passers-by. They would also like to keep in touch with family or doctors. Now and then, information regarding one's health was also sought after. Older adults seemed to accept remote monitoring of their health so as to know if they were contacting diseases such as heart attack and diabetes. They might also make use of such service for chatting with friends about their health and to find out more information on health issues. Nonetheless, many believed that only common illnesses could be solved remotely and visiting a doctor was still essential for other illnesses.

It might also be possible that the older adults were already sicked and needed help to cope with it. One prominent result of illnesses was boredom. The mobility of a sick person was restricted and as such loneliness crept in. Older adults might need someone to talk to or something to play with. Older adults who were sick were also likely to be weak. They appeared to be open to concepts such as adjustable beds and chairs so as to facilitate getting in or out. Older adults also develop a preference for "good quality beds" if they developed insomnia.

Another common use was stress relief of aching body. They often seek relief by body or foot massage. Older working adults were also positive about such aids.

The rest of the functions will be discussed in Appendix A.

5.6.2 Usability issues

Only usability issues concerning air purifier and tele-shopping device were discussed. The rests were shown in Appendices B and C.

Air-purifier

Air-purifiers were welcomed by many older adults. This might be due to their association with health and cleanliness. The most prominent problem regarding air-purifier was maintenance. Many were concerned about how to get it repaired. One person commented that he might forget where replacement parts might be stored. Another hoped that it would require very little maintenance since caregivers were often not around to help him.

Tele-shopping device

Four of the older adults had not received formal education. It was likely that more were unable to use devices needing to look at words especially English. Conversing with someone at the shop they wished to buy from was acceptable. One prominent disadvantage of tele-shopping was the risk associated with usage. Many were concerned about not being able to choose and feel the product being bought. One suggestion was that only common household products such as grocery were likely to be bought. This seemed to rule out personal products where quality could be a major concern. Others were concerned that “wrong press” of buttons could result in “something bad.” Besides risk of usage, older adults also perceived risk that the sales person delivering the goods could be a “bad person.” Some suggested that it would be fine as long as they knew who was delivering the goods.

5.6.3 Projections

Only projections concerning air-purifier and tele-shopping devices will be discussed. The rest were shown in Appendices B and C.

Air-purifier

One person claimed that he liked air-purifier as he was “too lazy to clean the house.” The device was seen as “not too expensive,” just like air-conditioner, but “healthier.” Just like purified water, it would also give a person “big advantages” in terms of health improvement. For some, the person in the picture was seen to have eye disease or persistent coughing or he might be sensitive to dust.

Another perception was that the person was sick and not able to clean the house. Some users thought that the caregiver was not always around. The air purifier would then keep the house free from dust.

Generally, the impression was that an air-purifier was inexpensive and useful for health maintenance.

Tele-shopping device

Some older adults believed that the person using it was “literate” and had “knowledge of computer.” Otherwise, he was “old, aching, and walked on cane, and there was no one to help him.” Alternatively, he could also be sick and “could not walk.” Many older adults believed that the items that were to be delivered would be “costly” and might deter purchases.

Some older adults also saw the figure as a “younger person,” possibility with “two children.” This could also be a big family. The purchases were likely to be made from shopping malls.

Generally, older adults associated the device with younger adults or big family. The latter could be the results of perceiving that help was needed if an older person was to use it. Designers might also have to think about dealing with the perception of costly items.

5.7 Analysis of Projective Technique

There were many strengths of projective technique when compared to direct interview methods.

5.7.1 Strengths

First, it was well improbable that a user would admit that they would someday need a stigmatizing device such as a wheelchair. As such, asking them if they would like and how they would use such a device would subject to gross departure from actual feelings. Their perceived identity of a healthy older person would overwrite their real world experience in their response. In fact, by using a third person method, the users were willing to explain in what situations that using such devices were reasonable. The statement such as “I think he is lazy or crippled to use the wheelchair” would have made it clear that only through physical impairment would warrant the use of wheelchair.

Second, projective technique was more likely than conventional interviews to obtain negative feedback. Due to using a third person perspective, users need not say that they did not like the product. Instead, they indicated a rejection through comments suggesting that the person in the picture were different from themselves. For example, in several instances, users said that the person in the picture was ‘doing big business,’ ‘is educated,’ ‘is young,’ or ‘is lazy.’ If users were willing to identify themselves with

the person, they would claim that the product is very useful for older people. The best response would be to say outright that they would use it.

Third, projective tests were able to elicit tacit knowledge pertaining to environment the products were going to be used in. The pictures used could not be completed without users taking a subconscious effort to fill in missing information. Such information would complete a coherent setting on which the product would be usable. Taking a dialogue as example:

Subject commented, “(how the device is useful) depends on who is the man.”

Interviewer asked, “Who is the man?”

“He is single.”

This revealed that given the users experience in their own cultural settings, a single man was more likely to use the product.

Forth, projections led to discovery of products semantic meanings that were important to design. For example, one subject commented on the micro carrier, “The wheelchair is bulkier than the micro carrier.”

Such information could not be inferred from pictures. Nonetheless, the user assumed that this was the case in order to complete his projections regarding the context of usage. Further interview revealed that the user’s mental thoughts were based on the proposition that, “The micro carrier can bring him to shopping malls…(whereas) the wheelchair is more for (visiting) neighbors.”

Semantic meanings provided users expectations of products. Knowing that users expect that micro carrier was light so that they could use it for shopping implied that designers had to pay attention to size, weight, storage, and portability issues.

5.7.2 Weaknesses

There were also weaknesses on projective tests. First, users who had strong psychological defense might persistently refuse to project their feelings. Such subjects would response vaguely. For example saying, “If you think this product is good then it is good. If you think it is bad, then it is bad.”

Such response was not useful and defeated the purpose of projective test. It was also possible that the subject might not have any schemas to make use of. If this was the case, probing further would extract erroneous data. To avoid both problems, the researchers had two complementary roles they had to play well. On one hand, they had to ensure that the subjects were comfortable with them so that they would reveal any of their thoughts. On another hand, they had refrain from probing the users too much and gave them enough freedom to develop their own projections.

Second, the pictures designed for the test had an impact on the credibility of the test results. For example, users found it easy to think that the shelf in the bedroom was used for storing clothes. Had the shelf been in the living room, the users would have think that it was used for storing other objects, such as CDs and magazines. Thus, the pictures used had important role to play in affecting the mental processes of the users. Designing enough information to stimulate the users' thoughts and start them thinking, while at the same time withdrawing any information that would sway the users

perception was difficult. This would require a mixture of talent and experience on the part of the stimuli designer.

Third, responses given might come from fictional sources but crept into the data. For example, one subject who watched documentaries commented, "… this computer is so convenient. Don't have to go and find things outside. Find things he wants…" Further interview revealed that she was not able to relate exactly what information the man might be looking for. Such information comes from hearsay and not social reality and as to be identified and disregarded.

Forth, cognitive dissonance might develop if the pictures used shared many similarities. In one of the interview, impression of the man in the picture endured from one picture to another. At the end of the interview, the subject commented that, "Now I am sure that this person is old and sick."

This had to be avoided by ensuring that each picture had to be sufficiently different from each other. Otherwise, the variety of responses from the users would be restricted due to a fixation of perception.

Fifth, usage of projective test was labor intensive. Each of the subjects had to be separately interviewed; their responses had to be individually transcribed and analyzed. This investment might be too much for on going product development. Alternatively, this test could be designed during the design specification phase to identify user needs and critical issues to take into account. The date collected could also be used to create scenarios.

Sixth, projective test was qualitative in nature and was subjected to the researchers projecting their own schemas during the analysis. It was important to develop a systematic and objective method to classify the data. As such, reading into subjects responses take place with more than one. Therefore, examiners could cross validate each others point of view to ensure no grave departure from the actual meaning. It was important that the subjects' comments were written verbatim before examination by experts in the field. Each comment should then be inferred to fit into a specific needs category. Inferences were only made after these categories emerged. There were several categorization techniques (Weller and Romney, 1988). For example, the researchers could first categorize the first six subjects' data by pile sorting into different categories (Weller and Romney, 1988). Then, the remaining data were slotted into the categories created as they were collected. Another method was to use existing categories such as Murray's twenty needs and slotted each data into the respective category. The former method was more suitable for new and unexplored needs structure, while the latter was suitable for identifying established needs structure.

With respect to both strengths and weaknesses of projective tests, this test would be most useful in two design situations: (1) Where the product is new and unprecedented, and designers need to understand the usage environment and culture governing users actions; and/or (2) It was known or suspected that the products had stigmatizing effects on their users. For the former case, projective tests could be used to extract use cases and scenarios from the users own experience before needing mockups or prototypes. The pictures and tests could be rapidly prepared and performed. For the

latter case, projective tests could reduce the effects of psychological defenses against identifying oneself with social undesirable associations with products. Considering the amount of transcriptions and analysis required, projective tests might not be viable in commonly acceptable products.

5.8 Discussion

Initially, projective tests were used because there was a lack of usage examples and prototypes for realistic evaluation of new products. Schema theory had suggested that users could orientate in new environment based on past experiences. Drawings of new products in desired context could therefore allow users to make use of their experiences to generate relevant usage examples.

Also, tacit knowledge which was frequently used in familiar environments might manifest in narrations. It was a pity that users were not able to tell stories as originally intended. One possible reason could be that the pictures were too ambiguous. Second, the older adults could be fearful of talking about technologies as a result of techno phobia. Third, their relatively lower education level might hinder their ability to articulate their point of view. However, Klein (1999) claimed that story telling was a normal process in human communication.

For the sixteen users, the total number of different needs registered were one hundred and eighty six. This did not take into account usability issues and projections. The vast amount of data required reduction. While pile sorting was used, other methods meant for sorting large number of data such as the affinity diagram seemed to fit into this purpose (Bayer, and Holtzblatt, 1998).

When comparing the needs structure of older adults and present model, some needs were not satisfied (refer to figure 5.2). One reason was that these needs were not associated with technological features. Examples were desire for religious activities, to participate in social work, to avoid meeting decision-making people, and to maintain spouse's health. Religious activities were important to older adults especially those that were less physically effective (Erikson, 1997). However, users were not able to associate this need with the new technologies. Similar cases happened in social work where one older adult mentioned that he would like to help out as volunteer for the apartment. This could be due to the lack of schemas in these instances. As commented by one user, "God is natural but technology is man made." It could also be that there were not sufficient cues in the stimulus materials to prompt users to think about religious or social issues. The stimuli reflected a housing environment and projections might constrain to these premises. Unsatisfied needs present a challenge to designers. If products were means to needs satisfaction, unsatisfied needs would represent a deficiency in design that could be fixed with better design solutions.

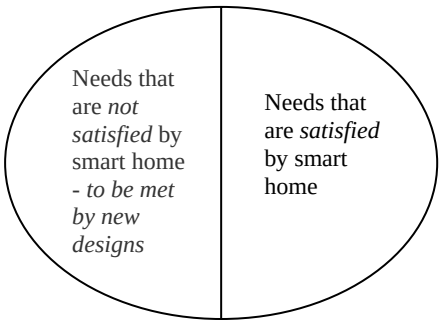


Figure 5.2 Partial satisfaction of needs by smart homes

The attitude of avoiding meeting decision-making people was mentioned above (section 5.6). However, most of the older adults were not likely to belong to this

category. This was because of the tendency that such users would avoid being interviewed. The desire to maintain spouse health was also expected (Fiske, 1980). However, this need was not reflected upon. This could also be due to the nature of the stimuli depicting a single male figure.

This usage of projective test may be improved so that a larger variety of user needs can be covered. Through the literature review, we are well familiar with the needs of older adults and we could have designed the testing material to be more suggestive. The direction can move towards a more comprehensive stimuli design, questionnaire, or sampling method. One way of doing so can be an anticipation of the needs to elicit and careful expression of certain themes of interest in the stimuli. If there are too many themes of interests, prioritization has to be in place.

Besides needs, other design factors such as usability and projected needs were identified. In these aspects, projective test can act as an early endeavor by designers to analyze how products may be used by users, what needs they satisfy, and consider the various design factors for requirements definition.

Chapter 6 Survey 2: Identifying Correlational Relationship between Smart Home Functions by Storytelling

6.1 Identifying Correlational Relationship between Smart Home Functions by Storytelling

Analysis performed in survey 1 organized a set of smart home functions namely: communication, mobility, health, outdoor activities, mental activities, safety, and housework. In the transcriptions, many of these functions appeared to be dependent. For example, older adults mentioned that the automatic carrier could be used for going to the park for a stroll. While the carrier served a mobility function, it was actually used to satisfy a health function. As such, correlational relationships could exist between these functions and this could spell redundancy to some smart homes design. For example, if users could satisfy most of their needs by having the efficacy to move around, would they still need other smart home devices such as remote telemedicine system to keep in touch with the clinic? Having the correlational relationships between functions identified would allow designers to more closely study the functions that could potentially challenge their design. Storytelling provided a basis for such an analysis.

6.2 Purpose of Survey

The purpose of this survey was to understand the correlational relationships between the functions we identified earlier, so that designers were better informed in making decisions. An assumption was that smart home functions contained a relationship structure. As such, some functions act as means to fulfill the other functions. As a result, not all functions might be required in order to satisfy user needs. Structuring

the relationships would require understanding of users' mental model. Such a model contained schemas which might be hidden from users' consciousness (Teglasi, 2001). As such, the method used has to enable elicitation of schemas with fewest distortions. Storytelling was used in human factors, marketing, and psychotherapy for such a purpose (Klein, 1999; Teglasi, 2001, Crossley, 2000).

Storytelling was used in Thematic Apperception Test (TAT), which made subjects tell stories base on what was seen in drawings and pictures. Telling story required the subject to construct a working model base on both external and internal sources of information. The internal sources consisted of schemas that were habitual reactions to situations (Teglasi, 2001). Parts of the process of organizing stories were subconscious, thus unknown habits might arise within the story content. In fact, a story was the primary means by which episodes in everyday life were represented in the memory (Teglasi, 2001). Stories told were superimpositions of prior experiences (Teglasi, 2001).

Standard questions asked in TAT include: (1) what is happening in the picture, (2) what happened before, (3) what is the person thinking/feeling, and (4) how does the story end (Teglasi, 2001)? A story may be analyzed by breaking it into several elements including: (1) dilemma/circumstances, (2) intention, (3) complication, (4) means, and (5) outcome (Teglasi, 2001).

Narrative analysis was a method used to bring the life of the narrator together into a convincing whole by look into his life stories. Crossley (2000) claimed that stories were already used frequently in biographies to make meaning into life of famous

people. Other people also tell stories to convey and make sense of who they were (Crossley, 2000). Crossley (2000) argued that human psychology had a narrative structure, which was used to think, perceive, imagine, interact, and make moral choices. The interview protocol of narrative analysis contained questions probing different aspects of a persons' life included: (1) life chapter, (2) key events, (3) significant people, (4) future plans, (5) stresses/problems, (6) ideology, and (7) life theme (Crossley, 2000).

Klein (1999) claimed that human organize one's ideas, concepts, objects, and relationships into stories. And each story contains one or more of these elements: (1) agents, (2) predicaments, (3) intentions, (4) actions, (5) objects, (6) causality, (7) context, and (8) surprises (Klein, 1999). As such, one or more of these elements could be abstracted in stories. In fact, Klein (2000) used stories to understand decision making in time crucial situations such as fire fighting. He argued that a good story was a package of causal relationships – what factors resulted in what effects, and should be plausible, consistent, economical, and unique. Klein (1999) used stories to understand decision making methods and hidden expertise the fire fighters were not aware of.

6.3 Sample Population

The subjects and their relatives were described in table 6.1. There was only one non-university student - subject 15. Her father was working and the story revolved around a normal work day. Since there was no relevance to our research, this story was discarded. As shown in table 6.1, there were nineteen subjects left, eleven males (57.9%) and eight females (42.1%). Among the kins, seven were males (36.8%) and

twelve were females (63.2%). The age ranged between 61-85 years old (mean=70.8, and s.d.=7.8). Twelve of the kins were the subjects' grandparents (63.2%), five were parents (26.3%), one was an in-law (5.3%), and one was an aunt (5.3%).

Table 6.1 Sexes, ages, and relationships of students and kin in story-telling

S/N	***1**	**@2**	**3**	***4**	**5**	**6**	**@*7**	***8**	**@9**	**10**
Sex/Age of student	M 22	F 23	M 22	M 25	F 24	F 33	F 22	F 23	M 23	M 25
Sex/Age of kin	M 73	F 65	F 74	M 61	F 80	F 63	F 65	F 83	F 71	M 68
Relationship	Grand parent	Aunt	Grand parent	Parent	Grand parent	In-law	Grand parent	Grand parent	Grand parent	Parent
S/N	**11**	**12**	**@13**	**@14**	**#15**	***16**	***17**	**@*18**	**@*19**	***20**
Sex/Age of student	F 22	F 22	F 22	M 25	F 16	M 25	M 21	M 24	M 22	M 23
Sex/Age of kin	F 70	M 85	F 74	M 61	M 62	M 64	M 80	F 80	F 67	F 62
Relationship	Grand parent	Grand parent	Grand parent	Parent	Parent	Parent	Grand parent	Grand parent	Grand parent	Parent

*Subjects produced episodic story form. These stories were not used in correlational analysis.
@Subjects produced only one function of each type in their stories. These stories were not used in tallying of occurrences of functions to predict needs strength.
#Subject's kin was working and was living a life no different from a middle age adult. Thus the story was excluded from analysis

6.4 Method and Procedure

Twenty five students including five pilot subjects were interviewed. They were recruited through recommendations of graduate students and by posting message on the emailing system of Nanyang Technological University. Each of them had a kin of more than sixty years old. They were also in communication with this person for the past three years and met at least once every month. The subjects were each paid S$15 for their participation.

The subjects were first briefed. The aim was to guide them how to write useful stories. Initially, they were told to write about their relative based on true experiences of themselves or their family members (Teglasi, 2001). The stories needed to contain a beginning, and middle, and an end (Teglasi, 2001). The story should comprise of a series of connected events. The story need not be nice to read (Klein, 1999). Fictitious elements were permissible to make a story complete. This point was added, so that fragmented memory would not be an obstacle to good story telling. Each subject was given one piece of A4 size paper. Later, some asked for an extra piece when they ran out of writing space.

The next part of the briefing focused on the requirements of the story. First, the story should contain seven functions namely, (1) mobility, (2) health, (3) safety, (4) mental activities, (5) housework, 6) outdoor activities, and (7) communication. The coverage of the functions was given in table 6.2. These examples arose from data gathered from survey 1.

Table 6.2 Coverage of the seven functions included in storytelling

1	Communication	To keep in touch with family, relatives, and friends; To look for someone to talk to; To know what the young children are doing; Not to miss phone calls; To know the condition at home when one is out; To know what friends and relatives are doing; To call for help in emergency.
2	Mobility	To go out; To go for stroll; To go for exercise; To go to the hospital; To get the telephone; To get things from high places; To carry heavy things;

		To move around the neighborhood.
3	Outdoor activities	To watch movie; To shop for personal items like clothes; To visit parks; To visit friends; To eat out; To run errands; To work; To go for stroll.
4	Safety	To know who is coming into the house; To avoid opening doors at night; To know when strangers enter the house; To inform police in emergency; To monitor young children; To monitor maid; To monitor the house when one is out; To know the identity of people outside the house.
5	Mental Activities	To search for information; To keep the mind busy; To learn new things; To watch television program news; To keep up with current affairs; To remember things.
6	Housework	To buy groceries and household items; To cook; To clear dishes; To reach things at high places; House keeping.
7	Health	To monitor one's health condition; To maintain one's health; To prevent and cure illnesses; To relief pain; To ensure help in emergency; To seek help from care givers when needed; Not to think about one's illnesses; To maintain fresh air at home; To exercise; To be massaged; To prevent falling down.

An example was given in figure 6.2. As shown in the table, the students were required to write down and indicate the location of the related function on the right hand

margin given in their writing paper. The entire story must contain at least one of each function and had no limitation of the number of times each might appear.

Story		Need
Tired on the day before, Sandy wakes up especially late in the		
morning. She was feeling rather heavy and dizzy. Reluctantly,		Health
she took out a thermometer from the drawer. It was certainly		
not the best time to be sick while fear lurks in the mind of		
every person. The thermometer indicates a 37.9 on the digit		
screen. “Damn!” she exclaimed, “Shit!” She picks up the phone		Communication
and called Sarah, her colleague at Alpine Works.		

Figure 6.1 Example of part of a story

During the pilot studies, it was noted that students were unsure of the time period for which they should recall to create the story. The students agreed that the last ten years were sufficient to generate good stories which were still vivid in the memory. Therefore, detailed instructions as “within the last ten years” was included in the actual tests. Another issue was that critical events might happen during these ten years and that changed a person’s life dramatically. For example, a stroke might render a person bed ridden and one’s behavior and outlook would change. Another criteria was that stories should be based on things that happened after the last critical event, if there was any. Some of the pilots’ stories were made up of fragmented events. These stories greatly reduced the number of correlational relationships. Thus, subjects were asked to indicate “why it happen” and “how it was resolved.” Otherwise, all the students found the instructions and tasks clear.

The interviews were divided into two sessions, one in the morning – between 10am to 11:30am, and one in the afternoon – between 3pm to 4:30pm. Twelve attended the 10am session and eight attended the afternoon session. The students were given as much time as they like in writing the stories.

6.5 Analysis of Stories

The contents of the stories varied. There were two basic forms – episodic and continuous. Episodic stories contained elements that jumped in time sequence. For example, a subject told the story of his grand mother. First he described her as a strong-willed woman who was confined to the house ever since she got a stroke. As such, she could only do things within the house. The next part of the story was not linked. It went on that she could not use the telephone and as such tried to seek help by shouting within the house. The author went on to describe her personality and habits. The story related to things that happened over a long period, did not contain a central problem, and thus correlational relationships relating parts of the story were few. This type of stories were highlighted in table 6.2 in superscript *. Because of the lack of correlational links these stories were not useful for analysis.

A continuous story contained elements surrounding the resolution of a problem. For example, subject #15 recalled the story of his grandfather experiencing a heart attack in the middle of the night and called for help. The story continued that he called for his son to get his medical records and medicine. After that, they went to the hospital and got hospitalized. The story ended by his grandfather realizing the importance of taking care of his own health and strolling whenever he could. The continuation of connections between events linked up the elements within the story such that correlational relationships could be identified and established. Such stories were therefore more useful for analysis than episodic stories. There were ten continuous stories altogether.

6.5.1 Correlational Analysis

Due to the differences in nature of episodic and continuous stories, only continuous stories were used in correlational analysis since episodic stories had few of these elements. The investigator went through these stories with an associate who was a graduate student in Human Factors Engineering in Nanyang Technological University. According to the functions indicated on the right hand margin, relationships were noted if both persons agreed that a relationship within a story contain both conditions of our definition of a correlational relationship between two functions: (1) The intention to carry out the *causing function* should appear before the intention to carry out the *effect function*; and (2) The sequence was likely to reoccur within the commonly known cultural environment.

For example, subject #3 wrote:

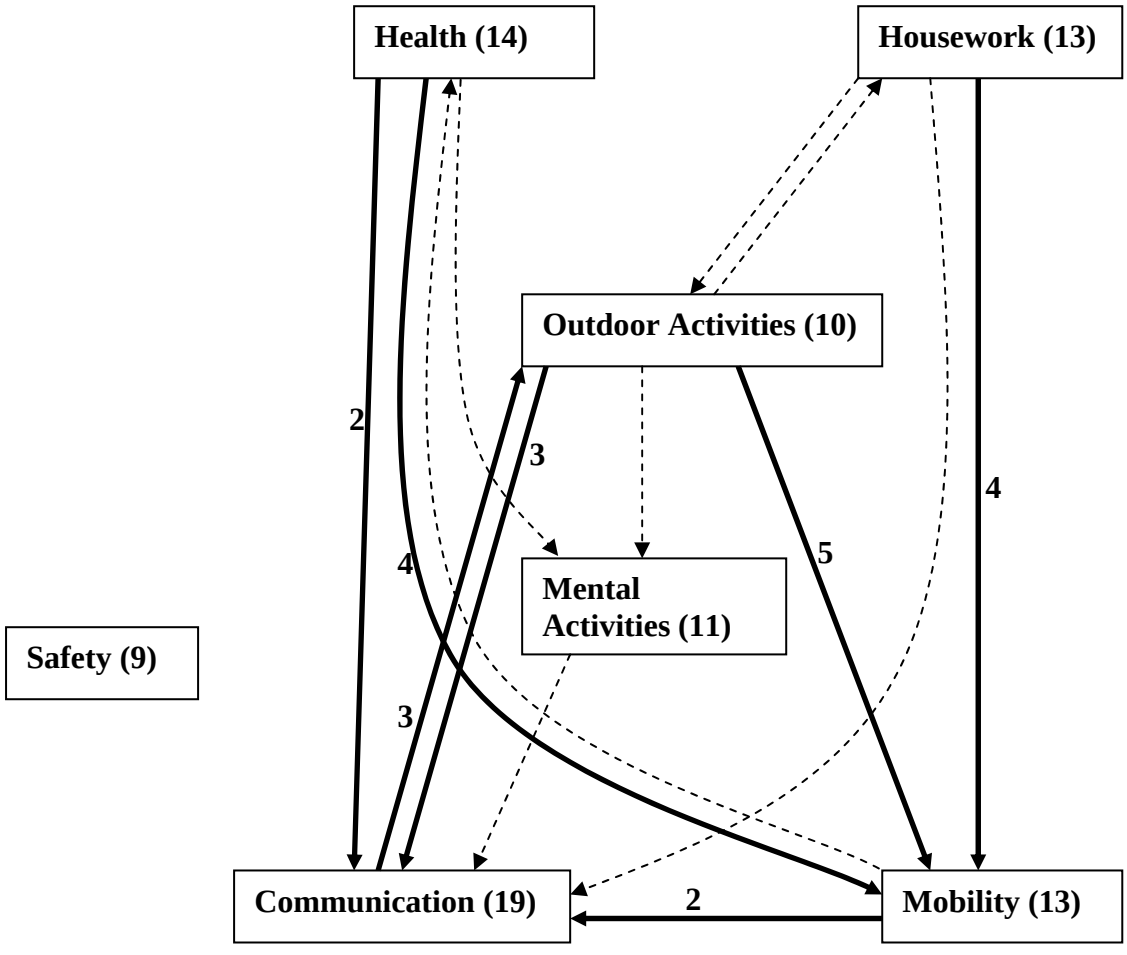
Story		**Functions**
Annually, my grandmother would come over to our house [1]after making offerings and praying respects to our ancestors. On most occasions, she would [2]travel on her own to our house. With her, she would bring the food that are prepared for the offering. Before my mother and grandmother prepare dinner, grandmother would often stay in the living room. Among the things that she would do in the meantime includes: [3]reading newspaper, watching television, and [4]chatting with the family in the bid to gain a better understanding of how we have been getting along. In the late evening, she would offer to [5]prepare dinner. During dinner, grandmother would		[1]Outdoor activities [2]Mobility [3]Mental activities [4]Communication [5]Housework

[6]discuss some recent happenings of the whole extended family. …		[6]Communication

In the short paragraph, three correlational relationships were identified. Between function 1 and 2, the outdoor activity of making prayer led to the need for travel. Making prayer was a common event in Chinese culture and was likely to reoccur. Between function 1 and 4, the investigators agreed that within the Chinese custom, part of the reasons for having a prayer was to use it as a family gathering. It was common that special events were used as an excuse for everyone to come together. In this sense, communication needs arose before outdoor activity needs. Between function 1 and 6, the need to discuss family issues, a communication need, arose before the chance for a gathering occurred. Therefore again establish the same form of relationship as between 1 and 4. All the stories were analyzed in the same way and the number of correlational relationships were counted and tallied.

A correlational structure between functions was identified as shown in figure 6.2. The correlational relationships were tallied. Each types of relationships, for example communication function causing outdoor activity, outdoor activity causing mobility, or health causing mobility needs to arise, was counted separately. The final results showing the number of occurrences in each pair of correlational relationships were shown in figure 6.2. Many of the relationships were weak with only one case. To reduce cluttering, these cases were shown in broken links. The number of relationships relative to the number of occurrences of each function may seem small. However, since a function was identified only if it was pointed out by a subject, functions could be left out by mistake. Nonetheless, this restriction simplified the

analysis since whether an action or a need was a function could be ambiguous. For example, in one story, an older man was admitted into the hospital. Feeling bored, he decided to ask his grandchild to get him a cell phone. The subject only indicated a communication function for this episode. However, one could argue that the 'cause' of this communication function was mobility function – which was the inability to travel. Nonetheless, the subject did not see as such and his judgment was taken as the final verdict.



In the figure, ⇢ showed links with only 1 correlational relationship found in the sample. At the same time, → showed links with 2 or more correlational relationship found in the sample. The number next to → showed the number of correlational relationships.

Figure 6.2 Correlational relationships between smart homes functions

In figure 6.2, the direction of the arrow showed the direct of possible causal relationship. If an arrow began from outdoor activities and ended with communication, outdoor activities may be the causing function and communication may be the effect function. (1) Outdoor activities → mobility relationships had the highest number of occurrences. Followed by (2) health → mobility, (3) housework → mobility, (4) outdoor activities → communication, and (5) communication → outdoor activities. Considering the number of occurrence of each function found to contain a relationships, without considering what relationship those were, there were found to be more communication functions (19) when compared to the other functions such as mobility (13), health (14), housework (13), mental activities (11), outdoor activities (10), and safety (9).

6.5.2 Analysis of Needs Strength

An opportunity with story telling was the exploration of needs strength of smart home functions. This could be easily shown by tallying the number of occurrences of each function in the nineteen stories. While this method was disputable due to many possible reasons for high or low occurrences, it would also be foolish not to make use of such a simple analysis (Weller, and Romney, 1988). This counting was employed by excluding stories containing only one of each function, as indicated by @ in table 6.2. Such stories would lower the variance and distort the face value of the results. In the end, twelve stories met the criteria. Table 6.3 shows the distribution of frequencies of occurrence between functions. Since the subjects were asked to write stories containing at least one of each function, the least mentioned function would have at least twelve occurrences. Any number above twelve would better show the importance of the function in terms of vividness in the subjects' experience rather

than forcing to meet the criteria of the test. These numbers after deducting twelve from the total were shown on the second row titled 'excess cases above 12.' Again, communication function was found to have the highest occurrence.

Table 6.3 Distribution of frequencies of occurrences between smart homes functions

	Mobility	**Communication**	**Safety**	**Health**	**Mental Activities**	**Housework**	**Outdoor Activities**
All cases	17	25	13	18	17	18	12
Excess cases above 12	5	13	1	6	5	6	0

6.6 Results

Communication and mobility functions were end results of many other functions. For communication, there were 3 cases of outdoor activities, 2 cases of health and mobility, and 1 case of mental activities and housework. It was the cause in 3 cases of outdoor activities. For mobility function, there were 5 cases of outdoor activities, and 4 cases of health and housework. From figure 6.2, it was probable that communication and mobility were the most important means or supporting functions to fulfill many other functions at home.

Function of safety occurred nine times but was not linked with any other functions. One possible indication was that it was not supported or was substitutable by other functions.

In terms of needs strength, communication appeared most often in the stories (25). There was no significant departure from mean for mobility (17), health (18), mental

activities (17), housework (18), and safety (13). The lowest number of appearances was outdoor activities function (12).

6.7 Discussion

In this survey, there were few survey controls. The needs strength we deduced from frequencies of occurrences of functions might not reflect real strength. Rather, it could reflect limitations in choice of activities among the older adults. For example, low instances of mobility and high instances of communication could mean that older adults had a higher chance of satisfying their needs by asking their care takers rather than doing it themselves. The presence of others gave the older adults an opportunity to ask. Additionally, stories salient to the subjects are more likely to be remembered, and might better reflect worries of the subjects rather than the older adults. But the existence of frequencies of variables was so easily obtainable that one could not miss it as an indicator of relative importance (Weller, and Romney, 1988).

The use of storytelling generated much information and was in hindsight a good method for understanding needs structure. Causal relationships were naturally embedded within the stories and can be identifiable (Klein, 1999). But additional research would be necessary to prove the existence of causality. Klein (1999) noted that stories without details had limited scientific value. This was true for episodic stories that were abandoned due to limited usefulness.

The method can be improved by first briefing the subjects to think about a problem in the older adults' life. After which, they can write a cohesive story with as much details as they could surrounding the event. This way, the stories will be of continuous

form and more correlational relationships can be examined. Nonetheless, this simple survey provided an exploratory insight into a probable functional structure of smart homes.

Mobility did not arise before any other functions to aside from one instance. But it arise after the other functions in fifteen cases. Since other functional needs arose first, mobility may be lower in the abstraction level of functionalities.

Similarly, communication function was resulted after other functions in nine cases. But it arose before the other functions in three cases of outdoor activities. In these instances, the communication needs with family members may be fulfilled through outdoor activities such as family gatherings and prayers to the ancestors. In most instances, communication could be a low level function; but in other instances, it could be high level too.

The functionalities of smart home were sorted by two experts in survey 1. Since there were only two sets of data, they were not submitted for further statistical testing. Examination of the functional structures in figure 6.2 indicated that the two experts to some extent used different abstraction hierarchy to label the needs. This was important to note because it was probably the same way designers envisioned smart home products. While different companies saw different opportunities for smart homes, for example mobility devices, telemedicine, fall detector, communication devices, they were in fact competing with each other for the same needs. For example, while one company was building a telemedicine system that enabled the older adults with walking disabilities to take medical examination at home, another company built

automatic carrier transporting older adults from one place to another. The older adults who need to solve their health needs can consider both products as possibilities. On one hand, they can change their habits and take medical test at home instead of visiting a clinic, or buy the carrier and continue to travel to the same familiar clinic for medical tests. While it is not obvious that communication and mobility have much in common with other smart home tools, they can compete with many of smart homes innovations and being a versatile smart home solution.

These findings added interesting perspectives to designing user activities. Mobility tools such as vehicle and bicycle enable man to travel, trade, make purchases, and find entertainment. Communication tools such as telephone and writing enable passing on information and strengthen cooperation. The reason why older adults developed so much dependency can be indirectly caused by the lost of these functions. For example, when they are not able to walk long distances, they cannot visit their friends, visit the clinic, buy groceries, engage in social activities, and go for exercises in the community. When older adult are unable to move around without pains in the knees, they will make use of younger kins to run errands. Edwards et al. (2001) focused on this aspect in their project, Accessibility for Impaired Mobility (AIM), which dealt with people with disabilities, see section 3.1.5.

Also in the information age, many transactions took place in electronic format. New communication tools, such as computer, touch screen banking machines, electronic filing of income tax, and personal digital assistance, also appear from time to time making users who lost touch with these advances also losing contacts with parts of the society. Many of these problems can be solved by continue to maintain the efficacy of

the older adults to move within the city and communicate with different parts of the society.

From this study, it pointed out that smart homes functions and tools could be different but in conflict by trying to satisfy the same user needs. Similar, when users have a problem such as poor health, they will need to incorporate some tools to help them but these tools need not be in the same functional category. Mobility devices will solve a health problem by allowing the older adults to travel to nearby clinic. Likewise, housework need not be assisted a servant but by enhancing efficacy to buy groceries independently. Users can adapt their activities to changing difficulties of aging. As such, designers need to identify how users choose to make their change and what factors are involved when they pick between competing products, for example telemedicine versus mobility device. While it is more common to identifying usability problems whereby the product has already been decided, defining user requirements from activity perspectives can be more useful to innovative products since users are readapting to new tools in the market and which tools will be adopted is uncertain. It is well possible that tools with the minimal tangible and intangible costs, for example dollar cost, learning curve, effort to change and readjust to new lifestyle, living with cultural taboo, living with stigma, and handling side effects, will be the best smart home tool for the users. More research is needed in this direction.

Chapter 7 Survey 3: Identifying Needs Structure of Smart Homes for Older Adults

7.1 Identifying Needs Structure of Smart Homes for Older Adults with Cluster and Factor Analysis

In chapter 2, we noted that needs of older adults might be viewed from six perspectives – spirituality, productive aging, anti-aging, dependency avoidance, nurturance seeking, and biological. Following, survey 1 was undertaken to understand how usage of smart homes could fulfill the needs. This resulted in smart homes functions and other design factors such as usability issues and projected needs. Survey 2 was performed to understand the relationships between these functions and identified mobility and communication as two basic functions. These results were also companied by examples of daily life of older adults.

All of the above provided background data to identify a needs structure of the older adults – the original aim of this research. Needs structure of an older adults should reconcile the differences between needs of older adults and functions of smart homes. The author had not found any theoretical research that can indicate how needs convert into product design. When the word “needs” was mentioned in the literature, it could cover anything from emotional pleasure to physical activity. A need for love need was a need (Maslow, 1994). And traveling from home to work place was another need. It was easy to distinguish the two by categorizing the latter as a biological need.

This reasoning was similar to what several researchers including Murray (1938) had suggested by separating the activities of the mind and body into different entities.

Murray (1938) he decoupled these problems by defining a separate set of Viscerogenic (biological) needs from psychogenic need. As such, the need to stay alive would be different from the need for exhibition. These needs were independent from each other, which was a suitable assumption for psychologists since it isolated psychological problems from physical problems.

However, for ergonomists, this view might mislead product design. Ergonomic design was predominantly employing tools to facilitate human activities aiming to fulfilling a need (Zarakovsky and Sengupta, 2003; Leont'ye, 1978). But psychological needs that were detached from physical activities offered little clues to what sorts of relationship exists between the two. Suh (2001) suggested that transformation from user needs to product function should take place in a "solution neutral environment – that is without thinking of existing designs." This "art" of satisfying user needs could be seen as a "black box approach." When needs were known but activities were not, planning of activities was more of an art than science. For example, a company planned to introduce medicine caddy that managed medicine for older adults. However, there was no precedence to follow and plan how would users adopt this innovation. Designers would have to decide, 'how would the caddy look,' 'how big should it be,' 'how many days of medicine should it contain,' 'how much should it costs,' 'who will buy it,' 'which functions should be automated and which should not,' and 'what functions should be incorporated.' One might hope that an experienced designer would be able to produce concepts that users would like. Meanwhile, some human factors practitioners were looking at activity theory as the bridge between user motives and goals (Bedny and Karwowski, 2003). From this point of view, an activity was a result of mediation between user's knowledge, preferences, and tools. Future

development of this theory might give us a good basis for predicting good designs from user needs.

Therefore, our assumption was that there was a potentially complex relationship with abstraction levels between needs and smart home functions. If one could prove that there were relationships between psychological needs and smart home functions, one could identify a functional needs structure that could be used for design. We had to be aware that many different needs structure can exist. It was a matter of perspective. The root word for theory was theoria, which was the same root word for theatre (Bohm, 1980). This brought us back to the original purpose of theory development, which was to orientate our point of view to the best perspective. Therefore, needs of smart homes for the older adults should also be categorized in such a way. Our perspective should be to look at users' motivations in purchase, and this should originate from users' model of their own needs. This would shed light into how users categorize products according to their needs. Other matters of interests would be to identify the needs strength of design features and usability issues.

Honeywell's interests in home monitoring were also looked into (Technology Review, 2003). They showed interests in home monitoring with smart homes. However, it is not clear what should be monitored at home, which includes: time for medication, and activities such as sleeping, going out, eating, and bathing. Their relative importance would depend on interests of the older adults and it would enable prioritization of development efforts.

7.2 Method and Procedure

7.2.1 Custer Analysis and Factor Analysis

In scientific studies, a large number of variables were often identified. However, it as difficult to use all these variables at once. Designers might want to categorize them into fewer numbers. An example was Maslow's needs hierarchy. While Murray's needs received higher recognition in psychology, its twenty categories were too many to use compared to Maslow's five (Schiffman, 2001). Where many variables were identified in qualitative studies, many of them could be identical. Thus, many variables could be combined. Two of such methods were cluster and factor analysis.

Cluster analysis was mainly used for the purpose of identifying groups within a population (Hair et al., 1998). However, the same procedure could also be used to cluster variables, and to reduce the number of variables (Hair et al., 1998). Similarity could be measured by correlation or distance between variables. Cluster analysis would always produce clusters and it was important to substantiate the results with conceptual understanding.

First, the researcher should decide what similarity measure to use, and should the data be standardized (Hair et al., 1998). There were no definite guidelines for any of the above choices and investigator had to evaluate with conceptual understanding. Correlational measure made use of similarity of patterns between variables (Hair et al., 1998). It was an alternative to distance measure. As such, correlational measure would be interpreted differently from distance measure (Hair et al., 1998). But it had an intuitive appeal and was used commonly in other multivariate methods.

Second, cluster analysis had strong mathematical properties but weak statistical foundations. The requirements of normality, linearity, and homoscedasticity had little bearing on the method (Hair et al., 1998). However, researcher should pay attention to the representativeness of the sample. This would ensure generalizability of the clusters.

Third, cluster analysis could be classified into two categories: (1) hierarchical and (2) nonhierarchical. Hierarchical methods combine (agglomerative method) or divide (divisive method) clusters based on highest similarity or dissimilarity between available clusters. Nonhierarchical methods selected seed points and combined objects within the vicinity of the seeds. Hierarchical method was preferable unless these seed points were known (Hair et al., 1998). Among the hierarchical methods, there were several algorithms to choose from. A popular algorithm was average linkage. The cluster criterion was to combine or divide two clusters by measuring the average distances between all variables in both clusters. It tend to produce clusters with similar variance (Hair et al., 1998).

Forth, a stopping rule guides the number of clusters to extract. One rule was to look at similarity between two clusters that were combined at each successive step. One might stop the process when value of similarity made a sudden jump (Hair et al., 1998). Another rule was that of practicality – how many clusters were manageable by the researcher? Researcher might choose the number of clusters that were viable for further study and best suited the theoretical foundations (Hair et al., 1998).

Finally, the researcher should examine any outliers that appear in the solution. If any single member cluster appears, one should see if it was liable for deletion or was it not represented well in the solution (Hair et al., 1998). Then the researcher might rerun the analysis or assign names to the clusters (Hair et al., 1998).

Another method, factor analysis, could be used for the purpose of data summarization (Hair et al., 1998). It attempted to condense the number of variables with minimum loss of information. The method analyzed the correlations between variables and categorized them into logical groups. It could also predict how much each variable was accounted for by the final groupings. Factor analysis could be used for exploratory or confirmatory analysis. In exploratory analysis, the researcher had no preconceptions of the inherent structure. In confirmatory studies, the researcher predicted the upcoming structure based on theory and evidence (Hair et al., 1998). While factor analysis was good for categorizing variables, it was a supplementary approach. It was always important to conceptually explain the solutions (Hair et al., 1998).

First step of factor analysis was to analyze the correlational matrix. It was important to note that lesser than desirable sample size might result in “overfitted” data that was sample specific (Hair et al., 1998). Better generalizability would require observations versus variables of 2:1. If this ratio was not achievable, researcher should analyze the solution cautiously (Hair et al., 1998).

Second, the research had to decide on the number of factors to abstract. From one perspective, one could set to account for a total variance of 60% (Hair et al., 1998).

From another perspective, one could make use of scree test criteria (See chapter 7). With “latent roots” versus “number of factors” plot, one could apply a stopping rule where the curve began to straighten out (Hair et al., 1998).

Third, the initial solution was usually not optimized. Factor rotation was employed to find the best linear combination of the variables so as to achieve theoretically more meaningful solutions (Hair et al., 1998). Varimax rotation was a common method used. It was an orthogonal rotation method that ensures that variances explained by each factor remain independent from one another (Hair et al., 1998).

Forth, the factors obtained from the solution will contain variables. These variables were used to interpret the factors. Variables of higher loading were considered more important and relevant (Hair et al., 1998). The names of the factors were labeled by the researcher and priority was given to the variables with highest loading. Sometimes, factors not containing clear solution could be labeled as undefined and left aside thereafter (Hair et al., 1998).

7.2.2 Preparation of Stimuli Representing Features of Smart Home Design and Questionnaire

Fifty-three stimuli were prepared for categorization. They were smart homes features conceptualized to solve problems of the older adults. These concepts were inspired by the literature review, and the previous surveys in this thesis. Four of these concepts were shown in figure 7.1. In the figure were four examples of the concepts used in the survey. Some of the concepts were illustrated by drawings and caption, as shown in concept examples 1 and 2; others were verbal statements without illustrations as

shown in concept examples 3 and 4. The statements were used because some concepts were abstract and difficult to illustrate.

Usability issues and Honeywell's interests in home monitoring were also difficult to represent as figures and they were shown as statements. The concrete concepts represented by drawings, and the abstract ideas represented by statements were treated separately. This was because the abstract concepts may not fit well into product design. On the other hand, needs strength of usability issues, and examples of home monitoring were examined.

The full set of stimuli can be found in Appendix D. A questionnaire was prepared and each of the stimulus, appeared on different pages in A5 size.

Concept Example 1	**Concept Example 2**
	
Concept Example 3	**Concept Example 4**
Home delivery for groceries I bought.	Fully automatic air-con will adjust itself. Fully automatic VCR can automatically record my favorite TV programs.

Figure 7.1 Examples of stimuli used in the ratings

There were two questions for each stimulus. The intention of the two questions was to capture the needs strength of these features from two perspectives - positive emotions and negative emotions towards a design. From chapter 4, we understood that human subconsciously evaluate products from both perspectives. Thus, while a product may seem attractive, issues such as poor usability can deter a user. These questions were: (1) I would like to own a product that does this, and (2) I would not know how to use a product like this. They were modified from two questions in Attitudes Toward Computer Usage Scale (Popovich et al., 1987). Seven-point Likert scale was used as shown in figure 7.2. The subjects chose the most relevant respond with respect to each question.

1	2	3	4	5	6	7
Totally disagree	Very much disagree	Somewhat disagree	Neutral	Somewhat agree	Very much agree	Totally agree

Figure 7.2 Seven-point Likert scale used for rating of stimulus representing features of smart home.

During the pilot session, it was observed that subjects had problems with question two. This was because the negative phrasing of "would not" formed a double negative when subjects looked at choices of "totally disagree," "very much disagree," and "somewhat disagree." This question was changed to "I would know how to use a product like this." Following this modification, the questionnaire was translated into Chinese.

7.2.3 Sample Population

Thirty-two older adults participated in the ratings. Three were pilot subjects. All subjects were residents of a studio apartment for older adults above 55 years of age. The apartment was similar to the one visited in survey one. The subjects were

recruited by the clubhouse in the apartment. The clubhouse was given $15 dollars for every participant. The money was spent on an outing for these subjects and other welfare costs for the residents.

There are twenty-five subjects ranging from 54 to 86 years old (mean=67.4, and s.d.=7.6). There six males (24.0%) and nineteen females (76.0%). The large number of females might be attributed to the interests of females in group activities. Twenty of the subjects have children (80.0%). The number of children range between 0 and 7 (mean=2.4, s.d.=1.7). Twenty-one of the subjects were married (87.5%) Among them, three were widow(er) and one divorcee. The other three were single (12.5%).

7.2.4 Procedure

Older adults interested in the survey were grouped into small groups of no more than seven. In the beginning, each group was briefed for fifteen minutes on the purpose and method of the survey. The briefings were done separately for English and Chinese groups. Two young workers of the clubhouse helped the investigator to monitor the progress of the subjects. The investigator was present at all time. The surveys were performed afternoons between 1 - 4pm during three consecutive weeks.

During the survey, it was observed that some subjects had difficulties understanding the differences between question one and two. They commented that if they ‘like’ a product, they would know ‘how’ to use it. As a result, they gave the same response to question two as to question one. Question two was therefore removed.

In addition, five subjects could not understand how to respond and their data were discarded. Therefore, twenty five sets of data were available for analysis.

7.3 Analysis and Results

7.3.1 Missing Values – Imputation

Some values were missing in the ratings. One reason was that some subjects could not comprehend some of the stimuli. Another reason was that some subjects rated more than once on the same scale. This was treated as a random error. Table 7.1 shows distribution of missing data. Number on top represents the page number of the stimuli 6, 7, 10, and so forth. Pages not shown had no missing values. Subject numbers was shown on the left column. The distribution had no more than two missing values for any stimulus. Missing values appeared to be related to some subjects.

Table 7.1 Analysis of missing data

	PAGE # and Contents of stimuli																				
Subject #	**6-Night lights**	**7-Window alarm**	**10-Sitting aid**	**11-Automatic carrier**	**13-MedCaddy**	**14-Outdoor fall**	**16-OCR pen**	**22-Home automation**	**23-Documents reader**	**25-Helping others**	**26-Communicator**	**30-Transgeneration**	**33-Alarm stranger**	**36-Health detector**	**40-Meal alert**	**41-Outdoor alert**	**43-Techno phobia 1**	**44-Numeric only**	**47-Techno phobia 2**	**48-Learning to use**
1																				
2																				
3																				
4																				
5																				
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7																				
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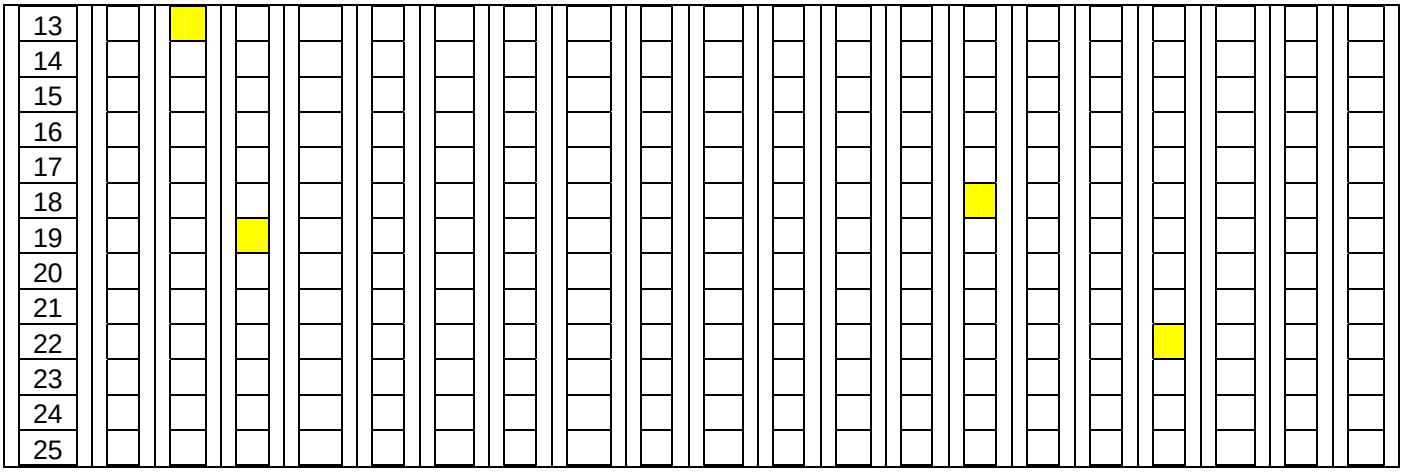

Imputation with mean substitution was performed to replace the missing values for analysis (Hair et al., 1998). It replaced the missing values of variables with the mean value of that variable from available responses.

7.3.2 Cluster Analysis of Needs Represented in Drawings

Cluster analysis was used for categorization of stimuli into related groups. Stimuli from pages 1, 3-21, 23, 26-28, 35-37, and 51 were used, see Appendix D. This allowed an analysis of stimuli representing obvious features of smart home.

Table 7.2 Agglomeration Schedule of cluster analysis of needs represented in drawings

Agglomeration Schedule

	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
Stage	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
20	2	4	.357	17	15	21
21	2	8	.312	20	9	23
22	5	7	.312	14	18	25
23	2	27	.234	21	0	25
24	1	3	.231	10	19	27
25	2	5	.217	23	22	26
26	2	17	.143	25	0	27
27	1	2	.025	24	26	0

Figure 7.3 showed the dendrogram of the cluster agglomeration structure.

Hierarchical cluster analysis was performed with agglomeration schedule. The similarity measure was based on correlation between variables using average-linkage method. The statistical procedure was performed with SPSS release 11. The agglomeration schedule was shown in table 7.2. Three large groups emerged after stage 25 and analysis was performed on these three groups of stimuli.

The first group consisted of stimuli on pages 6, 7, 8, 15, 17, 21, 23, 27, and 28. The second group had stimuli number 3, 5, 9, 13, 14, 16, 19, 26, 36, and 37. The third group had stimuli number 1, 10, 11, 12, 20, and 51. Page 18 seemed to be an outlier. The contents of each group are summarized in table 7.3.

Three main themes were observed. The first was related to household chores and safety issues. The second was related to personal health and safety issues. The third was related to active aging issues, see table 7.3. The outlier – 'to chat with others while I am in hospita' may fit well with groups 1 or 2.

There were 28 variables and was formally not enough for factor analysis which requires 2 subjects per variable. Still, it was possible to use factor analysis to provide another perspective as shown in the next section.

7.3.3 Factor Analysis of Needs Represented in Drawings

There were twenty-eight drawings, see pages 1, 3-21, 23, 26-28, 35-37, and 51 of Appendix D. They were factor analyzed with principal components analysis using a

correlational matrix on SPSS release 11. The results were treated with varimax rotation. The final results were showed in a scree plot in figure 7.3.

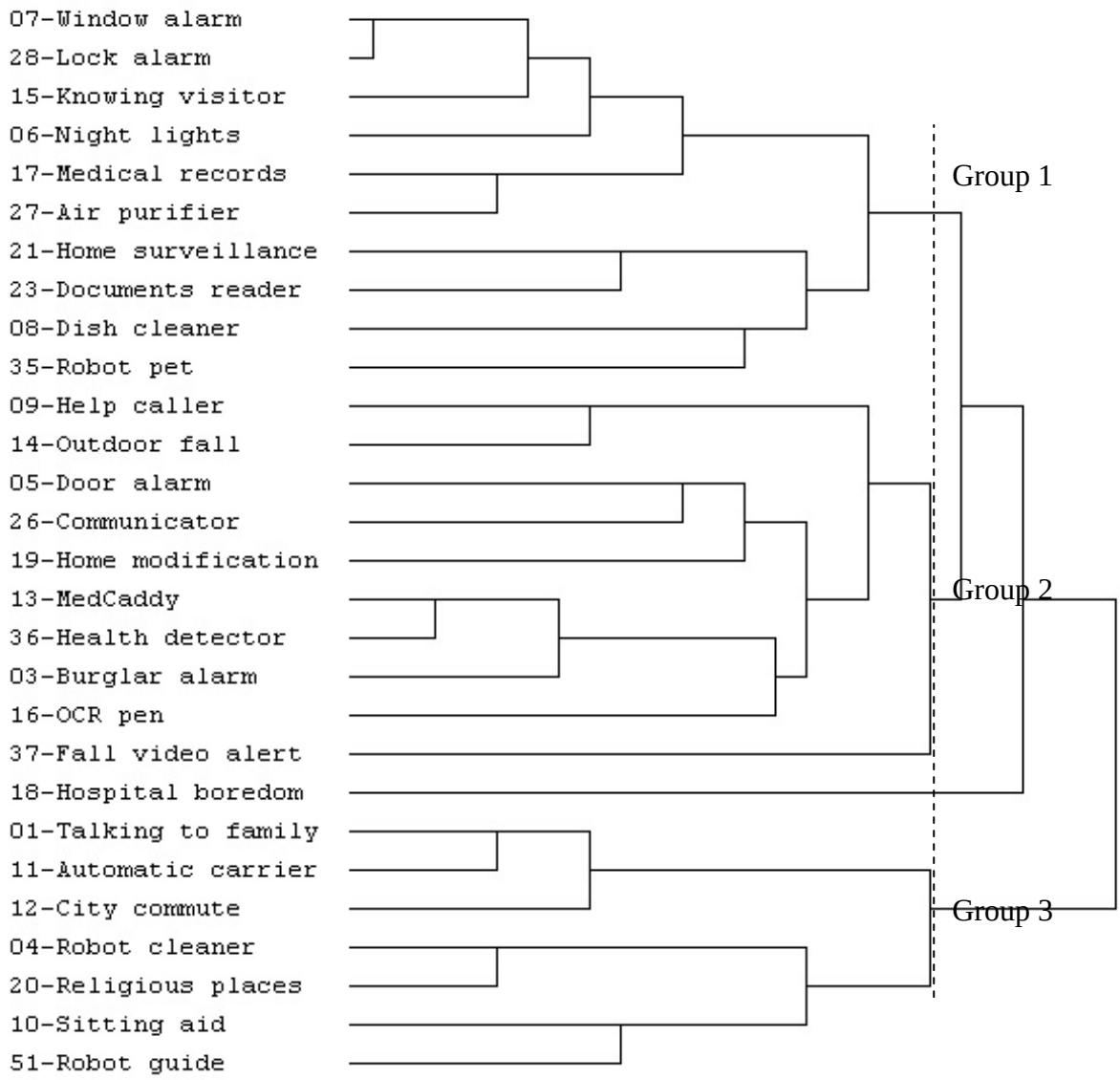

Figure 7.3 Dendrogram of agglomeration structure of hierarchical cluster analysis of needs using average linkage method

Table 7.3 Contents of groups of stimuli categorized with cluster analysis

Page no.	*Group 1: Household responsibilities and security*	Page no.	*Group 2: Personal health and safety*	Page no.	*Group 3: Active aging*
6	Lights to show the way when I wake up at night.	**3**	Resting in my bedroom at night. If a stranger enters my place, I will know.	**1**	To communicate with my family and know how they are doing.
7	To ensure that the windows are locked at night.	**5**	To ensure that my main door is closed before sleeping	**10**	Chair to help me stand up easily.
8	To clean up the utensils after cooking.	**9**	To call for someone when I need help.	**11**	To buy things in the neighborhood.
15	To know who is calling outside the door.	**13**	Record the time when I take the medicine.	**12**	Help to travel in the cities.
17	Card to carry medical record and personal information in case of emergency.	**14**	I am alone and I don't feel so well. Watch to inform my family who are not with me.	**20**	Automated carrier to visit religious places.
21	I am outside and no one is at home. Screen in my pocket allows me to check on my house.	**16**	The pen has an eye and speaker that can read text aloud.	**51**	Robot cat or dog to bring me where I want to go.
23	A machine that reads letters aloud.	**19**	To be helped going to the toilet.		
27	Air-purifier to keep the air clean.	**26**	To chat with many other older adults.		
28	To ensure that the main gate is locked at night.	**36**	Toilet that can detect if I am sick.		*Outlier:*
35	Robot dog or cat to play with.	**37**	To inform my family when I fall down at home.	**18**	To chat with others while I am in hospital.

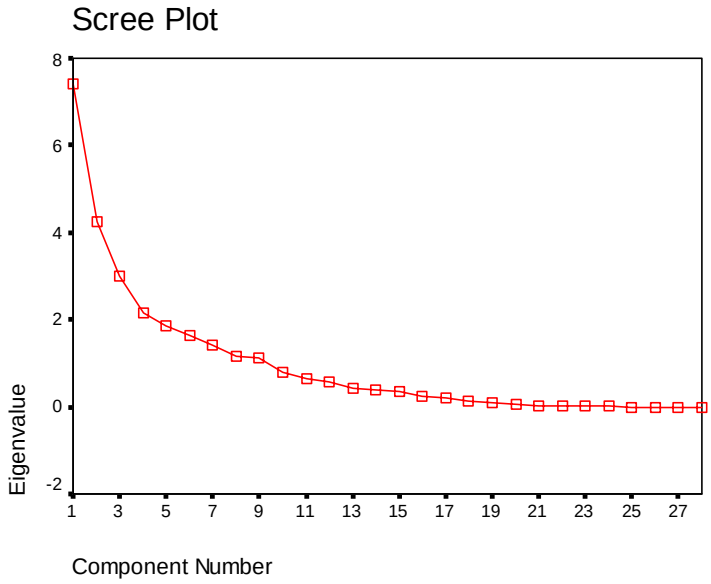

Figure 7.4 Scree plot of factor analysis of needs represented in drawings

There was a large reduction of explained variance after four components. The second analysis set the number of factors at four. The total variance explained by the four factors was 60.1%. Taking communalities of 0.4 as the minimal acceptable level, four variables might not be well represented by the factor solution. These variables were:

Page 9 - To call for someone when I need help

Page 18 - To chat with others while I am in hospital

Page 37 - To inform my family when I fall down at home.

Page 51 - Robot dog or cat to bring me where I want to go

The component matrix was rotated with varimax rotation with Kaiser normalization. The rotated component matrix was shown in table 7.4.

The complexity of table 7.4 can be reduced by paying attention to variables loading highly on their own factors. The three variables with highest loading on their factors were bolded, see table 7.4. For factor 1, variables 6, 27, and 28 had an alpha of 0.887. For factor 2, variables 5, 13, 36 had alpha of 0.84. For factor 3, variables 4, 8, 20 had alpha of 0.73. For factor 4, variables 3, 13, 36 had alpha of 0.83. As shown in table 7.4, the factors were interpreted as (1) Household responsibilities and security, (2) personal health and safety, and (3) active aging. One factor was undefined.

Table 7.4 Rotated Component Matrix of factor analysis of needs represented in drawings

		Factor			
		1	2	3	4
Page		Household responsibilities and security	Personal health and safety	Undefined	Active aging
01	To communicate with my family and know how they are doing.	-.223	-5.259E-02	.534	**.603**
03	Resting in my bedroom at night. If a stranger enters my place, I will know.	-.172	.606	2.409E-02	-.493
04	Robot to clean the floor for me.	-.137	-5.702E-02	**.797**	.131
05	To ensure that my main door is closed before sleeping	.200	**.687**	-.407	-.115
06	Lights to show the way when I wake up at night.	.569	7.599E-02	6.854E-02	-.590
07	To ensure that the windows are locked at night.	**.821**	-4.021E-03	9.401E-02	-.320
08	To clean up the utensils after cooking.	.342	-4.403E-02	**.709**	5.251E-02
09	To call for someone when I need help.	.234	.432	6.156E-02	.229
10	Chair to help me stand up easily.	.190	.511	.341	.260
11	To buy things in the neighborhood.	6.182E-02	2.879E-02	.438	**.790**
12	Help to travel in the cities.	-.100	7.853E-02	.116	**.778**
13	Record the time when I take the medicine.	8.258E-03	**.828**	1.445E-02	-8.476E-02
14	I am alone and I don't feel so well. Watch to inform my family who are not with me.	.194	.669	.302	.322
15	To know who is calling outside the door.	.751	.203	-.145	-3.547E-02
16	The pen has an eye and speaker that can read text aloud.	.364	.543	-8.237E-02	-4.933E-02
17	Card to carry medical record and personal information in case of emergency.	.637	.300	.158	.205
18	To chat with others while I am in hospital.	.252	.186	-.316	-.108
19	To be helped going to the toilet.	.478	.420	7.476E-02	.174
20	Automated carrier to visit religious places.	9.041E-02	.171	**.762**	.114
21	I am outside and no one is at home. Screen in my pocket allows me to check on my house.	.139	.542	.284	-.384
23	A machine that reads letters aloud.	.496	6.409E-02	.278	-.528
26	To chat with many other older adults.	.516	.474	-.437	.177
27	Air-purifier to keep the air clean.	**.772**	.262	4.169E-02	-.154
28	To ensure that the main gate is locked at night.	**.920**	5.376E-02	7.495E-02	-.100
35	Robot dog or cat to play with.	.383	.228	.450	-.337
36	Toilet that can detect if I am sick.	.235	**.850**	-.268	-.111
37	To inform my family when I fall down at home.	.380	.248	-.347	-2.887E-02
51	Robot cat or dog to bring me where I want to go.	.185	.403	.428	-5.451E-02

7.3.4 Factor Analysis of Needs not Represented in Drawings

Twelve stimuli in page 24, 25, 29 - 34, 47, 50, 52, and 53 were not represented in drawings but only in words, see Appendix D. These stimuli were factor analyzed with principal components analysis using a correlational matrix on SPSS release 11. The results were treated with varimax rotation. Bartlett's test of Sphericity showed a

significance of 0.06 thus rejecting the possibility that the matrix was identical. There was sufficient correlation for analysis.

All communalities exceeded 0.5 except for stimulus "Products which I buy and I can share with my family," which scored a 0.44. Figure 7.5 shows the scree plot of the eigenvalue distribution.

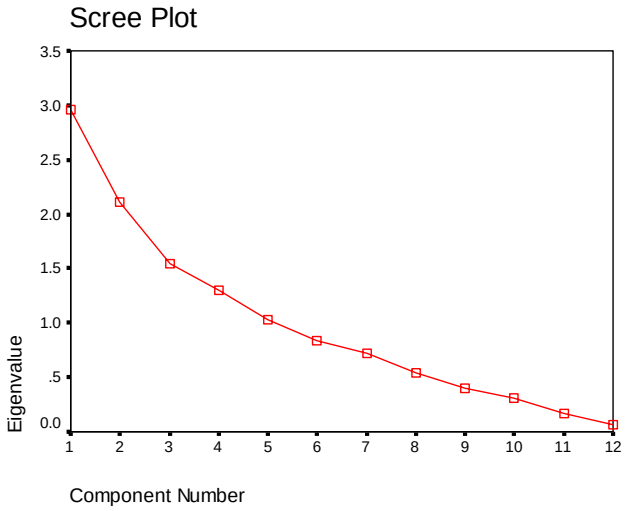

Figure 7.5 Scree plot of factor analysis of needs not represented in drawings

Four factors were abstracted, as shown in table 7.5. Total variance explained for four components was 66.0 %.

The four factors identified were (1) independent living, (2) living with family, (3) productive aging, and (4) companionship.

Table 7.5 Rotated Component Matrix of factor analysis of needs not represented in drawings

		Factor			
		1	2	3	4
Page	Stimulus	Independent living	Living with family	Productive aging	Companionship
24	Things that provide me with the chances to enjoy life in the countryside.	.485	.560	.267	-.121
25	Things that provide me with the chance to use my free time to help other people.	-.133	4.656E-02	.875	-3.244E-02
29	Product to improve or maintain the health of my spouse.	.352	.419	-.408	.529
30	Products which I buy and I can share with my family.	.374	1.911E-02	.542	-7.408E-02
31	Some useful products make me look old and sick. (e.g. cane and hearing aids). I want useful products that do not make me look old or sick.	.157	5.820E-02	.635	.313
32	Medical devices that are bought specially for me.	.157	.482	-.417	.509
33	An alarm to inform me when stranger enters my house.	5.961E-02	-5.818E-03	-.199	-.840
34	Things that allow me to stay with my children.	.138	.814	-.118	3.125E-02
47	I hope my children would buy electronic products for me. I do not wish to buy them myself.	.487	-.491	7.989E-02	.405
50	Products that allow me to know when my children are coming to my place.	.805	.214	-8.607E-02	4.553E-02
52	Products that replace maids to do housework.	-2.299E-02	.633	.298	.204
53	Products that take care of my needs at home so that I need not stay in old folks home.	.862	1.179E-02	.127	5.923E-02

7.3.5 Analysis of Home Monitoring Needs

The vision of many current smart homes were directed towards monitoring of older adults (Technology Review, 2003). The purpose was to detect what older adults were doing at home. However, past research has never dealt with or discussed what type of monitoring was appropriate. An analysis of needs strength would provide an understanding of the scenarios that an older adult would like to be monitored. Five items were used for this purpose: page 38, 39, 40, 41, and 42.

Anderson-Darling normality test showed non-normality on most of the variables. Friedman test was used for analysis of differences of mean between the variables. It

was a similar to two-way blocked ANOVA of "subjects' responses" versus the "five types of monitoring." Table 7.6 showed the results of test.

Table 7.6 Results of Friedman test of "subjects' responses" versus "five types of monitoring"

```
S = 10.44  DF = 4  P = 0.034
S = 15.96  DF = 4  P = 0.003 (adjusted for ties)
```

Types of Monitoring		N	Est Median	Sum of Ranks
Page42	**Products that allow my children to know where I am**	25	5.0000	89.0
Page38	**Products that inform my family when I took my medicine**	25	5.0000	83.5
Page41	Products that inform my children when I go out	25	4.8000	79.5
Page39	Products that inform my children when I am taking a shower	25	4.8000	65.0
Page40	Products that inform my children when I am eating	25	4.4000	58.5

```
Grand median = 4.8000
```

Friedman test was significant at 95% after adjustment for ties. Most interests in home monitoring were in "taking of medicine" and the "location of older adults." The result could reflect the relative perception of usefulness of each type of monitoring. Knowing when the older adults had their meals and showering scores the lowest.

7.3.6 Analysis of Usability Issues

Usability issues were represented on pages 2, 22, 43-46, 48, and 49, see Appendix D. They were also investigated with Friedman test of "subjects' responses" versus "usability issues" blocked by "subjects." The result was a significant at a 95% confidence level, see table 7.7.

Table 7.7 Results of Friedman test of "subjects' responses" versus "usability issues"

```
S = 35.34  DF = 7  P = 0.000
S = 45.09  DF = 7  P = 0.000 (adjusted for ties)
```

Usability Issues		N	Est Median	Sum of Ranks
Page_45	**When I buy an electronic product, the sale people should teach me patiently how to use it**	25	6.164	158.5
Page_48	**When I buy a product, I wish to attend classes to learn how to use it**	25	5.539	136.0
Page_2	Home delivery for groceries I bought	25	5.164	120.0
Page_44	Electronic products that I can use without having to read any words. I can read numbers instead.	25	5.039	112.5
Page_46	When I buy a product, I need to know how to get it repaired if it breaks	25	4.914	110.5
Page_22	Fully automated air-con will adjust itself. Fully automated VCR can automatically record my favorite T.V programs.	25	5.164	107.5
Page_49	Electronic products that require no maintenance	25	4.039	84.5
Page_43	My electronic products in my home must be handled by my children – not me	25	3.287	70.5

"Patience from sales person in teaching how to use a product" and "attending classes" scored highest among the usability issues. Surprisingly, many older adults did not consider children handling all the electronic devices as preferable.

7.3.6 Highest Needs Strength

The multitude of features of smart homes could not be implemented at the same time. It would have resulted in needless development costs and overwhelming features (Reinertsen, 1997; Jenson, 2003). A list of features with the highest scores would present a good idea of where designers could start. These were presented in table 7.8.

Table 7.8 Top Ten Features of Smart Homes

Page		Mean
3	Resting in my bedroom at night. If a stranger enters my place, I will know.	6.08
5	To ensure that my main door is closed before sleeping	6.28
9	To call for someone when I need help.	5.88
13	Record the time when I take the medicine.	5.92
15	To know who is calling outside the door	6.04
18	To chat with others while I am in hospital.	5.88
30	Products which I buy and I can share with my family.	5.96
33	An alarm to inform me when stranger enters my house.	6.42
37	To inform my family when I fall down at home.	6.48
45	When I buy an electronic product, the sale people should teach my patiently how to use it.	6.44

Mean for all responses = 5.0373
s.d = 2.1405

Two-way ANOVA was used test if the difference between the features was significant. However, normal probability plot yielded a skewed plot. Therefore, the normality assumption may be inappropriate. Friedman test was thus performed as a non parametric test as shown in table 7.9.

Table 7.9 Results of Friedman test of "subjects' responses" versus "top ten smart home features" blocked by "subjects"

```
S = 8.72  DF = 9  P = 0.464
S = 13.75  DF = 9  P = 0.131 (adjusted for ties)

                    Est    Sum of
C62           N   Median    Ranks
Page_13      25   7.0000    130.5
Page_15      25   7.0000    132.0
Page_18      25   7.0000    114.5
Page_3       25   7.0000    155.5
Page_30      25   7.0000    117.0
Page_33      25   7.0000    158.0
Page_37      25   7.0000    149.5
Page_45      25   7.0000    146.0
Page_5       25   7.0000    137.5
Page_9       25   7.0000    134.5

Grand median =   7.0000
```

The probability that there was a difference between the features was 0.13, which was not significant at 95%. Therefore, it was not possible to differentiate the above features by their relative importance.

7.4 Discussion

7.4.1 Problems Faced in the Survey

Several difficulties were faced in identifying needs of older adults in smart home. First, in order to link the research to design, it was necessary to make use of design examples in drawings. However, drawings include elements that might bias the subjects' opinion of a need. For example, older adults might not like the look of wheelchair or they might not like to use it for visiting their friends. As mentioned before, designs produce tools that make certain activities possible so that needs can be fulfilled (Bedny and Karwowski, 2003). However, subjects might also feel that aspects of the tools interfered with other needs (e.g. aesthetic needs). As such, the needs structure might be affected by the type of tools available. However, providing tools as stimuli enhanced the external validity of the results. It was because the externalization and internalization of activities was a complex mediation between user needs and tools (Bedny and Karwowski, 2003). But it was in the value of such end results that designers should study.

The second difficulty was in finding the right subject sample. Subjects residing at the studio apartment should be most ideal, see survey 1. However, the usage of ratings and statements in stimuli required literate subjects. Many of the older adults in Singapore had low level of literacy, but the research was confined to persons with at least some education. Some older adults did not understand how to use a scale and

they used only the extreme of one or seven. In the end, it was necessary to eliminate five subjects. It might be better if the scale was changed to three or five points. If it were not for the large number of stimuli, paired comparison would have been a better method.

The third difficulty was related to the stringent requirement for subjects, which made it difficult to find large number of participants. It was almost futile to obtain permission from older adults without proper introduction by someone, since there was a sense of mistrust among the older adults. The search was thus restricted to the studio apartment recommended by the Ministry of Community Development and Sports, and meditated by the club house. However, once the researcher established trust with the subjects, they were friendly and helpful.

Another issue was that many subjects could not differentiate between question one - "I would like to own a product that does this," and question two – "I would not know how to use a product like this." One possibility was that the survey used a questionnaire with both questions placed side by side as shown in figure 7.6.

	Question 1 I would like to own a product that does this.							Question 2 I would know how to use a product like this.						
Example	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree
Page 1	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree
Page 2	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree
Page 3	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree
Page 4	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree	1 Totally disagree	2 Very much disagree	3 Somewhat disagree	4 Neutral	5 Somewhat agree	6 Very much agree	7 Totally agree

Figure 7.6 Example of the questionnaire design

Another possibility was that a person tends to combine both positive and negative feelings (Cacioppo and Gardner, 1999). This was reflected by comments of some subjects that "If I like it, I would know how to use it." Another reason was cognitive dissonance - a person would avoid contradicting himself in the second response and therefore repeat the earlier evaluation.

7.4.2 Discussion of Results

Needs Represented in Drawings

Cluster and factor analysis of the stimuli shown in drawings identified two sets of factors as shown in table 7.10.

Table 7.10 Comparison of Factors Elicited from Cluster and Factor Analysis

Results of Cluster Analysis	Results of Factor Analysis
1. Household responsibilities and security 2. Personal health and safety 3. Active aging	1. Household responsibilities and security 2. Personal health and safety 3. Active aging

The two classifications were in agreement. Subjects organized their activities in three main categories – (1) household responsibilities and security, (2) personal health and safety, and (3) active aging. The first factor described roles of older adults in caretaking and wellbeing of the family. The family needed help in washing, handling mails, cooking, and keeping the house clean. Often, security at home was overseen by the older person – in making sure that doors and windows were locked. Carrying of personal record was surprisingly included in this category. Nonetheless, the factor loading of this item was low and spread across other factors.

Personal health and safety factor described the attention on ones decline and need of taking care of one's health. Issues raised included illness detection, calling for help, and handling of medications. Another problem of being old was the increased vulnerability to criminals.

Active aging reflected another aspect of older adults' activity. It was different from the above two because it concerned relationship between the older adults and society. It depended highly on ability to travel and make contact with others in shopping, traveling, and religious activities.

Analysis of Verbal Statements

Factor analysis was also performed on verbal statement. Four factors were identified: (1) independent living, (2) living with family, (3) productive aging, and (4) companionship. The results were quite different from the previous factor analysis. The nature represented by words inclined towards psychological concepts and ideals.

First, older adults had a desire continue living at home and not institutionalized. They would welcome products that take care of them and reduce their dependence on others. A problem of independent living was accompanied by separation from family members. Many older adults desired knowing when their children would visit them.

Second, some older adults desirde staying with their children. They might attempt to do so by staying productive at home by doing housekeeping. They might desire products that make their housework easier.

Third, some older adults desired products that enable them to participate in community. They like to express their concerns for friends and relatives. They also desired maintaining social status by displaying an image of being young and active.

Forth, older adults had desire for maintaining relationships with spouses and children. Products that kept the spouse healthy or closing the family ties would be good.

Implementation of these needs would be difficult; obviously, they did not rely on physical design – and they could hence not be illustrated with drawings.

Usability Issues

Learning how to use a product was very high on the priority list. Older adults needed more attention from salespersons explaining how to use electronic products. The author also observed some older adults turned to other older adults for explanations. As such, sales persons had to know how to deal with older customers..

Through the interviews, some older adults expressed a desire to learn how to use new products, although they lacked the opportunity to do so. It was surprising that many older adults felt that electronic products need not be handled by their children. Maybe they were made to believe that they were not be able to perform well and left the tasks to someone 'more competent.' However, Czaja (1997) showed that older adults were optimistic about using new technology (Czaja, 1997). One should provide opportunities for older adults to learn and use these products and designers should also learn to design interfaces for older users.

Home Monitoring

Some older adults were surprised by the multitude of functions that could be monitored by smart homes. Some commented that their children would feel annoyed; this was probably a projection of their own feelings. They could also be annoyed by the lack of privacy in so many situations. Monitoring of location and medication showed greatest promise among the rest.

Top Ten Features of Smart Home

The top ten features of smart homes were shown in table 7.11. There were seven needs from drawings, two needs from statements, and one from usability issues. Five of the needs were regarding 'personal health and safety issues,' two came from 'household responsibilities and security' issues, and one came from "productive aging." One additional need regarding companionship had a negative factor loading, and was therefore discarded.

Table 7.11 Sources and distribution of needs in the top ten features list

Page no.	Content	Source	Type of Needs
3	Resting in my bedroom at night. If a stranger enters my place, I will know.	Drawings	Personal health and safety
5	To ensure that my main door is closed before sleeping	Drawings	Personal health and safety
9	To call for someone when I need help.	Drawings	Personal health and safety
15	To know who is calling outside the door	Drawings	Household responsibilities and security
17	Card to carry medical record and personal information in case of emergency.	Drawings	Household responsibilities and security
18	To chat with others while I am in hospital.	Drawings	Personal health and safety
30	Products which I buy and I can share with my family.	Statements	Productive aging (Companionship)
33	An alarm to inform me when stranger enters my house.	Statements	
37	To inform my family when I fall down at home.	Drawings	Personal health and safety
45	When I buy an electronic product, the sale people should teach my patiently how to use it.	Usability	-

The personal health and safety were thus of greatest importance. However, the responses might be biased since these concepts were simpler to understand compared to others. Nonetheless, the listing provided a direction for development of smart home products.

Chapter 8 Discussion and Conclusion of Needs of Smart Homes for Older Adults

Needs of older adults in smart homes were identified in literature review. The six needs – spirituality, productive aging, anti-aging, nurturance seeking, dependency avoidance, and biological needs were well supported by literature. It was believed that older adults were able to devise activities to meet these needs once products were made available. However, there was a lack of theoretical perspective in understanding how needs transform into functions of smart homes. For example, if an older adult has a need for spirituality, what will she do? She may desire attending a sermon at a temple or staying away from excessive social affairs. What she really does will be difficult to predict without understanding the culture and habitual schemas of the actor. Without these information, the process of invention is almost an art or a black box. Theories are needed to explain the formation of activities starting from needs, and to plan activities to solve these needs.

An established theory in development to predict activity from needs is the activity theory (Bedny and Karwowski, 2000). According to Leont'ye (1978), there was a need behind every activity, and the goal of this need directed the activity. It was not possible to engage in an activity without a need as this would mean one doing something without a purpose.

Seven smart home functions were identified to support activities of older adults. These were categorized from examples of use constructed by the subjects themselves. These seven functions were: communication, mobility, safety, health, outdoor activities, housework, and mental activities. In one way or another, interaction

between older adults and smart homes can take place using one of the above functions. The seven functions appeared to be structured in multiple hierarchies. Communication and mobility were the means of accomplishing many of the others functions, aside from safety. As such, it was probable that the most basic functions smart homes and other technology should focus on were communication and mobility. It was because satisfying these functions would lead to the satisfaction of many more above them. However, maintenance of security did not have as much reliance on communication and mobility as the other functions. It was because security was inherently an activity that takes place at home. Its purpose was that of deterring contact from unwanted individuals and as such stands much on its own.

In the last survey, fifty-three features of smart homes were used to abstract needs structure of older adults. Needs relevant to smart home design grouped into three categories of (1) personal health and safety: *personal needs*, (2) household responsibilities and security: *household needs*, and (3) active aging: *active aging needs*. If we compare this to the structure of activity, we can see a fit reconstruct a new corresponding structure. Figure 8.1 showed a structure of activity proposed by Engestrom (1999). This structure showed that activity was mediated by many elements, such as subject (older adults), goal, artifacts (smart home), and other social factors. In the structure of activity, the directions of the interactions might seem rigid but it was not the case. Interactions between the elements of activity could take place in many different ways and the proposed structure was merely a simplification of our complex world.

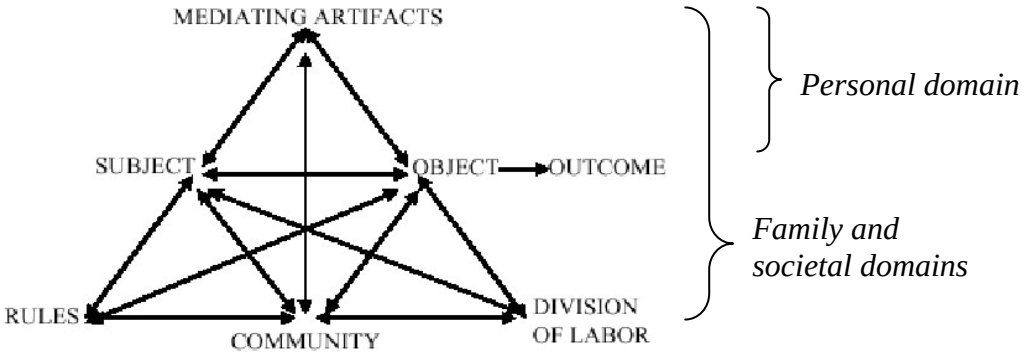

Figure 8.1 Structure of Activity proposed by Engestrom (1999) with additional interpretation on classification of personal, family, and societal domain needs

Taking care of personal needs is essentially solitary activity acting in a *personal domain*. Thus, it can be represented by the upper triangle mediated between mediating artifacts, subject, and object. Taking care of household needs were essentially activities acting in the *family domain* since they involved interaction between the older adult and family members. Taking care of active aging needs would involve activities acting in the *societal domain*, since older adults were interacting with the society. In the structure of activity, the last two needs would be covered by the mediation between mediating artifacts, subject, object, and community. As such, by removing elements of rules and division of labor which were not within our scope of analysis, we propose a similar needs structure as shown in figure 8.2.

In figure 8.2, *personal domain* is incorporated in the mediation between older adults, their goals, and the smart homes. There are no other people involve. As such, the domain covered personal needs such as health of the older adults, and their own safety. In figure 8.1, community comprised of both family and society. Similarly, in figure 8.2, no attempt was made to separate them. Family and societal domain were

covered through mediation among all elements found in the structure. In research on activities of older adults, actors being will decide the outcome of the mediation. Actors being family members would give rise to household needs such as security and housework. Actors being friends and relatives would give rise to active aging needs such as visitations and gatherings.

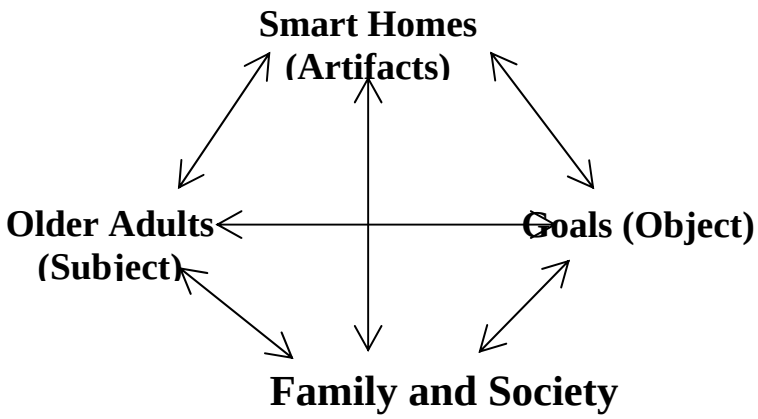

Figure 8.2 Proposed Structure of Activity in the Smart Home

The remaining needs: independent living, living with family, productive aging, and companionship seemed to fit well into the model as well. Companionship and living with family depended on the relationship between the older adults and their family members. Productive aging describes the relationship between the older adults and the society. Independent living describes the user's personal living space. On the other hand, usability was an inherent characteristic of products, in this case the smart home.

Aging needs could not be fulfilled without performing some activities. Tools in the smart home were the means of doing so. These tools were categorized into functions using pile sorting. The relationship between aging need and smart home tools was

shown in figure 8.3. When an older adult encountered smart home tools, they would be able to use them to fulfill needs in various domains.

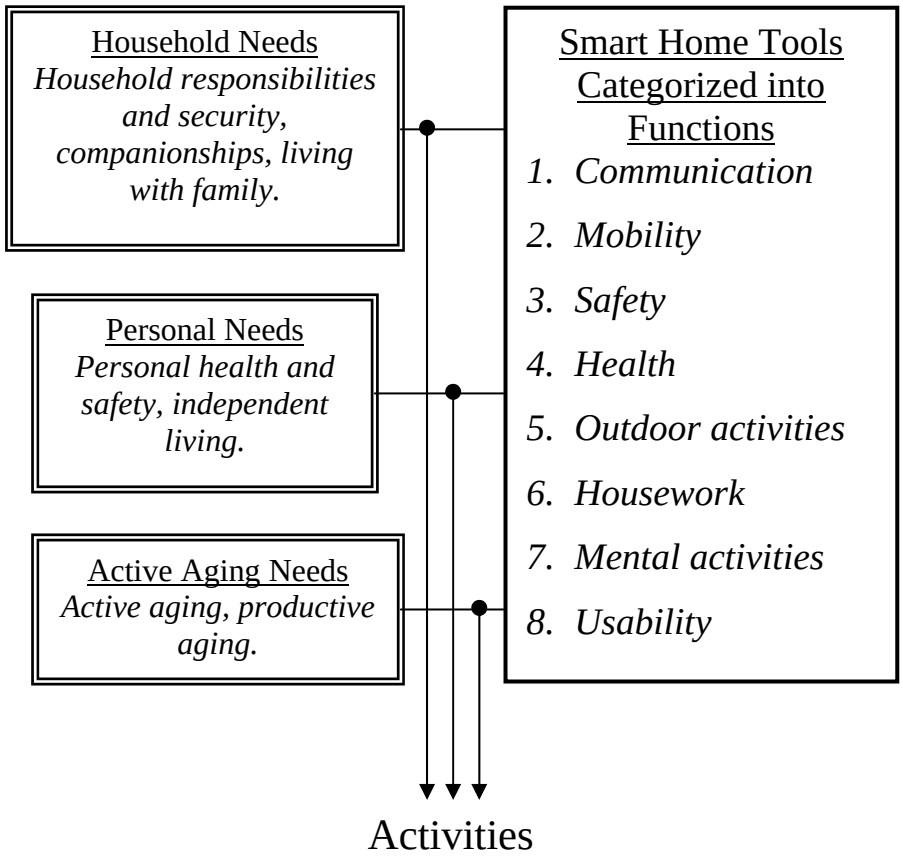

Figure 8.3 Relationship between aging needs and smart home tools

For now, activities inferred in figure 8.3 would be similar to Activities of Daily Living and Instrumental Activities of Daily Living. Many of the smart homes features discussed in chapter 5 would support seniors to carry out these activities.

ADL and IADL have great relevance to the present environment older adults live in. However, as homes in the future contain new devices, activities of older adults can change. For example, it is becoming more important to learn using the Internet. For now, many older adults can live without being connected. In the future, to what extend this can impact their life is still unforeseeable. Perhaps they will find their life

increasingly expensive since they need to do everything physically. They may also face the difficulties to vote or staying in touch with their children and the community. Smart homes can change the usefulness of the present IADL list. Communication may be more reliant on Internet than telephone, mode of transport may turn towards fuel efficient mass transit, online shopping may become more common, housework can be done with machines, and managing bank and investment may become more digitized. As such, it is important to consider the change of activities older adults would need to participate in order for smart homes to make their life easier. For example, if online shopping can make purchase easier and cheaper, consideration has to be made to expand or make changes to IADL.

8.1 Personal Needs of Older Adults

Personal needs of older adults evolved around health and safety. As discussed in chapter 2, aging for older adults was a process of deterioration of health, physical, and mental abilities. These pervasive problems were the main catalysts for development of personal needs. In fact, they seemed to represent the most critical needs of older adults in smart home.

Smart homes might be able to provide a better environment for the older adults. Many older adults' experienced a gradually hearing loss and thus the capability to engage in discussion. This resulted in many older adults being ignored (Welford, 1976). Tools for communication might therefore be important. Simple example was messaging device with a button press for alarm when help was needed. The distance of communication could range from the adjoining rooms to long distances.

Eight percent of older adults above 75 years of age suffered from dementia (Stuart-Hamilton, 1996). Early stages of the disease could lead to short term loss of memory. However, it was difficult to spot the disease as memory loss was treated as normal process of aging (Stuart-Hamilton, 1996). As a result, various forms of identification were good to carry around. This could contain medical records. In one of the stories written in one of our survey, a man tried to find his medical records before he was admitted into the hospital even though he had a serious asthma attack. Medical records could easily be misplaced and confusing to keep. Thus, a card like storage device would provide good organization.

Many older adults fear falling, a fact mentioned by several persons during the interviews. The fear was compounded by their experience of seeing someone else falling, which changed his life dramatically (Simouneau, and Leibowitz, 1996). Artifacts that reduced the risk of falling or help a person to recover from a fall could be useful. Older adults might be monitored with a multitude of sensors. Similarly, assistance could be provided in the form of home modifications, such as railings. Mobility aids such as canes and wheelchairs could also help, but there were stigmatizing and aesthetics problems related to these tools.

Other tools in this category included: improved lighting, intruders identification and home security, home monitoring, house cleaning, and tools to help reading books and articles.

8.2 Household Needs of the Older Adults

Older adults in Singapore appeared to have a strong sense of attachment to their family. This originated from the interdependence between parents and children in

Asian culture (Nisbett, 2003). One popular need was in sharing artifacts with family members. Some older adults commented that such products were good, since they represent collective living and caring. Older adults demanded less for themselves and hope for more for their family. In western culture, artifacts at home could be markers of personal space, and the space at home between older adults and their family becomes more distinct and divided as they grew older (O'Brien et al., 1999).

In our case, it would be ideal to consider building "family technology" or *transgenerational technology* for every family member. When one builds an apartment suitable for people with disabilities, it will often bring convenience to others as well. As a result, interdependency between family members could be enhanced (Nisbett, 2003).

Hospitalization could be lonely, and many families in Singapore took turns visiting their old parents in hospital. In one story, a man asked for a cell phone so that he could call anyone when he was bored and lonely in the hospital. Communication between older adults and caregivers could be enhanced by communication tools. A simple solution was teleconferencing. However, present technology might still be too complicated to understand. To make the technology popular, usability issues had to be solved.

It was observed during the interviews that older adults had some responsibility for security at home and locking all doors at night. Some older adults got up several times at night to ensure this! The great security concern might be unique to the local Singaporean culture (Dejean, 2003). Hence it was not surprising that there was much

concern about safety. Four of the ten highest rated features concerned safety. Despite the safe environment in Singapore, products to enhance safety still warrant attention. Artifacts might be needed to "keep an eye" on strangers approaching the house and identifying who they were. A less "smart" alternative was to merely allow users to look outside without opening doors and windows. Monitoring the interior of an apartment could also serve as a form of added security.

Home security was the combined effort of older adults and their family members. Keeping communication between these two parties was thus important. Cell phones could play a big role in this aspect. However, some older adults found it difficult to use cell phones, particularly when finding numbers and reading messages. It would be worthwhile to study the usability issues of modern communication devices and the older adults.

Other household needs included: monitoring of medications, monitoring of health in case of fainting, tools to help reading books and articles, mobility aids to move around the house, to maintain communication with other older adults for support, and sickness detection for syndromes of serious illnesses.

8.3 Active Aging Needs of the Older Adults

Active aging needs were not well represented in the top needs of most of the older adults, maybe because older adults have the means to participate in social activities; some of them came to participate in the surveys themselves. However, some respondents commented that they would not use a wheelchair to go out. This might explain for the low likings for stimuli representing mobility devices on page 11, 12 and 20: 3.78, 5.1, and 3.75 respectively, which were much below the mean of 5.04.

There was significant differences between these three items ($p = 0.02$). Item 12 received the highest responses in using mobility device to travel in the cities. The reason could be that many of these older adults were able to walk short but not long distances.

Mobility was one of the most important functions of smart homes. The most difficult activity for older adults was walking, bathing, and going outside (Kutty, 1999). A large number of older adults need walking aids after 79 years old (25%), and none was not affected at all (Simouneau and Leibowitz, 1996). In a survey, no older adults could walk faster than 1.4 m/s after that age, and that was the speed needed to cross the pedestrian crossing in Sweden (Simouneau and Leibowitz, 1996). Even such small matters as inability in crossing a road can have long term effects on the confidence of the older adults in becoming independent. Older adults who could go anywhere without help - visiting the hospital for a health check, buying things for cooking, visiting friends, families, and religious places, would be greatly empowered.

To accomplish this might take more than a piece of equipment. Some older adults might not be agile enough to drive, sensors might not be intelligent enough, and roads and pavements would need upgrading. There was a research need to help solve these problems.

Another problem was stigmatization of wheelchair and walking aids. Despite the need, many older adults did not use walking aids. But walking aids need not look stigmatizing. Wheelchairs did not need two big wheels. They could have four small wheels and luxurious seats defining class and comfort. Otherwise, instead of sitting,

users could stand on the mobility devices too. Once stigma was removed, these might be acceptable by younger adults as well. However, it would take studies to understand the effects of changing semantics and removing stigmatization.

8.4 Usability Issues of Smart Homes

Smart home design could be based on needs of older adults. Also, the knowledge of needs must be complemented with good usability. Usability did not cater solely to physical and cognitive deficiencies. It should also cover motivational factors in using technology. If an older adult was unwilling to learn about a new piece of equipment, any discussion about physical and mental capabilities would be fruitless. Welford (1976) pointed out the importance of recognizing motivational factors of older adults. If the benefits of a new piece of equipment were unclear, an older person would not to use it.

Technology commonly adopted by older adults seemed to be limited to straightforward devices such television, and radio. These devices had minimal complexity. A television needed only one button press to be activated. A radio might only need a power control. The addition of a tuning control adds another level of complexity (Jenson, 2003), and might well represent the limits of the older adults' working memory. Reduction of working memory of older adults was well documented (Smith, 1996) and could fall from 7±2 chunks to 5±2 chunks.

Perhaps this could explain the limited use of technology gadgets. Nonetheless, the message was that older adults require simpler devices. They could not see the benefits of technology clearly, and the cost-benefit of learning might not be in their favor. It

seemed ironical that advancement in technology almost always meant complex gadgets. But this made them useless to older adults. Technologies had to adapt. The one-button strategy advocated by Norman (1986) was important – particularly for the older adults.

Among the usability issues mentioned above, older adults required sales person to teach them patiently. They did not identify usability issues. This could be inherent in their belief that mistakes were the users' fault. Simple products would make learning easier.

8.5 Conclusion

Good smart home development requires proper planning, design and development. Arguments in this study were not fully conclusive, but provided directions for future research.

Common needs of older adults include: spirituality, productive aging, anti-aging, nurturance seeking, dependency avoidance, and biological. These could be the desire of older adults even though it was hard to support. These needs lied deep in the subjects' consciousness and they would not necessarily identify with them (Leont'ye, 1978). Nonetheless, the needs were well supported by the literature and there was no reason to refute them. Needs provided the motivation behind users' goal seeking behavior. Thus, understanding needs was invaluable for design.

The study showed that needs in communication and mobility functions were very fundamental. Communication and mobility functions might provide methods to

satisfy many other needs such as security and health. As such, in designing a medical product, its designer should consider how users might adjust their daily activities to fit in the device. If buying a mobility aid can satisfy both safety and health, there will be no need to install both security alarm and health management devices. In exploring these issues, we need to understand the types of communication older adults engage with their family, relatives, friends, and society. How will these activities change with aging and how can technology help them? In mobility, we will need to know where older adults travel to and for what purpose. Additionally, we need to understand what problems they face with aging and how infrastructure and products can help them to improve their life. There is huge potential for research in these areas.

Products for the smart homes could be classified into three categories: personal health and safety, household responsibilities and security, and active aging. Through cluster and factor analyses, these areas were shown to be independent of each other. As a result of this study, we may suggest that many products can be developed. These include: intruder alert system, lock security system, help calling devices, camera for monitoring outdoors strangers, communication devices for hospital stay, and fall detection system. In addition, usability must be improved for existing products. There will also be challenges in transgenerational design; a concept with good market potential. Several other concepts are summarized in Appendix G.

Successful smart home developments require a good business sense. While this research looks to benefit older adults, it requires good economics for smart homes to become a reality. While we try to create a needs structure for general older adults, it is important to recognize that older adults have diverse needs. Some older adults will be

more likely to take up smart homes than the others. According to research in home modification, the likelihood of home modifications increase for older adults who are staying alone, who are above 80 years of age, use walking aids, need of personal care, have experienced a fall, have severe heart problems or stroke, have “fair health” (as opposed to “good health”), unemployed, live longer than ten years in the same home, live in an apartment, or live in rented housing (Kutty, 1999). Such research will help to identify the early adopters of smart homes and improve the likelihood of smart homes in becoming a successful innovation.

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Appendix A - Seven Functions of Smart Homes

Health Function

Health function serves an array of needs related to the importance of health. Many older adults were aware of their deteriorating body and actively try to maintain their health. They tried to stroll frequently while they were still healthy, keep the air fresh, and massage their body for better blood circulation and vibrancy. It was interesting to note that many older adults believed that massaging was a replacement for exercises. These steps were taken to slow down or prevent the eminent weakening of their body. Beside the physical body, older adults were also aware of the dangers of dementia. Many of them attempted to keep up with their mental activities through learning and remembering things.

Despite these preventive measures, older adults were realistic about possibilities of sudden illnesses. Many of them seek confidence that in the event that they met with heart attack, giddiness, or fall, help was imminent. For emergency, help could come in many ways, such as family, police, volunteers, hospital, neighbors, doctors, or even passers-by. They would also like to keep in touch with family or doctors. Now and then, information regarding one's health was also sought after. Older adults seemed to accept remote monitoring of their health so as to know if they were contacting diseases such as heart attack and diabetes. They might also make use of such service for chatting with friends about their health and to find out more information on health issues. Nonetheless, many believed that only common illnesses could be solved remotely and visiting a doctor was still essential for other illnesses.

It might also be possible that the older adults were already sick and needed help to cope with it. One prominent result of illnesses was boredom. The mobility of a sick person is restricted and as such loneliness crept in. An older adult might need someone to talk to or something to play with. An older adult who was sick was also likely to be weak. They appeared to be open to concepts such as adjustable beds and chairs so as to facilitate getting in or out. Older adults also develop a preference for "good quality beds" if they developed insomnia.

Another common use is stress relief of aching body. They often seek relief by body or foot massage. Older working adults were also positive about such aids.

Communication Function

Communication functions cover a wide array of needs. Older adults make use of it for emergency and keeping in touch with others. Issues of communication include: phone management, fear of missing call, social contact, and contacting caregivers in mishaps. There is a chance that communication functions actually over write other functions in terms of needs coverage.

Older adults suffered from several physical deficiencies such as loss of hearing, and walking speed. These problems lead to problem in handling phone calls. When the telephone rings, many older adults find it difficult to react quickly. One has to get up from the chair with weak arms and legs, and walk towards the ringing phone. Sometimes, older adults could not act quick enough to perform these. One coupled issue is that of afraid of falling down. Examples of friends and relatives who fell and health had never recovered since act as warning to older adults. They do not want to

walk too fast with their ailing body just in case of mishaps. This may be solved by products that older adults can bring with them – such as the mobile phone. Telephone that moves to find its user may also be ideal, since people may not want to carry a mobile phone at home. Another problem of phone handling is that older adults may not hear it ringing. Older adults may need to be told of ringing phone to take note of it.

Another purpose of communication is to keep in touch with other people. It is normal for everyone to need to talk to someone else. For older adults, it tends to evolve around friends, children, parents, and siblings. They also make use of communication to understand how their grandchildren are doing. Many grandparents pay attention to the development of their grandchildren, in case of "mischief." They perform this duty when their children were away or busy. They may wish to know how they are doing at home or in school. It may not always be trivial matters that require communication aids. It may also be possible that older adults have urgent matters to tell friends or relatives. Many older adults take up the responsibility of taking care of the house. As such, they would wish to keep in touch with the house to know that no intruder has entered. Older adults can also be afraid of living alone. It is due to the perception that it is dangerous and they can be robbed if there is any "bad person" lurking nearby.

Many mishaps can happen to older adults and these require contacting caregivers for help. Mishaps include: burglary, robbery, fall, heart attack, giddiness, immobility due to diabetes, asthma, accident. There is a range of parties that older adults would call if any of these happen: hospital, doctors, police, children, neighbor, passer-by, relatives, volunteers, and family members. In case of medical emergencies, medical aids at

home may sometimes be necessary. This may be given by direct contact with doctors through technology. This, while waiting for aids, can reassure to the victim. Another problem, robbery, can happen anywhere to the older adult. It was often reported to happen in lifts and many older adults are afraid of it. As such communicators need to be mobile as well. In fact, some residences of older use puller cords as emergency help calling device. The problem is that they are situated at corners of the house which can be feet away from the older adults. They hung from the ceiling so one might not reach it if one is lying on the floor. Lastly, they cannot be brought outdoor. Intrusion into houses may not be handled by older adults themselves, some of them expressed fear of confronting the burglar. Rather, machines can contact the police or neighbors if possible and they would feel safer this way.

Safety Function

Safety is often mentioned by the older adults. Older adults tend to take a lot of precaution for maintaining safety, at least in Singapore.

Older adults tend to control access to one by limiting contact with strangers. With proper introduction, one will find the older adults friendly and trusting. It may be a product of collective Asian value that strangers are treated with suspect. The term stranger is much associated with sales people who were treated as nuisance and cunning. As a result, older adults are often weary of who is coming to the house. They would avoid opening the door or open it to too much in case people would force their way in. This is even when a metal grill stands in the way. They would also like to know when strangers are lingering outside the house. Technology to enable older adults to know these while safely indoor may be good. Strangers are often treated as

threats to burglary and more so when older adults are sleeping or outdoor. They would like to know if the house is in order now and then. Some older adults suggested video taping strangers in case of crime.

Safety also extends out to family members, such as the children and housing conditions. They would like to know if the children slept well or is doing “mischief,” if the maid is stealing food, or the kitchen catches fire. When scenarios of burglary or fire happen, older adults would like to notify the police quickly, with some indicating that one button press is all they think should be sufficient. It the case of burglary, they have reservations in confronting the burglar. They would like the alarm to be automated or “secret,” so that they would not be harmed.

Outdoor Activity Function

Outdoor activities of older adults are often simple and recurrent. These include: to buy food, to go for a stroll, to buy electronic products and furniture, to buy household items, and shopping for clothes. In purchase, they tend to frequent the market and shopping malls. Sometimes, older adults may need help with these activities when they are busy, developed headache, or suffer from pains after surgery. Help may come from technology that allows one to buy food and household supplies from home. Another aspect of outdoor activities is the fear of memory loss when outside. This is related to early stages of Alzheimer’s disease. Identification tags that may help the older adults to come home are suggested.

Many older adults take strolling as a habit. They like to do it at parks, mountains, seaside, or just around the neighborhood. Other than strolling, other activities include visiting a friend for a chat, to visit the hospital, watching a movie, and going for tea.

Housework Function

Housework is an important function to the older adults. This may be due to the residual habits of the older adults in taking care of their children. They had interest in the cleanliness of the house, and how a maid is performing in doing housework. Some complained that having robot is better than maid since robot would not take grudges when scolded. Problems of continuing doing housework at old age lie in physical weaknesses. Older adults may not dare to climb to reach high places. This is associated with the fear of falling. But it is hard to prevent as many objects are better off located in high places to save space. Furniture may be redesigned so that high objects may be lowered when necessary. Another problem is that older people may not be able to carry groceries one used to carry when young. One of the most frequently mentioned object is rice.

Taking care of the house include many complicated procedure that one may tend to forget some of them. Reminders are often associated with housework perhaps because forgetfulness results in untrustworthiness and is considered bad. Things to be reminded include: to cook meal for children, to bring grandchildren to and back from school, appointments, medical checkups, shutting of flames for cooking, to wake up on time, and to eat medicine. However, many are also concern with “losing mental abilities” if one do not try to remember things.

Mobility Function

Mobility function has some overlap with outdoor activity functions. The difference could lie in the different levels of abstraction. Mobility is an important mean for outdoor activity. It supports activities such as purchase, visitations, finding food, strolling and exercises, hospital visits, and moving around the house.

Mobility is required to move a variety of distances. Many of older adults' activities happen around the neighborhood. It is not known if physical weaknesses or habit is the main reason. However, mobility needs may range from neighborhood to houses of friends, shopping malls, and hospital. These may require different kinds of mobility aids. Presently, many mobility aids require carrying stigmatizing objects such as canes and wheelchair. Many older adults, especially those in the early stages of walking difficulties, rather move slowly then to use them. Additionally, the use of wheelchair often requires assistance to push it around and on and off transports. It is observed that when a wheelchair is in use, the older adult is not in control of where and when one is going. This lost of control may result in poor outdoor experiences, leading in unpleasant shopping experiences. One feedback from some older adults is that they do not like maids to push them around. This may be attributed to treating maids as strangers to the house.

Older adults are also wary of going out alone at night. They may attempt to seek company when they need to leave the house late. However, it is common to find them out after meals. Outdoor movement is synonymous to healthy way of life. The air is also considered fresher than indoor. It could be possible that moving outdoor, even on a wheelchair, is considered healthy.

At home, mobility is required to perform housework properly. For example, objects may be located too high for older adults to climb safely. They may need to buy groceries which are too heavy for them to carry. They may need to answer a phone that is ringing from far away. And they may find it difficult to get off bed and chairs once seated or lied down.

Mental Activity Function

Mental activities are activities that rely more on mental abilities rather than physical abilities. These are: learning skills and electronics products, remembering things, watching news and television programs, web surfing, and collecting medical information. Even some seemingly physical abilities may have the intention of maintaining mental awareness as the real motive. These may be: going for meal, visiting others, shopping, and strolling.

The importance of mental activities may come from the fear of being mentally inept. Catching on Alzheimer's disease is a fear of many older adults. A common belief is that once a person stop using one's mind, it will become useless. It is thus important that a person keep engaged in some form of mental work. This may take any form of activities that interest the older adults.

Some older adults are concerned about their health. They may like to know that latest development in cure and prevention. Others may spend time in shopping, strolling, or visiting friends and relatives. To keep on learning is also important to some older adults. They would like to learn new skills and computer if possible. However, it is not known why they did not take the first step to learn about using computer. One subject mentioned of inconvenience that no courses are available near her house. It is

difficult to know since older adults do travel further for shopping and visitations. Another common activity that older adults feel would benefit the mind is to remember things. They feel that remembering things help to keep the mind healthy.

The following list contained all the items collected from the question – "How is this product useful to the man?" They were subsequently used for pile sorting by two human factors experts.

'Count' showed the number of times a particular usage appeared in all the subjects. Blue and green colored text highlighted the region where data were extracted from different subjects. So serial numbers 1 to 8 were extracted from subject one. Serial numbers 9 to 16 were extracted from subject two and so forth.

S/N	Count	Item
1	6	To buy food (including Malay, western, chinese) (from Shopping Malls, market)
2	2	To make air fresh at home (to be healthier)
3	2	To ensure a pleasant smell at home (by filtering) (to prevent foul smells)
4		To use chair as stairs to reach out to high things
5	2	To do without a maid (in bathing, housework, fetch drinks)
6	2	To save people (who falls down) (on good heart)
7	2	When one have no strength, to answer calls without going to the phone (on wheelchair)
8	2	To play and be happy (with a partner)
9		To see people outside the house and judge if they can be accepted before letting them into the house
10		To tape down people (and strangers) outside (or entering) the house as evidence in case of crime
11	4	To be inform of things to do in advance
12		To clean the house
13		To save the trouble of employing a maid
14	3	To be brought to the market (for a walk, stroll and buy things)
15		To answer the phone even when not hearing the phone ringing

16		To have a guide that brings one to friends' house
17		To look at what others are doing to learn from what they are doing well
18	4	To take a walk (as much as possible while one is healthy)
19		To identify the salesperson so as not to be cheated
20	2	To buy electronic appliances
21		To lie down on massage chair after work
22	2	To prevent burgulary
23	2	To be protected from nuisance people
24		To wake up in the morning in time
25	3	To save time and find convenience (in buying things)
26	2	To talk to children, parents, and siblings overseas
27		To buy funiture
28		To buy household items
29		To reduce fatigue
30		To improve blood circulation
31	2	To feel healthy and vibrant by having good air at home (by removing bad air)
32	2	To keep the air at home clean to prevent dust
33		To inform someone else such as the police when the door is opened for a stranger without looking
34	3	To know earlier when sick and seek treatment (under diabetes, heart attack)
35		To solve common illnesses without the doctor
36	3	To adjust the chair for comfort (downward when tired or painful) (higher when less painful) (when watching television program)
37		To adjust the bed's height for a sick person to get on and off bed easier
38		To reach clothes at the top of the cardboard
39	2	To seek help when sick, cannot walk and feel dizzy (from children)
40		To find out if the house has any problem when not at home
41	2	To see what the maid is doing at home (in stealing food or napping)
42		To be reminded of going to work
43	3	To be reminded of time to eat medicine
44	2	To be reminded of time to bring children to and back from school
45		To go out.
46		To relieve stress after work
47	2	To show off to others (in wealth)
48	2	To help with air flow when one has to close the windows to ward off dust because health is no good (to have pure air) (with cough and eye problem)

49	2	To know who is coming into the house
50		To share the same furniture with younger people
51		To call for help when met with snatch thief in the lift
52		To knows one should shut off flame when time needed to cook a soup is up
53		To know that working people are coming home and it is time to clear up and take out dishes
54		A device that is better than maid in a way that it would not take grudges when being scolded
55	3	To look for someone to talk to (friends)
56		To go out in pairs at night
57	2	To lie down and exercise (with massage) (for lacking exercise)
58		To sleep well
59		To prevent getting a cold
60		To adjust bed to get up and lie down
61		To keep in touch with the house when not at home to be alerted of intruder
62		To give off alarm so that neighbours would know if there is intruder
63		To seek medical aid at home when met with heart attack or giddiness and cannot go out.
64	4	To test own health when not feeling well (to find out general condition)
65		To know when the kitchen caught fire
66	2	To keep an eye on small children to know when they are up to some mischief
67		To try to remember things or else the brain is not useful
68		To go shopping
69		Not to have anyone pushing while in a wheelchair and live independently
70		To run errands
71		Not to rush for the phone
72		To avoid sleeping in the day by dozing off television so as to sleep better at night
73		Not to be afraid of living alone
74		To feel confident when not feeling well
75		To transmit program at community centre, where friends are there participating, to home and join in
76		To look at what grandchildren are doing in school and talk to them
77		To transmit television program
78		To surf the internet
79		To buy daily items from home (for daily or weekly delivery) (for fresh or

		dry food)
80		To but things from home after operation and cannot move well
81		To be told of information, such as illnesses, its cure and latest development
82		To be told of current affairs
83		To print out emails because it is painful to look at the screen
84		To see if there is a dangerous person at night
85		To take out clothes from cardboard without climbing ladder as bones break easily
86		To keep name, address, and other records in case one forgot who they are and where they live when out
87	2	To be reminded of cookin meals (for children)
88		To travel short distances without having maid to push the wheelchair especially for diabetic and stroke patients
89		To move in the outdoors such as garden and longer distances
90	9	To contact someone when fall down (police, children, neighbour, passer-by, relatives, volunteers, hospital, and people from the others rooms of the same house)
91	2	To contact friends, nearby or overseas, to know what they are doing (also relatives)
92		To get help in buying things when having backaches
93		To call for people when needed help
94		To chat about the health of friends by sending letter that reaches and return faster
95		To look at news
96		If an unknown person enters the house, and the phone is far away, a device is needed to activate an alarm and inform the police automatically
97		Does not have to come out of the house to see a doctor
98	2	To contact a doctor when one, suddenly, cannot walk
99		To fetch high things while feeling painful
100		To known that the person at the door is a salesperson and ignore him or her
101		When sick and cannot move, be be brought food and brewed some tonics
102		To move to his friend's place to chat
103		To buy things from shopping malls
104		To pass time and not to think about one's illnesses when one is bored
105		To look at mountain, seaside, or park

106		To look at somewhere where the monisters are having forum
107		To buy things without going down stairs
108		To improve blood circulation to improve vibrancy
109		To release tension
110		To communicate without having to mail letters
111		To ensure airflow when the room is stuffy
112		To inform the police secretly when stranger come into the house
113		To communicate with the doctor
114		To stay at home alone
115		To be informed of what to do and does not have to put everything in the brain
116		To be helped in finding direction in finding food to eat
117		To be helped in finding direction in going to park or seaside
118		For a person who is well, to move about himself
119		To go to the seaside
120		To go to the MRT
121		The phone to come to him when the telephone rings, as if someone is thinking of him
122		To seek fun when bored
123		To learn until old age
124		To maintain health when one is healthy
125	3	To seek help from family members when sicked on the street (from police, people at home, doctor) (with backaches) (when shopping, watching movie)
126		To see who is coming to the house
127		To use methods to pretend as if someone is at home when not
128		To go for a stroll, breath in fresh air, and exercise around the neighbourhood
129		To go to market downstairs to buy things
130		To have an object to mentally "hang on" to
131		To communicate with others and send letters to them when unable to move well
132		To contact hospital, and doctors in emergency
133		To be helped with rice and other heavy things one cannot carry
134		To have letters delivered conveniently and quickly without waiting for postman
135		To be informed when strangers approach the house so as to be alerted
136		To inform the police by a button in case of burglary, theft, or fire
137		To communicate with doctor from home when one cannot move conveniently
138		To get things at high places without climbing
139		To call for help, from family members, friends, or special persons,

		when having heart attack, rob, or accident
140		To have individual's privacy
141		To go to park
142		To buy things at provision shop
143		To go for a meal
144		To get a phone which is too far away
145		To have a pet while lonely, but not having to take care off it
146	2	To contact others when falls down while living alone
147		To avoid staying in old folk homes, rather to stay alone
148		To see friends or relatives for something urgent
149		To understand the electronic gadgets
150	4	To relief pain (in shoulder, back, headache)
151		To massage foot
152		To attend classes to learn to use a computer
153		To send important messages to relative or some very good friend
154		To prevent house from being affected by pollution as one is afraid of diseases
155		To avoid opening the door at night
156		To know what is happening to oneself without going and waiting at clinics
157		To sit up or lie down in bed
158		To be reminded to off the fire for cooking
159		To be reminded of appointments
160		To keep the mind active else it will become useless
161		To move around in wheelchair at home
162		To move around in the neighbourhood
163		To reach the phone before the other party has put down
164		To avoid paying for maids
165	2	To purify the air (and improve airflow) when air-con is on all the time
166		To prevent burglary when there is no people at home
167		To check on illnesses as one is taking medication
168		To be called by doctor for check up
169		To put do down the bed to relax
170		To inform neighbours in case of illnesses such as asthma
171		To look and see if children are sleeping well
172		To relief from loneliness when no one is talking to him
173		To be helped in buying heavy things, such as food
174		To go to other people's house
175		To use dog at night to bark at people
176		To go to the hospital
177		To phone for help in emergency and something important
178		To play with one and comfort him or her
179		To be told that the phone is ringing

180		To relief loneliness
181		To buy clothes from shopping malls
182		To buy household products from shopping malls
183		To learn things from television
184		Not to let strangers into the house
185		To take care of oneself when having high blood pressure, diabetes, or stroke
186	2	To contact friends or siblings in emergency (when not feeling well or in trouble)
187		To prevent forgetting about things to do and to cook when children are coming home to eat
188		To go for tea
189		To go and watch a movie
190		To be informed of strangers at the door
191		To be informed of anyone ringing the bell
192		To look after one, as if someone is at home, in case he or she falls down

Appendix B - Usability Issues of Smart Home Features

Air-purifier

Air-purifiers were welcomed by many older adults. This might be due to their association with healthy and cleanliness. The most prominent problem regarding air-purifier was maintenance. Many were concerned about how to get it repaired. One person commented that he might forget where replacement parts might be stored. Another hoped that it would require very little maintenance since caregivers were often not around to help him.

Tele-shopping device

Four of the older adults had not received formal education. It was likely that more were unable to use devices needing to look at words especially English. Conversing with someone at the shop they wished to buy from was acceptable. One prominent disadvantage of tele-shopping was the risk associated with usage. Many were concerned about not being able to choose and feel the product being bought. One suggestion was that only common household products such as grocery were likely to be bought. This seemed to rule out personal products where the image could be a major concern. Others were concerned that "wrong press" of buttons could result in "something bad." Besides risk of usage, older adults also perceived risk that the sales person delivering the goods could be a "bad person." Some suggested that it would be fine as long as they knew who was delivering the goods.

	Device	**Usability Issues**
1	Remote rooms/ Cyber Tunnel S6	P4 Easy to use S12

		Fear of using due to lack of knowledge S16 Used by the son
2	Remote shopping	P4 To use without being literate S1 Use conversation to communicate To contact the right shops S6 Dislike talking to T.V. Prefer to choose and purchase on site to judge affordability Fear of wrong button press resulting in something bad Old people are slow at learning S7 Daily or weekly delivery Phobia of computer S9 Salesperson has to be familiar S10 Can't see the goods S11 Wrong orders may not be reversible S13 Old people are not familiar with device S15 Unable to choose and feel
3	Massage chair	P4 Fear of using as subject has artificial knee cap S6 Paying by installment S9 Lie down for 15-30mins S13 Unsure of how to get repair Children to buy for parents
4	Customized computer	S7 Connect to telephone and talk to friends simultaneously S12 Need to attend class to learn using this S14 Can't see well enough to use computer
5	Air purifier/ freshener S1, S6	P4 Require few maintenance S11 Some caregivers only help once a week S12 May have to replace something and forget where it is placed S13 Not to pump in cold air like air-con S14 Off at night S15 Unsure of how to get repair
6	Security system S2	P5 System should be always operating Third party to solve the crime S1 Should operate automatically No need to press any button

		S2 To alert someone or the police S4 For people at home or not S5 To alert the police S6 To be informed when theft occurs To notify neighbors S7 To control if alarm should set off Real persons to monitor the system S8 To inform the police S9 Require a secret button to inform the police S11 Need a button to press
7	Telemedicine system S4(smart toilet)	P4 Need son to help S1 To print medical slips in Chinese S4 No replacement of toilet bowl S11 Doctor need to send a vehicle to fetch him Doctor call on patient to perform check up
8	Adjustable furniture	S4 Shelf for storing light things such as clothes and documents Shelf not for heavy things such as glass, ceramic, and vase Shelf may be dangerous Young people has longer legs (chairs) S7 Shelf for storing clothes S8 Shelf for storing towers, clothes, and blankets S9 Shelf for clothes, pillow, and blanket S10 Shelf for clothes and shoes S11 Shelf to for clothes S14 Need help to configure devices
9	Portable help calling device S1	P5 To be reliable, no false alarm S1 Contact children No need for the other party to carry one S2 Person will not carry it around S6 To inform home people or doctor S8 Contact family S9 Person may not wear it at home S10 People on street would not lend a hand To seek family members

		Keep buzzing until some passerby help S11 To contact police, family, and friends S13 To inform neighbors S16 Contact by phone through friends or siblings
10	Multimedia environmental support system	S4 Should be in living room (young people) S9 Can be installed in the bedroom
11	Event alarm	P4 Need to remember to use device S1 To record own voice S2 Device has to “talk” S6 To try to remember things without aids S12 May forget what to press S14 Maid to use it S16 Children leave a message saying they are coming home to eat
12	F & B robot	P4 Make use of numbers to control S4 Family servant S9 Mother cook and left food for son to heat and eat when he returns S14 Need help to configure
13	Smart wheel chair S7	P5 Require smart pet to guide S7 To take over control when required May be used without battery May be pushed by someone May be used as wheelchair S9 May suffer from sunshine, wind, and rain while traveling S10 Neighborhood and home use S11 People in neighborhood will help him S12 Used indoors S15 Mobility in areas where legs can go S16 Used downstairs
14	Smart carrier P4, S6, S9, S10	S4 Require to ensure that carrier not stuck outdoors due to no power S6 To move through doorways (home) S7 Require to move into clinic To be able to read newspaper Require to overcome problem of battery drain (may get others to push

		or do it himself) S9 Can be carried around Can be brought into a house S10 For outdoors S11 Seat too small Use in neighborhood S12 For nearby (outdoors) Needs rams
15	Movable phone S6, S9	S1 Older people don't use phone often S9 Acceptable behavior when no one is at home S11 Used in hospital and public places
16	Smart pet	S9 Can be switched off
17	Fall detection vision system S8	P4 Fully automated device P5 Require automated system To inform the police S1 Require to contact children Person to be contacted require no additional devices S2 Inform relatives S7 To connect to his children's computer S8 To alert neighbors S9 Contact hospital, neighbors, and volunteers S10 Inform neighbors Give off sound S14 Anyone who sees should help on good heart
18	Others	S13 Expenses should be supported by children

Appendix C - Projected Needs of Smart Home Features

Air-purifier

One person claimed that he liked air-purifier as he was “too lazy to clean the house.” The device as seen as “not too expensive,” just like air-conditioner, but “healthier.” Just like purified water, it would also give a person “big advantages” in terms of health improvement. For some, the person in the picture was seen to have eye disease or persistent coughing or he might be sensitive to dust.

Another perception was that the person was sick and not able to clean the house. Some users thought that the caregiver was not always around. The air purifier would then keep the house free from dust.

Generally, the impression was that an air-purifier is inexpensive and useful for health maintenance.

Tele-shopping device

Some older adults believed that the person using it was “literate” and had “knowledge of computer.” Otherwise, he was “old, aching, and walked on cane, and there was no one to help him.” Alternatively, he could also be sick and “could not walk.” Many older adults believed that the items that were to be delivered would be “costly” and might deter purchases.

Some older adults also saw the figure as a "younger person," possibility with "two children." This could also be a big family. The purchases were likely to be made from shopping malls.

Generally, older adults associated the device with younger adults or big family. The latter could be the results of perceiving that help was needed if an older person was to use it. Designers might also have to think about dealing with the perception of costly items.

	Device	**Projected Needs**
1	Remote rooms/ Cyber Tunnel S6	P4 Person must be able to press number Can be used to steal owner's things Person is literate S1 Person is working Deprive a person of a walk S4 Costly (not for family) For people owning business For faxing S6 Costly S7 Person is educated S8 Person doesn't go out often Person couldn't take airplane S10 Like telephone Person is single S11 Person is partially mobile Person is a businessman Product is faster than fax S13 For young people in courtship S15 Make people useless Too advance Scientists have nothing to do. S16 Person is working
2	Remote shopping	P4 Person is literate P5 Salespersons are scrupulous

		Salesperson can use for cheating Costly S2 Items are costly Like Internet S4 For working people Items are costly For busy people S5 Costly S6 Old people couldn't handle it Wrong button press resulting in something bad Old people are slow at learning S7 Person has knowledge of computer Items are costly Good for people who can't move (young or old) S9 Especially for old people Person have knowledge of computer S11 Person not able to move conveniently Person is 60+ Person uses cane House has no one who can help him S12 Person understands the device Person may have aches S13 Old people are not familiar with device For big family Person is young or middle age with 2 children Old people has no use of it S15 For young people Makes people useless S16 For buying from shopping malls
3	Massage chair	S1 Enjoyable device S2 Person cannot move easily Person is sicked S4 For working people Electricity is costly Need not be rich to buy For stressful people S5 Person is working S6 Costly Person is working S7 Person is not able to move well and is suffering from pain S8 Person is 50-60 years old Person has retired

		S9 Person is middle age to old age Person feels tiredness S10 For people with sickness The person is lazy or has disabilities Else he is busy and tired S11 Person is old Person lacks exercise Person stays alone and can't move conveniently S15 Against nature (God) S16 Costly Person has backaches Person above 40.
4	Customized computer	P4 Person is rich Old people are very simple and has no use for it For young people S1 Person is doing big business S2 Like fax machine Don't know about computer S4 Like fax machine Person know how to use device Person is University student or businessman Person is knowledgeable S6 For young people only Old people don't use this Old people has not knowledge of this S7 Person is educated and is able to afford it S9 Person is educated Person is technologically savvy S10 Person is smart S11 Person may be businessman Person is working from home S13 For young people Costly Not for old people S14 Person knows how to use computer and have used it before S15 Costly S16 Person learnt using computer before Person is working
5	Air purifier/ freshener S1, S6	P4 Old people are lazy to clean the house Old people will buy this S1

		Seems not too expensive "Pump out" foul air Like air-con Big advantage S2 Health is most important S4 This is healthier than air-con S5 Difficult to use S6 Like air-con S7 Person must have some standard of life Person knows that pure air is good Singapore's air quality is still good For people with coughing or eye problem S8 Natural air is better than this S9 Airflow if most important (to health) The room is stuffy Like purified water S10 Person is smart S11 The house is small Person is not able to move conveniently Person is staying at home all the time Person can't clean the house His caregiver is not there all the time S12 Singapore's air is polluted S13 Like air-con For both young and old S14 Some kind of air-con S15 Unnatural air No knowledge of how to use it
6	Security system S2	S2 Extremely useful S4 Costly (electricity) For big houses like bungalow For businesses S7 There may be false alarm S9 May result in misunderstanding S11 Costly Person must be influential to connect to the police S13 Police may not be able to cope Police may come for nothing There may be false alarm For people who boost about their wealth or leave valuables at home

		S14 Person may not know how to use it S16 People who get rob are ignorant to let strangers in
7	Telemedicine system S4(smart toilet)	P4 Old people can't use this independently P5 Device can't cure illnesses, only doctor can S1 Doctor will find it convenient Only for common illnesses For old people S1 For common problems only S4 Costly Convenient for doctor S6 Costly S7 Best for diabetic and heart attack patients S9 Person may be young or old S10 Person is sick Person can be 18-30 or above S11 Person cannot move conveniently Device is not as good as a doctor Person cannot afford a maid Person has serious illnesses Normal people can go to clinic S12 For long term illnesses Good for people who cannot control diet S13 Doctor may not be able to cope with so many appointments For old people For sick people S15 Device may commit mistakes in treatment (not as good as real doctor) S16 Person has diabetes, high blood pressure, or stroke
8	Adjustable furniture	P4 Costly S6 Like hospital bed S7 Costly S11 Person has disabilities S12 If one need it, one have to buy regardless of cost Costly S13 Like beds in hospital Comfortable S15 Person is lazy

		Costly
9	Portable help calling device S1	S1 For old people S2 Better than puller cord S4 For sick people S7 For people with early stages of memory loss S9 Helpers cannot find user when user call for help outdoor Person has to be home Person is staying home For old people S10 Person's brain is good S11 Person has disabilities S13 Not for young people Middle aged may use it Asthma patients may use it S15 Person is ill S16 Used only in hospital and old folks home
10	Multimedia environmental support system	P4 Scary Can see through walls Can be used to commit crime P5 Can be used to do good or commit crime S1 For big houses (four/five rooms) S4 For people who like to cook For young people S6 Person can be a mother, father, or grandfather S7 Looks like the system in the bank For private homes Person is educated S9 Person is from large family Home is a condominium, private housing, or 5 room flat For people who are better off For people living alone S11 Lack privacy S13 For 5 or 6 rooms flat For wealthy people S14 Person must know how to use S15 To make people useless S16 The mother has no time to look after children playing

		Family has no maid
11	Event alarm	P4 Person has bad memory P5 Person is free S1 Person may or may not be working S4 For people with dementia Young people uses this is pathetic S6 Being forgetful is not good May render brain useless S7 For old people For family with children, adults, and old people Children can also use S9 Not for lazy people For hardworking people For part time students and professional S10 Person is smart Person may be busy Good for people with bad memory S11 Person is running schedule, like working S12 Person is forgetful May render the mind inactive and useless S13 Person has family Person can afford it Person is educated S16 Person has poor memory Person stays alone
12	F & B robot	P4 Person knows how to press number Person can’t move P5 Maids give problems S2 Person is not able to move or cook Healthy people will get their own food S4 For children who are lazy For people who are busy S7 For people without maids For people with disabilities S9 Too advanced Person is too busy or attentive to cook S10 Cannot wash clothes S11 Food must be prepared Person must have a lot of needs (too much) Person may be working, can’t cook, and prepared meals in

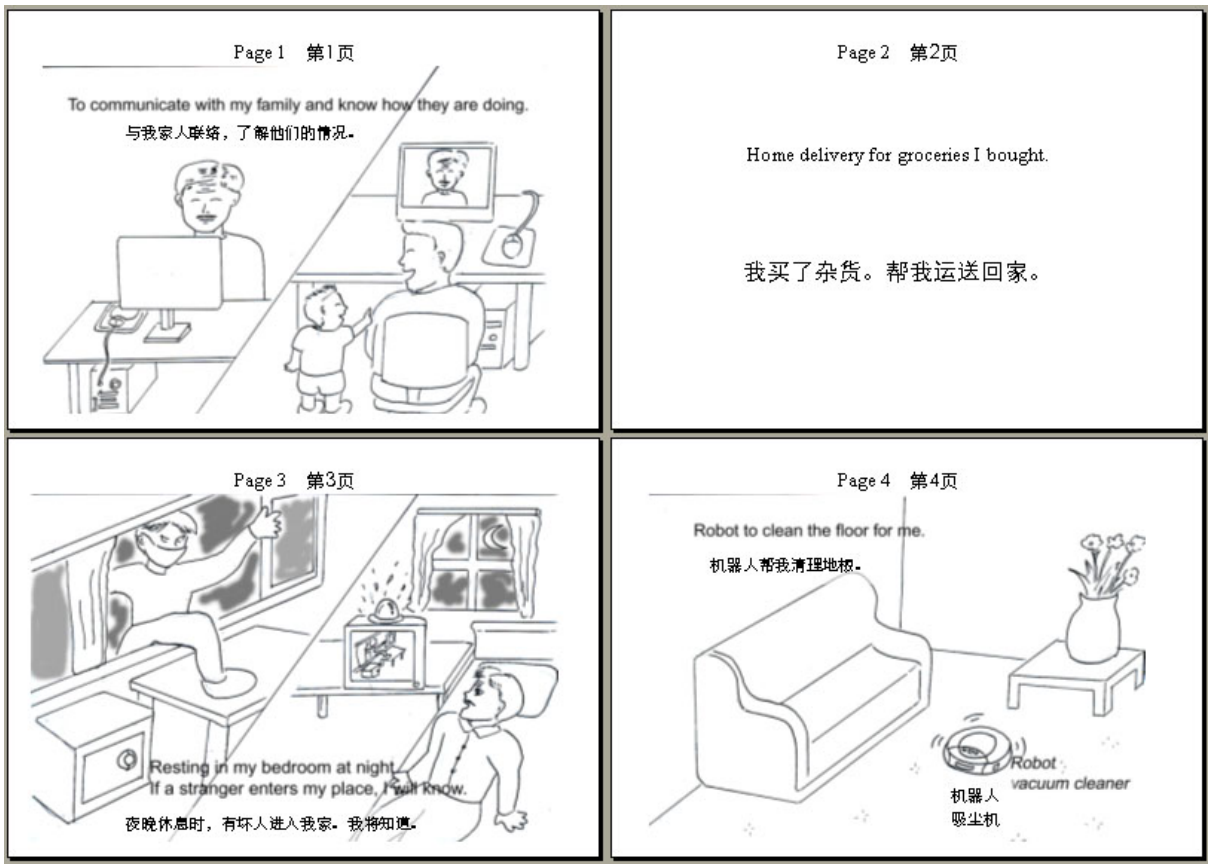
		advance S12 For paralyzed or lazy person S13 Time taken for cooking is too short to be useful S15 Person has no family Person is alone Device is inferior to real humans S16 Device is impossible to exist
13	Smart wheel chair S7	P4 Person's legs are weak Person's brain is still good P5 Person's legs are problematic S1 Person has disabilities Not good for a person to rely on this S2 Uses battery, requires computer Cannot travel to hospital Cannot travel on the road S4 Cannot cross road For people with disabilities S5 Can't go far S6 For wheelchair people S7 For people with disabilities For short distances For people with diabetes or stroke More conformable than wheelchair May be used without battery S8 Person cannot walk Device is bulky S9 Troublesome, requires vehicle to transport Tiring traveling in this Person has weak legs For old people Bulky S10 Person is crippled Person cannot use hands Bulky (has to shout for others to make way) S11 Person can't walk Not for shopping malls (wheels too big) S12 May go "hay wire" Like Mercedes Good for old people S13 For stroke patients May displace walking (bad for health) S15

		Person has weak legs or crippled Person is forced to use it
14	Smart carrier P4, S6, S9, S10	P4 Like motorcycle P5 More cushion Like motorcar Faster and lighter Like driving car Convenient S1 Like bicycle For person hands and legs not usable S2 Can move on road Like car S4 For children Not practical (need electricity) S6 Better than wheelchair Can go far Like small car For people who can't move S7 More convenient than wheelchair For longer distances than wheelchair Not as comfortable as wheelchair S9 For younger people Like motorcycle Looks stable Person's legs are still good S10 Person's feet can move Person can use hands Not bulky (use horns to ask others to make way) S11 Dangerous on road Person's leg is weak Can't go far S12 Dangerous on road S13 For stroke patients May displace walking (bad for health) S14 For old people Can travel over 10 miles Render person useless S16 Faster than wheelchair Like motorcycle
15	Movable phone S6, S9	P4 Person has not strength S1 For rich people with big house For person doing big business receiving a lot of calls S2 This is also computer

		No difference from telephone since have to pick it up S4 For people with disabilities Hand phone is better S5 For people using wheelchair S6 For people who can't move about S9 Family telephone S10 For crippled or useless person, else is busy S11 Person needs wheelchair Can't be used in hospital and public places S13 Person is old and sick Middle age and younger don't need this For big homes S14 Costly S15 "not so advance" S16 For anyone at home
16	Smart pet	P4 For children Old people may spend some time with it (this may be sublimation) P5 Faithful Good sense of smell S1 Useless, for fun only S2 Not useful S4 For bored people without friends S6 For children Old people will use when bored (sublimation?) S7 Can wag tail and smile Person would like live pets better Person is "up to date" or grandson likes it S8 Person doesn't go out often Person is rich No friends come to visit him S9 For family with children S11 Person cannot take care of himself and real pets Person is very lonely Costly S12 For people staying alone and lonely For terminal ill patients S13 For people living alone

		Person is lonely S15 Smart Not as smart as real pets Person is lonely Device as no feelings S16 For anyone who are alone
17	Fall detection vision system S8	S1 For a person who is sick or has disabilities Synonymous to portable help caller S6 Person is a patient or house owner S8 Person is living alone S9 For big family as neighbors would not respond For rich people S10 Person is crippled Person is not working S11 Person live alone Person can't move around Person cannot afford or refuse to stay in old folks home S12 Person is alone at home Scary (automation) S13 For old people
18	Others	P4 Old people does not want anything Person is rich P5 Salespersons are not trustworthy. They require you to pay before goods are sent. S1 Retirees spend more time sleeping Devices for sick people S2 Person is suffering from disabilities Person is sick S6 Old people are senile Costly S10 Good for the crippled and old S11 For people with health problems S12 Old people's mindset is hard to change S13 Costly Expenses should be supported by children Children have no time for parents, too busy earning money, wants comfort and pride S15 Technology will make people having less feelings

Appendix D – Stimuli used in ratings of smart home features for cluster and factor analysis



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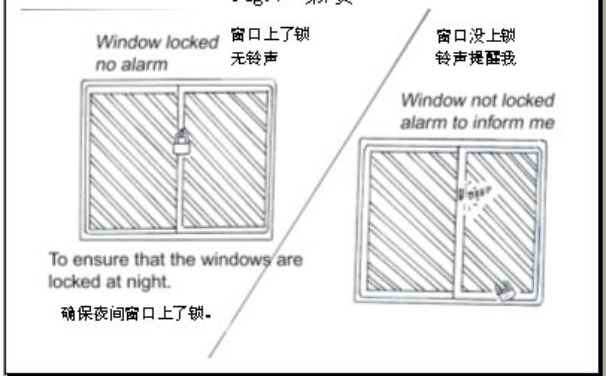
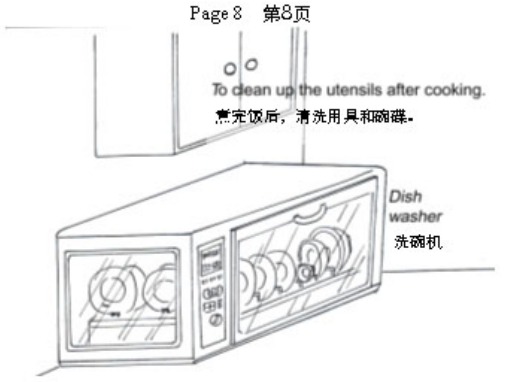


Page 8 第8页

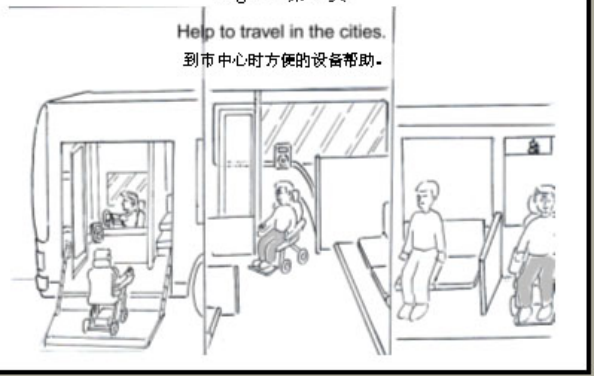


Page 9 第9页

Page 10 第10页

Page 11 第11页

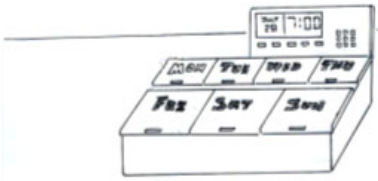
Page 12 第12页



Page 13 第13页

Put pills in the boxes.
One box for each day.

盒子里放着药丸。
一个盒子存放一天的药丸。



Record the time when I take the medicine.
记录我使用药物的时间。

Page 14 第14页

I am alone and I don't feel so well.
Watch to inform my family who are not with me.
我独自一人时感到不舒服。
手表将通知我家人。

Page 15 第15页

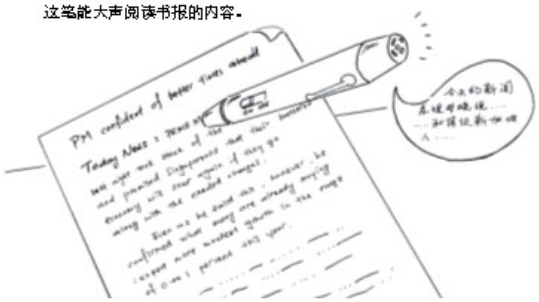
To know who is calling outside the door.
知道什么人在屋外。

inside
屋内

outside
屋外

Page 16 第16页

The pen has an eye and speaker that can read text aloud.
这笔能大声阅读书报的内容。



Page 17 第17页

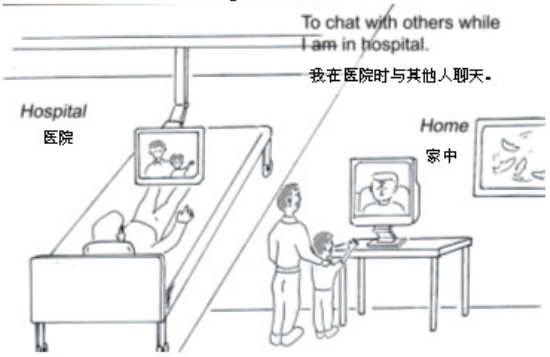
Card to carry medical records and
personal information in case of emergency.
卡能记录个人的医药报告与质料以共紧急的需要。

Page 18 第18页

To chat with others while
I am in hospital.
我在医院时与其他人聊天。

Hospital
医院

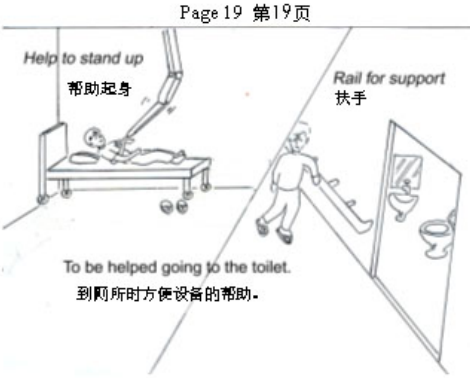
Home
家中



Page 19 第19页

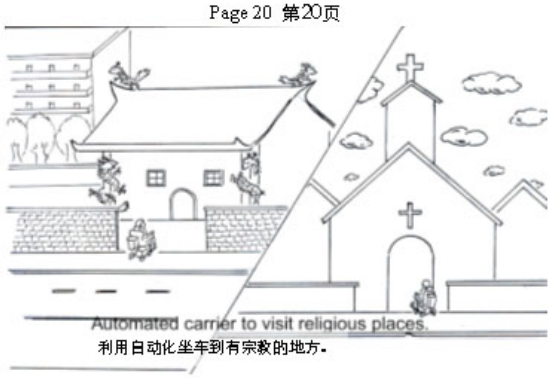
Help to stand up
帮助起身

Rail for support
扶手



To be helped going to the toilet.
到厕所时方便设备的帮助。

Page 20 第20页



Automated carrier to visit religious places.
利用自动化坐车到有宗教的地方。

Page 21 第21页

I am outside and no one is at home.
Screen in my pocket allows me to check on my house.
我出门后没人在家。我口袋里的银幕让我察看我家的情况。

Page 22 第22页

Fully automatic air-con will adjust itself.

Fully automatic VCR can automatically record my favorite TV programs.

全自动化的冷气机会自动调合空气。

全自动化的录影机能自动录制
我爱看的电视节目。

Page 23 第23页

A machine that reads letters aloud.
机器能大声阅读信件。

Page 24 第24页

Things that provide me with the chance to enjoy life in the countryside.

能让我有机会到乡间享受生活的事物。

Page 25 第25页

Things that provide me with the chance to spend my free time helping other people.

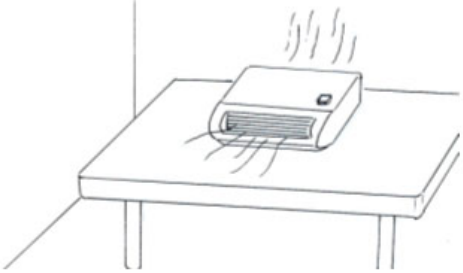
能让我有机会利用空余的时间帮助其他人
的事物。

Page 26 第26页

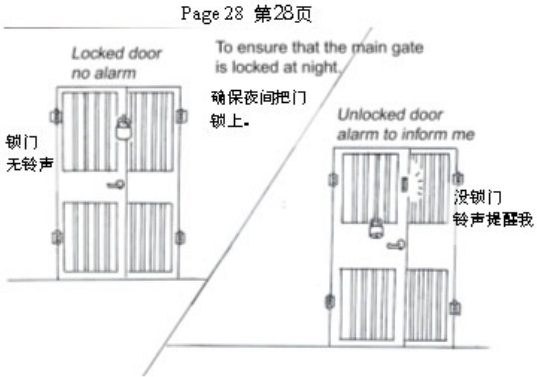
To chat with many other older adults.
与许多其他的年长者聊天。

Page 27 第27页

Air purifier to keep the air clean.
空气清新机能保持空气干净。



Page 28 第28页



Page 29 第29页

Product to improve or maintain the health of my spouse.

这产品能提升或保持我先生或太太的健康。

Page 30 第30页

Product which I buy and I can share with my family.

这产品由我购买后能与我家人共用。

Page 31 第31页

Some useful products make me look old
and sick. (eg. Cane and hearing aids)
I want useful products which do not make me look old or sick.

有些产品虽然有用却使我看起来衰
老。(如拐丈、助听器)
我要的产品必需有用而且不会使我看
起来衰老。

Page 32 第32页

Medical devices that are bought specially for me.

特别为我购买的医务器材。

Page 33 第33页

An alarm to inform me when stranger enters my house.

有陌生人进入我家时，警铃将响起并让
我提高警惕。

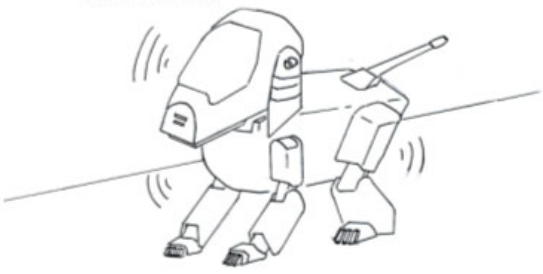
Page 34 第34页

Things that allow me to stay with my children.

能让我与孩子们同住在一起的事物。

Page 35 第35页

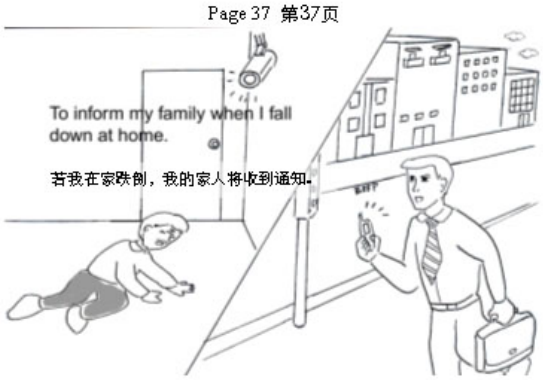
Robot dog or cat to play with.
机器狗或猫和我玩耍。



Page 36 第36页

Toilet that can detect if I am sick.
厕所能探测出我是否生病了。

Page 37 第37页



Page 38 第38页

Products that inform my family when I took my medicine.

我在吃药时，这产品将通知我家人。

Page 39 第39页

Products that inform my children when I am taking a shower.

我在洗澡时，这产品将通知我家人。

Page 40 第40页

Products that inform my children when I am eating.

我在吃饭时，这产品将通知我家人。

Page 41 第41页

Products that inform my children when I go out.

我出门时，这产品将通知我家人。

Page 42 第42页

Products that allow my children to know where I am.

这产品让我家人知道我在哪里。

Page 43 第43页

My electronic products in my home must be handled by my children – not me.

在我家中，并属于我的电子产品，必需由我的孩子控制 - 绝对不由我来操作。

Page 44 第44页

Electronic products that I can use without having to read any word. I can read numbers instead.

这电子产品不需我阅读任何字幕。我能利用数目字操作。

Page 45 第45页

When I buy an electronic product, the sales people should teach me patiently how to use it.

在我购买电子产品时，售货员应该耐心教导我如何使用它。

Page 46 第46页

When I buy a product, I need to know how to get it repaired if it breaks.

在我购买产品时，我必需知道它若坏了，要如何修理它。

Page 47 第47页

I hope that my children will buy electronic products for me. I don't wish to buy them myself

我希望我的孩子替我购买电子产品。我不希望自己去购买。

Page 48 第48页

When I buy a product, I wish to attend classes to learn how to use it.

在我购买电子产品时，我希望能上课学习如何使用它。

Page 49 第49页

Electronic products that require no maintenance.

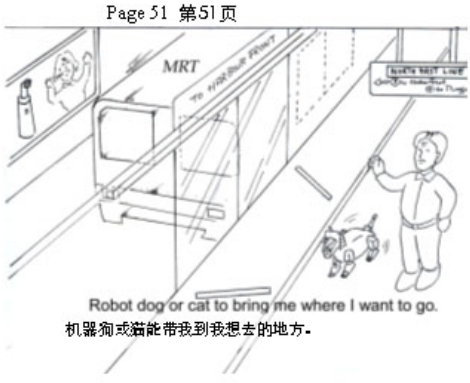
这电子产品不需保持或维修。

Page 50 第50页

Product that allows me to know when my children are coming to my place.

这产品能让我知道我的孩子什么时候会到我家。

Page 51 第51页



Robot dog or cat to bring me where I want to go.
机器狗或猫能带我到我想去的地方。

Page 52 第52页

Products that replace maids to do housework.

这产品能取代家庭女佣做家务。

Appendix E – Estimation of number of uncovered needs in projective test using regression analysis

Procedure of Calculation

Regression Analysis: Cumulative Number of Needs versus Number of Subjects and Squared Number of Subjects

```
The regression equation is
Cum number of needs found = - 14.5 + 21.9 Number of subjects
           - 0.572 Sq number of subjects

Predictor        Coef     SE Coef          T        P
Constant      -14.527       4.395      -3.31    0.006
Number o       21.916       1.190      18.42    0.000
Sq numbe     -0.57160     0.06804      -8.40    0.000

S = 5.142       R-Sq = 99.3%     R-Sq(adj) = 99.2%
```

Regression equation = -14.5 + 21.9 (number of subjects) – 0.572 (number of subjects)^2

Number of needs (excluding repetition) to be uncovered at "16th subject" = Gradient of equation at "16th subject" = 21.9 – 0.572 (2)(16)

= 3.596

Calculation of Projected Total Number of Needs

Total number of needs found (including repetition) = 314

Average number of needs found per subject (including repetition) = 314 / 16

= 19.625

Since each subjects supplied an average of 19.625 needs where 3.596 are new, the probability of uncovering new needs at the 16th subject = P(uncovering new needs at 16th subject)

= 3.596 / 19.625

= 0.1832 or 18.3%

Let the total number of needs = Y

Assuming that the chance of each of these needs being uncovered is equal. That is, each subject may have any 19.625 needs from Y at equal probability.

Therefore, projected total number of needs, Y = Number of known needs / [1 – P(uncovering new needs at 16th subject)]

= 188 / .8168

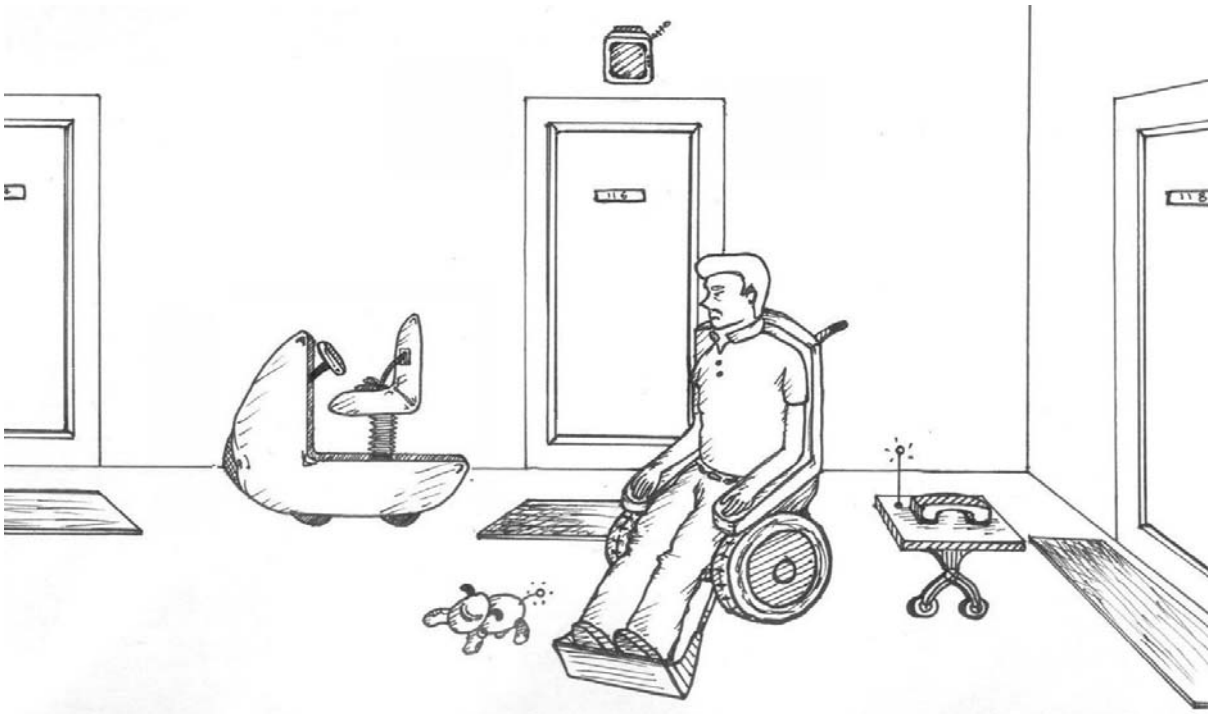
= 230.17

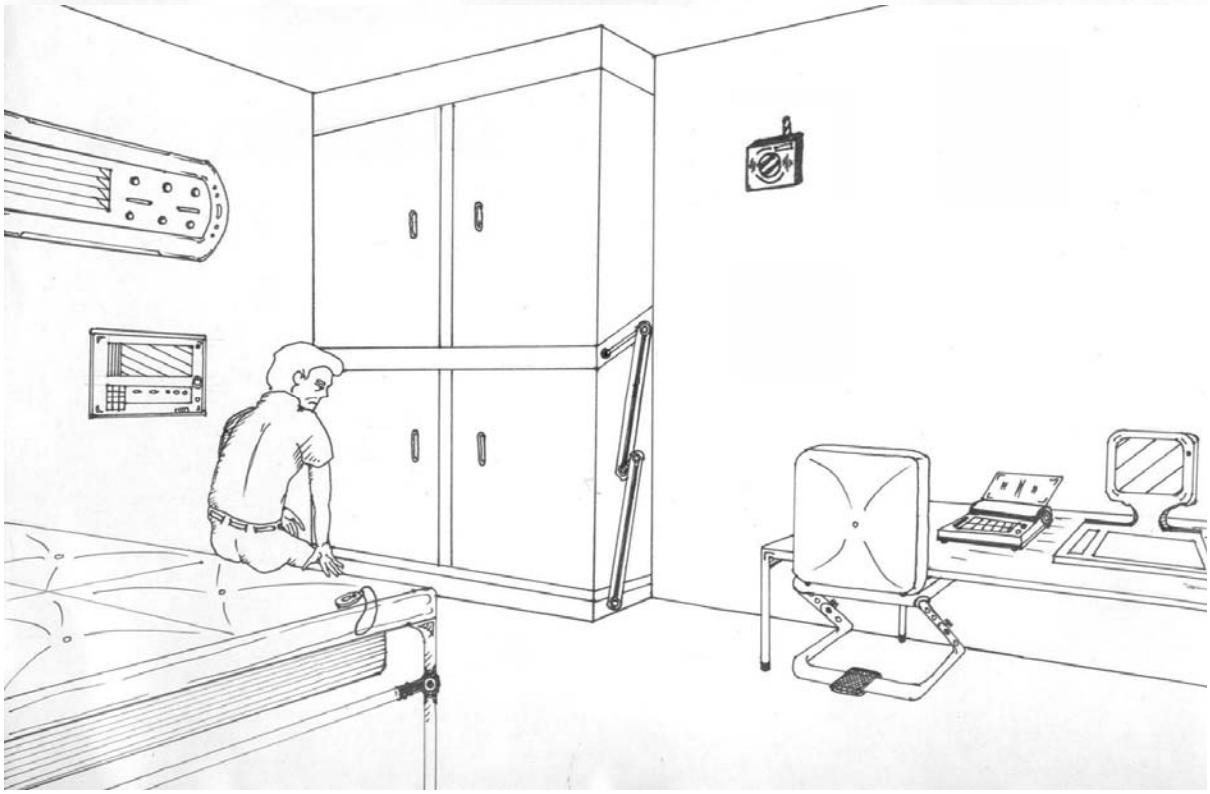
Calculation of Percentage of Needs Covered by 188 Needs Data
There was a projected number of 230 needs altogether.

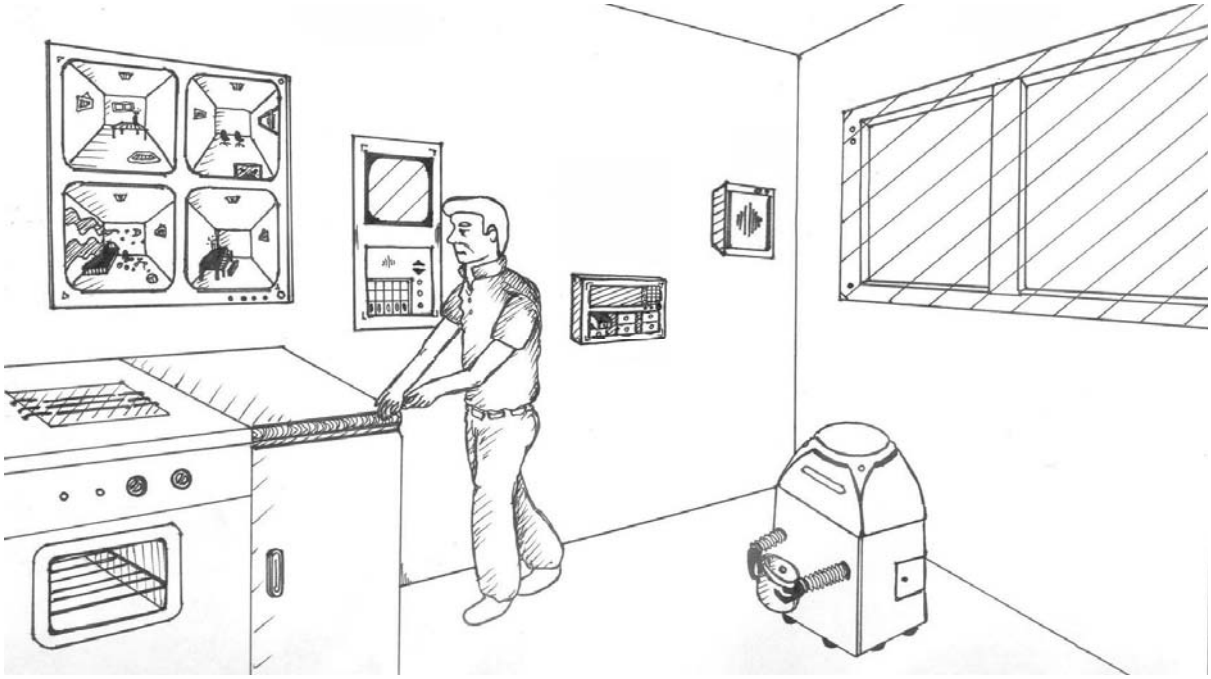
Percentage of needs covered = 188/230

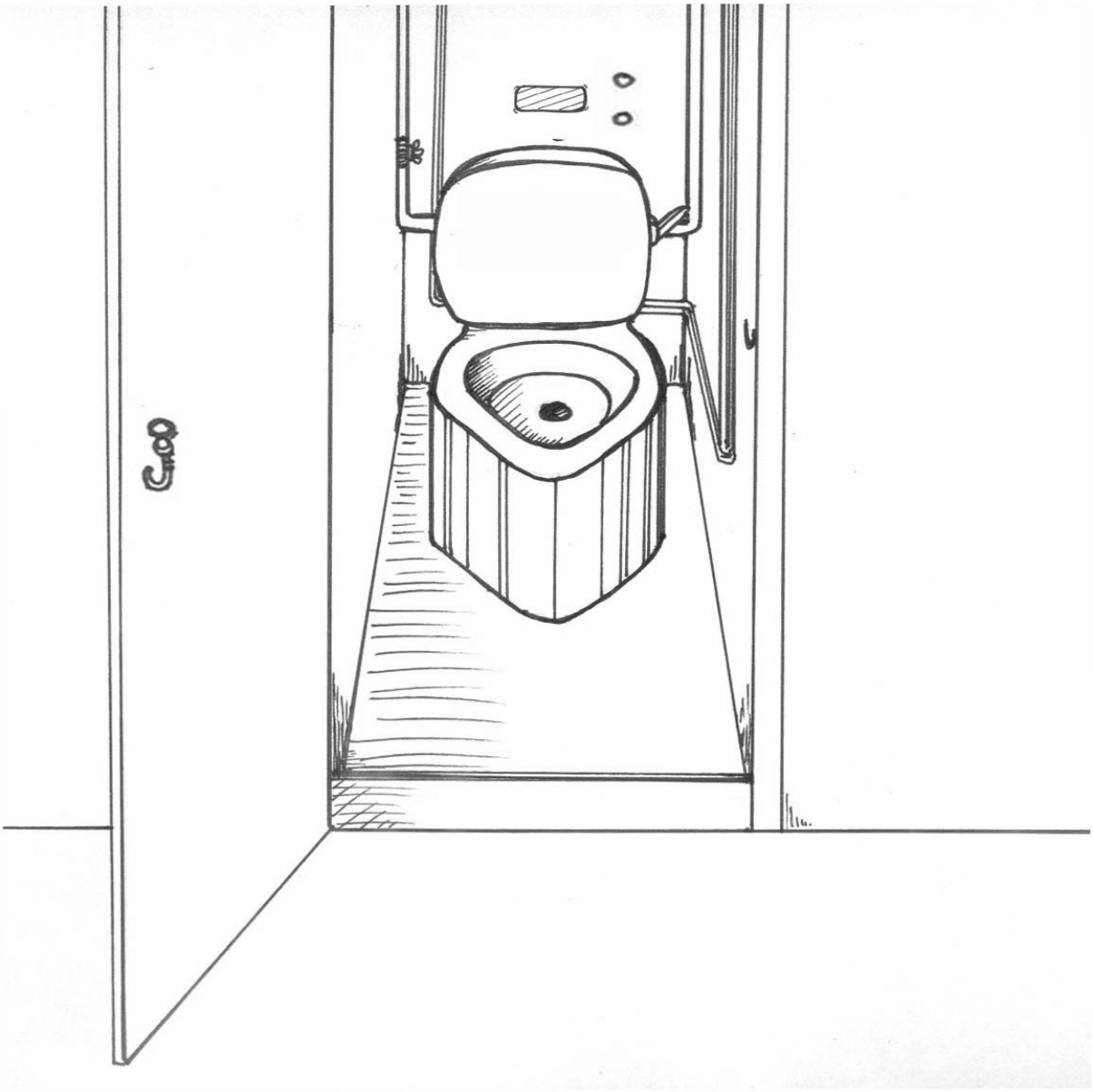
= 82%

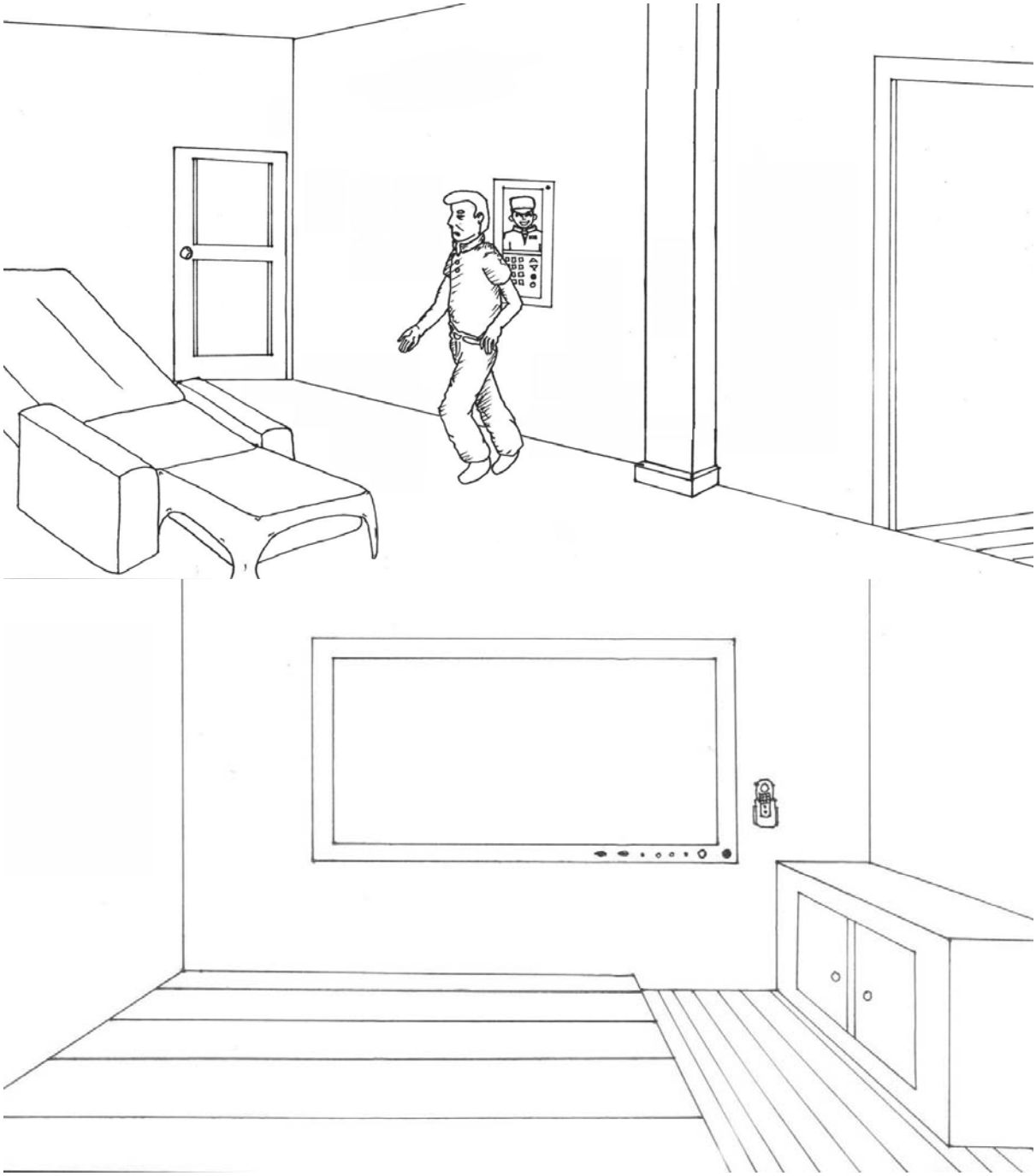
Appendix F – Stimuli used in projective test











Appendix G – Needs strengths of smart home features

Mean = 5.0373 Standard deviation = 2.1405

Stimuli page no.	Content	Score
1	To communicate with my family and know how they are doing.	4.7
2	Home delivery for groceries I bought.	4.9
3	Resting in my bedroom at night. If a stranger enters my place, I will know.	5.95
4	Robot to clean the floor for me.	4.45
5	To ensure that my main door is closed before sleeping	6.25
6	Lights to show the way when I wake up at night.	5.84
7	To ensure that the windows are locked at night.	5.72
8	To clean up the utensils after cooking.	3.4
9	To call for someone when I need help.	6.1
10	Chair to help me stand up easily.	4.42
11	To buy things in the neighborhood.	3.78
12	Help to travel in the cities.	5.1
13	Record the time when I take the medicine.	5.79
14	I am alone and I don't feel so well. Watch to inform my family who are not with me.	5.26
15	To know who is calling outside the door.	6.05
16	The pen has an eye and speaker that can read text aloud.	4.84
17	Card to carry medical record and personal information in case of emergency.	5.9
18	To chat with others while I am in hospital.	5.95
19	To be helped going to the toilet.	5.5
20	Automated carrier to visit religious places.	3.75
21	I am outside and no one is at home. Screen in my pocket allows me to check on my house.	5.35
22	Fully automated air-con will adjust itself. Fully automated VCR can automatically record my favorite T.V programs.	4.95
23	A machine that reads letters aloud.	4.37
24	Things that provide me with the chances to enjoy life in the countryside.	5.5
25	Things that provide me with the chance to use my free time to help other people.	5.44
26	To chat with many other older adults.	5.11
27	Air-purifier to keep the air clean.	5.75
28	To ensure that the main gate is locked at night.	5.65
29	Product to improve or maintain the health of my spouse.	4.8
30	Products which I buy and I can share with my family.	6.05
31	Some useful products make me look old and sick. (e.g. cane and hearing aids). I want useful products that do not make me look old or sick.	4.7
32	Medical devices that are bought specially for me.	4.3
33	An alarm to inform me when stranger enters my house.	6.46
34	Things that allow me to stay with my children.	5.2
35	Robot dog or cat to play with.	3.4
36	Toilet that can detect if I am sick.	5.58
37	To inform my family when I fall down at home.	6.65
38	Products that inform my family when I took my medicine.	4.6
39	Products that inform my children when I am taking a shower.	3.8
40	Products that inform my children when I am eating.	3.42

41	Products that inform my children when I go out.	4.26
42	Products that allow my children to know where I am.	4.9
43	My electronic products in my home must be handled by my children – not me.	3
44	Electronic products that I can use without having to read any words. I can read numbers instead.	4.85
45	When I buy an electronic product, the sale people should teach my patiently how to use it.	6.5
46	When I buy a product, I need to know how to get it repaired if it breaks.	4.45
47	I hope my children would buy electronic products for me. I do not wish to buy them myself.	4.89
48	When I buy a product, I wish to attend classes to learn how to use it.	5.58
49	Electronic products that require no maintenance.	3.9
50	Products that allow me to know when my children are coming to my place.	5.6
51	Robot cat or dog to bring me where I want to go.	4
52	Products that replace maids to do housework.	4.4
53	Products that take care of my needs at home so that I need not stay in old folks home.	5.8