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Perception of Smart Home Technologies to Assist Elderly People

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***Abstract*—In the last decade, the number of elderly population has increased significantly which affects human in many aspects, especially in healthcare. Many studies have shown increases in expenditures on long-term care. New models of care are needed including supported self-care and home-based services. Advance in sensor and network technologies have made these possible. A smart home which is a residence equipped with smart technologies providing services that enhance human way of living i.e. safety, security, entertainment, etc would allow elderly to maintain living independently in their homes and still in control of their healthcare cost and status. This paper reviews various topics on smart home technologies including smart home projects, smart home network, smart home appliance and sensor technologies for smart home. A successful adoption of smart home technologies requires appreciation of stakeholders' perceptions, needs and concerns. A survey has been carried out at a major hospital, nursing homes and general population to explore the perception of six smart home technologies to assist elderly people and concerns regarding the use of smart home technologies. Overall, the result showed positive feedbacks toward these technologies. Participants were concerned about issues such as lack of human responders, user friendliness of the device and the need of learning new technology. In terms of willingness of adoption of these technologies is still unclear. However, it is suggested that by giving real experiences of smart home technologies, their' usefulness and effectiveness would be more appreciated.**

I. Introduction

THE growing numbers of elderly population and increasing life expectancy have brought enormous challenges to many aspects of human life, especially in health and healthcare. According to the United Nations online database [1], currently the percentage of elderly population is 7.6% which is projected to rise as high as 16.2% in 2050 as depicted in Figure 1. Issues such as increased healthcare expenditure, burden to caregivers and insufficient and inefficient care are more likely to occur as the health of older persons normally deteriorates with increasing age, resulting in more demand for long-term care. The expenditure on long-term care provision in Germany, Italy, Spain, United Kingdom and United States of America is projected to increase significantly [2, 3].

In order to support the demand for healthcare due to population ageing, new models of care will be required. An appropriate balance of settings for long-term care, including supported self-care and home-based services are necessary [2]. The system should reduce the burden on caregivers as well as healthcare costs, while maintaining a good quality of care. Emerging technology can facilitate self-care and extend the self-reliance of the ageing population. The care of elderly could be enhanced through monitoring system, sensor technologies and communication systems.

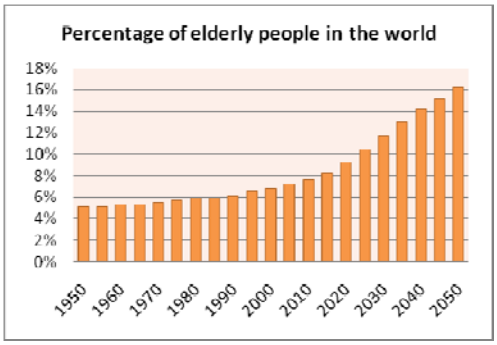

Figure 1: Percentage of ageing population in the world during 1950 and 2050.

Advance in sensor and network technologies have changed the way people live. A number of research projects have been carried out in order to improve human quality of living. Many smart home projects have been developed to explore the use of technology for home automation. King [4] defined smart home as "A dwelling incorporating a communications network that connects the key electrical appliances and services, and allows them to be remotely controlled, monitored or accessed". A smart home is equipped with smart technology and network such as smart lighting system, smart kitchen, energy usage monitoring, security system, etc that enhance people's life in many aspects i.e. security, entertainment, convenience and etc.

Smart home technology can be especially useful for elderly or disabled persons who wish to live independently. Smart home technology has led the idea of ageing in place possible in which elderly person can maintain living independently in their homes and still in control of their healthcare cost and status. Elderly persons can take the advantages of smart home technology such as monitoring system, emergency system, dangerous kitchen appliance detection, fall detection and etc

to maintain healthy and safety living while living independently.

The paper reviews smart home technology regarding current smart home projects, smart home networks and appliances, sensor technologies that are used in smart home. The paper also explores the perceptions, needs and concerns of elderly family in regarding using smart home technology for elderly care.

II. SMART HOME TECHNOLOGY

A. Smart home projects

Many research labs have investigated in smart home technology [5]. As the demographic is changing, a field of research in healthcare has resulted in increased interest in the potential of smart home technology for healthcare purposes. Several pilot projects employed smart home concept have been explored and developed with the aim of improving the quality of life and promoted independent living of elderly persons by using advanced sensor and network technology [6, 7] and the paper reviews further elderly care related projects which employ the concept of smart home both in EU and US.

The European Commission has funded a number of research projects to help with the growing number of elderly population in Europe [8]. These projects have been developed to determine how ICTs can meet the needs and maximise the potential of older people. One such project, the Easy line + project [8] examines the use of sensors, neural network and assistive software to develop a control system for white goods such as washing machine, dishwashers, fridges and freezers for easier use of older persons. A variety of sensors such as illumination sensor, temperature sensor, door sensors, radio frequency identification (RFID) and etc have been used in this project. As this project attempt to develop advanced white goods for easier use for elderly, human-machine interface (HMI) must be easy of use and available to any kind of user. The project researched user controls in the market place and found digital television with a remote control to be suitable as elderly people are familiar with and know how to use the basic functions. A touch screen device is preferably for a portable device. Another project called Persona [9], aims to harmonise Ambient Assisted Living Technologies (AAL) by developing sustainable, scalable and affordable services platform for support elderly in activities of daily living, mobility and displacement and protection from health and environmental risk. Persona assesses and evaluates a range of ICTs such as smart textiles, tele-services, bio sensor, smart devices and intelligent software tools. Persona provides basic functionalities and hardware components allowing easier integration to other assisted living/smart home services.

In US, University of Rochester developed the Smart Medical Home [10] which is a controlled environment laboratory setting for concept testing, pilot and prototype testing of technologies and products for personal health system. The smart medical home is equipped with infrared sensors, biosensors, computers and video cameras to collect the data that will augment the data collected by physicians and hospitals. Another project by University of Virginia, Smart In-Home Monitoring System (Figure 2) developed in-home monitoring of residents using a set of low-cost, non-invasive sensors together with data-logging and communication module and data management system in order to increase quality of care and provide quality of life indicators [11]. The collected data can be used for the observation of general health and activity level, activities of daily living (ADL), index of well being and the decline in ability over time. The university also developed other projects related with elder care such as gait monitor device, MARC robotic walker, sleep monitoring system, etc.

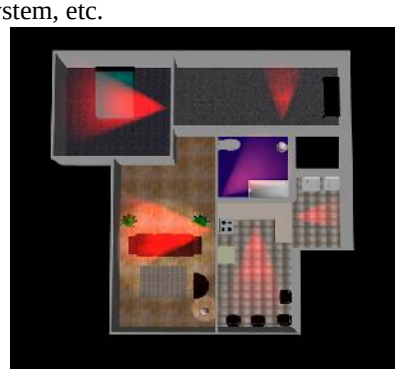

Figure 2: Smart In-Home Monitoring System [12].

B. Smart home network

A smart home incorporates a communication network in order to control or monitor appliances or services within the home. Smart home network technology can be classified by interconnection method into three main types: wire, wireless and both wire and wireless.

1) Wire: Appliances and services in smart home are connected through wiring system such as optical fibre, cable and Powerline. In this system, devices are normally connected directly into the main power supply. The data is sent through the normal wiring to activate or deactivate the appliances/devices. An example of wired communication network for smart home is X10, which is an international and open standard for home automation. X10 allows communication with appliances over standard electrical wiring. X10 has been developed for over 35 years yet still remains popular as it is inexpensive, easy to set up and widely available. Other technologies are, for examples, European Installation Bus (EIB), Universal Powerline Association, HomePlug and etc.

2) Wireless: Many of new smart home appliances use wireless communication technologies such as infrared and radio frequency (RF). As radio wave can penetrate through walls, floors and cabinets, devices within smart homes can communicate wirelessly. An example of home automation network standard is Z-wave which is a proprietary wireless communication for home automation. It employs low-power RF technology allowing home appliances to communicate with each other such as control of lighting, air-conditioning and security system. Other communication networks for smart

home that use RF as transmission medium are such as Bluetooth, ZigBee and Wi-Fi.

3) Both wire and wireless: Some of smart home network standards can work using both wire and wireless technology. For example, INSTEON [13] is similar to X10 but overcomes the limitation of wired network by using RF technology. It is used for home automation such as lighting, appliances, and other home applications control. INSTEON devices uses dual mesh network, RF signals and home electrical wiring to communicate with other devices.

C. Smart home appliances

Smart home appliances are intelligent artefacts that enhance human way of living in term of convenience, safety, etc. A number of appliances have been reviewed in [5]. In this paper, a survey of some of smart home appliances that can be used for elder care as follow:

1) Cooking hob and oven safety control: Many of the elderly people have a condition of forgetfulness in which safety and security of a person is reduced. Hobs and ovens are kitchen utensils regular used for cooking. Elderly person may easily forgets to switch the hob and oven off after finish cooking, especially electrically ones which is harder to notice. Forgetting to turn off these cooking tools create dangerous environment i.e. potential cause of fire, injury from accidentally contact. Hob and oven safety control have temperature sensors to control the heat of the hob or oven and cut off the power if the heat reaches the safety limit.

2) Sleeping pattern monitoring: A bed is equipped with sensors which can detect the presence, respiration, pulse and movement of a person in bed. A sleeping pattern monitoring can be used to detect health condition regarding sleeping such as restless sleep, rapid change in activity level or unusual change in typical routine of a person. For example a person who normally gets up early but on a particular day tends to be lying in. This may indicate that the person may have a serious illness or incident causing the person unable to move. Another example is during the night, a person is detected to leave the bed but has not returned for some times, this may indicate that the person may have accident or is in emergency situation.

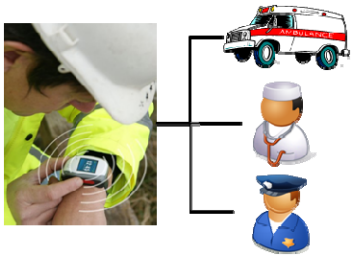

Figure 3: Conceptual diagram of emergency alarm

3) Emergency alarm: An emergency alarm is normally a device which contains buttons that is pressed when a user is in a dangerous or emergency situation and requires immediate help as illustrated in Figure 3. When a button is pressed, the device is automatically sent an emergency message to a designated person or organisations such as family, doctors, polices and etc. The device can be programmed to assign different button to each contact, for example button A for ambulance. The emergency alarm is also equipped with a location sensing sensor such as Global Positioning System (GPS) allowing location information to be sent with the emergency message resulting in quick response to the incident.

4) Automatic lighting system: The automatic lighting system allows any lights within the smart home to be switched on and off automatically when a person is in the area promoting a safer environment. The system uses motion sensor to detect the movement of a person to provide automatic illumination. Moreover, to save the energy, the system also equipped with photocell sensor allowing the system to operate only at night or in a dark environment. The automatic light system can be used in any rooms e.g. bedroom, living room, toilets, etc or at the stairways. An example use of the system is when a person walks downstairs during the night, the system can illuminate the stairways increasing visibility, promoting safety environment.

5) Video monitoring system: The video monitoring system usually composes of video camera and a computer system. It is used to monitor people within the smart home. Video cameras are installed in any places that need monitoring. Example locations are such as living room, kitchen, hallways and etc. The video cameras record visual data which is interpreted into useful information for monitoring purpose later. Video monitoring system is used for security and safety purpose as it can powerfully detect human activity and behaviour which resulting in a prompt response in case of emergency and unusual activity i.e. falls and other accidents.

Figure 4: Conceptual diagram of activity monitoring system

6) Activity monitoring system: An activity monitoring system is used to monitor activities of daily living such as walking, standing, cooking and etc of a person and allow unusual activity i.e. fall to be detected for a faster response. The activity monitoring system is composed of a wrist watch which is equipped with various sensors such as accelerometer, radio frequency identification and etc used for activity detection. The sensor data is sent wirelessly and stored in a computer system allowing authorised people such as family and healthcare professionals to monitor the activity of a user anytime anywhere as shown in Figure 4. When abnormal activity is detected that information is sent to any authorised persons to ensure a user receives help as quick as possible.

D. Sensor technology for Smart home

Sensor technology is an important component of smart home. Data collected from sensors are processed to provide intelligent services in smart homes. Examples of sensors are outlined as follow:

1) Radio Frequency Identification (RFID): RFID is a means of storing and retrieving data through electromagnetic

transmission to an RF compatible integrated circuit and is now being used as a means of enhancing data handling processes [14]. RFID has been used in various applications across industries such as asset tracking, manufacturing, supply chain management, retail, payment systems, security and access control [15, 16]. Application of RFID technology for a smart home are such as tracking device, activity monitoring system, RFID key card, etc. A basic RFID system, as depicted in Figure 5, comprises three main components: RFID tags, an RFID reader and a middleware.

An RFID tag consists of a microchip attached to a radio antenna mounted on a substrate. The purpose of the tag is to store data which can be altered or retrieved via radio frequency. There are three types of tags: passive tags, semi-passive tags and active tags. The passive RFID tags have no battery and require an external source to invoke a signal transmission. Semi-passive tags also require an external source to activate them, but have a significantly higher forward link capability providing a greater read range. An active RFID tag contains a battery and can transmit signals autonomously. The RFID reader interrogates RFID tags that are in the reading range using radio communication.

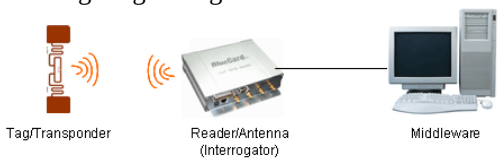

Figure 5: Basic RFID components

The RFID reader works with the antenna emitting a radio wave to activate the tag and to read or write data to the tag. The antenna can send the signal over an area ranging from a few centimetres to 100 metres or more, depending on the frequency used and the output power. Once the tag passes the electromagnetic field, it detects the activation signal and modulates it. The reader decodes the data stored in the tag and sends it to the middleware for further data processing.

Middleware is used for data processing, routing and managing the RFID reader. RFID middleware combines the RFID data with application logic and generates appropriate application events [17].

2) Accelerometer: is an instrument that measures the applied acceleration acting along the sensitive axis [18]. It is widely used for human activity recognition purposes [19 -21] because of its capability to respond to both frequency and intensity of movement, and measure tile as well as body movement. Accelerometers are relatively small and inexpensive which makes them appealing to real-life applications. There are many types of accelerometer for example, piezoresistive, piezoelectric, magnetoresistive, capacitive etc in which different key technologies are used to measure acceleration [22]. Conceptually, a variation of the spring mass system is used. In this system, when acceleration is applied, a small mass inside the accelerometer responds by applying force to the spring, causing it to yield or compress. Measurement of the displacement of the spring is used to calculate the applied acceleration. Examples of accelerometer sensor in smart home appliances are such as fall detection, activity monitoring system, etc.

3) Motion sensor: A motion sensor is used for movement detection. There are 3 sensor technologies that are used to detect motion: passive infrared, ultrasonic and microwave. The passive infrared motion sensor works by detection of the body heat. The infrared radiation cannot be seen by human as its wavelength is longer than a visible light. Any objects that generate heat also generate infrared radiation. Passive infrared motion sensor monitors the temperature and search for changes in infrared spectrum. This type of motion sensor is commonly used in indoor environment. For instance, motion sensor is linked to a light switch and when it detects presence of person, the light is switched on automatically.

When ultrasonic and microwave technologies are used for motion detector, they are considered as active motion sensors. These two technologies work similarly. They emit optics or sound waves and measure the reflection to detect motion. Ultrasonic acoustic wave cannot be detected by human ear, however may be sensed by certain animals i.e. dogs, fish, etc. An example use is an active motion sensor which emits radar pulses is attached to the gate. When any object enter the area, it disrupts the radar pulses in which the reflection time has changed, the motion sensor could trigger the gate to open.

Other sensors normally found in smart home technologies and appliances/devices are such as pressure sensors, temperature sensors, audio sensors, etc.

III. Perception of Smart Home technologies to assist elderly people

Although smart home technologies demonstrate potential benefits in assisting elderly people, a successful adoption of such technologies would require a thorough assessment of the need, perception, and concerns of related stakeholders i.e. carers, elderly persons, elderly families and relatives, etc. Able to understand their perceptions would allow the development of new smart home technology which meets user requirements.

There are a few studies which have investigated the perception or views of using smart home technologies for elderly care. One of these studies is by Demiris et al [6] who explored the perceptions and expectations of older adults in regard to installation and operation of smart home technologies to improve their quality of life and/or monitor their health status. Devices and sensors in health-related issues such as preventing and detecting falls, assisting with visual or hearing impairments, etc were discussed and the result showed that the seniors, in general, have positive attitude towards these devices and sensors. The study also indicated that older adults were concerned about falls and they perceived technologies that monitor activity levels and sleep patterns as useful. This leads to their follow-up study [7] which investigated in older adults' perceptions in specific smart homes technologies i.e. bed sensor, gait monitor, stove sensor, motion sensor and video sensor. Their finding indicated an overall positive attitude towards those technologies for non-

obtrusive monitoring and seniors were concerned about privacy violation, visibility and accuracy of the devices. A study by Steele, Atkins and Yu [23] investigated wireless devices i.e. MDKeeper, pressure sensors, fall detection from acceleration measurement, location tracking devices using RFID and video monitoring and assessed their effectiveness and practicality of real world use for assisted living system and elder care. Based on their questionnaire surveys, these devices were perceived as effective for elder care in home environment. In addition, non-intrusive and mobile devices such as wireless watch are more preferable.

This research aims to explore the perception of people who are associated with elderly such as carers, elderly persons, elderly families, relative and friends in regarding the use of smart home technologies to assist elderly people. The study seeks the perception i.e. usefulness, effectiveness, etc, concerns and willingness of adoption of specific smart home technologies for elderly care. The selected technologies are such as cooking hob and oven safety control, sleeping pattern monitoring, emergency alarm, automatic lighting system, video monitoring and activity monitoring system and are described in Section II-C.

A. Research methods

A survey was conducted on the participants and a questionnaire was designed. The data collection method used is self-administered questionnaires where participants were presented with the questionnaires in persons. The purpose of the inquiry is explained and the participant is left to complete the questionnaires which were picked up latter. This method is selected as it ensures high response rate, accurate sampling and minimum of interview bias [24]. 35 Questionnaires were given out at a major local hospital, nursing homes and the general population to give the questionnaire greater exposure. Each questionnaire is assigned with random participant number which allow the participant if later decided be to withdrawn. The information regarding the survey description and intention, participant's privacy and right were marked on the first page of the questionnaire. Each participant was given a week to complete the questionnaire.

B. Questionnaire design

The core information needed for this research is the perceptions which are usefulness, effectiveness, adoption willingness and the concerns of using smart home technologies for assist elderly people. It was clear that the participants first needed to be informed of the smart home technologies and what their potential usage, therefore a detailed description of each technology is presented alongside the questions. To help non-technical participants to understand each technology better, a conceptual diagram of the usage of the technology is also provided.

Table 1: Question using Likert-type format

To what extent would the technology be useful in elder care?	Not at all Useful <==========				Very Useful
	1	2	3	4	5

The questionnaire is divided into two sections: Section 1 collects participant's information such as gender, age, IT experiences, etc. The second section detailed the main questions and is divided into 2 parts: Perception of each technology and concerns of the use of smart home technology. In section two, Likert-type format is used where the participant indicates the extent to which they agree or disagree on the statement. A Five level is used where 1 represents the most negative feedback and 5 represents the most positive feedback an example is shown in Table 1. According to previous studies [6, 7, 23], privacy issues are often raised, thus the question about the extent of privacy concern was asked. Additional spaces were also provided for participants to input other factors that may cause concern on certain technology. The next part asked the participant the extent of concern of several factors such as privacy violation, lack of human responder, user-friendliness of the device, the need for training, stigmatisation resulting from using/installing the technology and the cost of technology.

IV. Result

The response rate of the survey was 51.4% and the following data is attained.

A. Participant demographic

A total of 18 participants were involved in this study. Fourteen participants were female, three were male and one participant did not specify. During the survey, it was observed that most of the carers were female including both professional i.e. nurses and non-professional i.e. partner, relatives and friends. The age range of the participants was large, ranging from 26 to over 80 years old and mostly age between 51-59 years old. 27.8% of the participants were not carers, 22.2% were professional carers and 50% were non-professional carers in which mainly were relatives of the elderly as shown in Figure 6. In general, the participants were users of personal computers (PCs), mobile phones and use computer applications such as email, web browsing, and advanced applications i.e. PhotoShop, and Excel,etc.

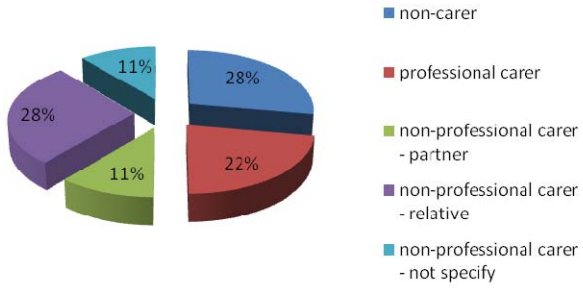

Figure 6: Categories of participants

Table 2: Participants' IT/Computer experiences

Use personal computer/laptop	77.8 %
Use mobile phone	83.3 %
Use email and web browsing	77.8 %
Use advanced applications	66.7 %

B. Perception of smart home technologies for elderly care

In the second section of the questionnaire, the perception of six smart home technologies which are cooking hob and oven safety control, sleeping pattern monitoring, emergency alarm, automatic lighting system, video monitoring system and activity monitoring system were asked. The result is shown in Table 2.

The participants perceived most of the technologies to be useful in elderly care where cooking hob and oven safety control, sleeping pattern monitoring, emergency alarm and automatic lighting system were perceived as very useful while video monitoring and activity monitoring systems were seen as useful. Similarly, nearly all of the technologies were being seen as effective in home care expect video monitoring system which received neutral feedback. Emergency alarm and automatic lighting system were perceived as very effective. Participants strongly agreed that sleeping monitoring pattern, emergency alarm and automatic lighting system would help elderly person in a home environment. The participants agreed all technologies except cooking hob and oven safety control would help carers in nursing homes or hospital environment. Overall, emergency alarm and automatic lighting system received the best feedback while mixed feedbacks were received for video monitoring system and cooking hob and oven safety control, sleeping pattern monitoring and activity monitoring system had positive perception as shown in Table 3.

Table 3: Perception of six smart home technologies

Smart home technology	Usefulness	Effectiveness	Help elderly	Help carer	Adoption willingness
	median	median	median	median	median
Cooking hob and oven safety control	5	4	4	3	3
Sleeping pattern monitoring	5	4	5	4	3
Emergency alarm	5	5	5	4	3
Automatic lighting system	5	5	5	4	4
Video monitoring system	4	3	4	4	2
Activity monitoring system	4	4	4	4	3

1 – most negative 5 – most positive

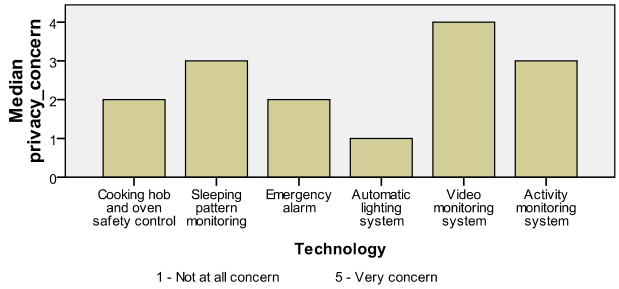

Figure 7: Privacy concern of the six technologies

Privacy concern of each technology was asked in the questionnaire, the result is depicted in Figure 7. All monitoring-based systems were perceived as violation of privacy. The privacy scale of video monitoring, activity monitoring and sleeping pattern monitoring were 4, 3 and 3, respectively, where 1 represents not at all concern and 5 represents very concern. The participants were given additional space to put further concerns of each technology. The issue was raised most about cooking hob and oven safety control was that it may cause confusion to the elderly. For the emergency alarm they were concerned of the false alarm that may cause by an unintentional press or the elderly may press the button to seek attentions. Reliability of the automatic lighting system was the issue that concerned by many participants. One participant used the system and found the system was prone to failure. Most concerns of a video monitoring system were privacy invasion as well as the fear of abuse by those monitoring.

In general, participants were willing to an automatic lighting system to use in their own residences. The decision to adopt cooking hob and oven safety control, sleeping pattern monitoring, emergency alarm and activity monitoring system were neutral. Video monitoring system, on the other hand, was not be willingly adopted by the participants, this may due to the fact that the technology seems to violate the privacy of its users.

C. Concerns regarding the use of smart home technology

Participant also rated concern factors regarding the use of smart home in general. Concerns such as privacy violation, lack of human responders, user-friendliness of the device, the need of training of new technology, stigmatisation resulting from installing/using the technology and the cost of the technology i.e. device and retrofitting were asked. The result showed that the participants were quite concerned with the user-friendliness of the device and the need of training of new technology. When this is looked with IT/computer experiences of the participants, the result surprisingly revealed that most of the participants with computer experiences rated these factors as quite a concern. Other issues were rated as concern were lacking of human responders and the cost of the technology. Unexpectedly, participants were not concerned about the stigmatisation caused by using smart home technologies as illustrated in Figure 8. Participants thought the top five activities that should be monitored were falling, cooking, walking downstairs, walking upstairs and walking, respectively.

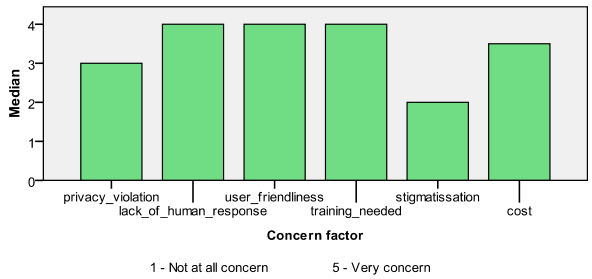

Figure 8: Concerns of the use of smart home technologies

V. Conclusion

Over decades the number of elderly population has increased dramatically. This affects human in various aspects especially in healthcare where admission number and healthcare cost will significantly rise. In twenty first century where sensor and network technologies have been advanced, new model of care is possible. Smart home is defined as a place that equipped with technologies that allow people to maintain living independently while in charge of their own healthcare and its cost. It will allow people to age in home, enhance people way of living i.e. safety, security, convenience, etc. In this paper the topics related with smart home technologies including several smart home projects, different type of networks that are used in smart home, smart home appliances and sensor technologies for smart home have been reviewed.

Smart home technologies show great benefits in elderly care and to successfully adopt of these technologies perception, needs and concerns must be thoroughly assessed and understood. A survey has been carried out at major local hospitals, nursing homes, and general population to explore the perception of six selected technologies such as cooking hob and oven safety control, sleeping pattern monitoring, emergency alarm, automatic lighting system, video monitoring system and activity monitoring system to assist elderly people. The result showed positive feedback toward these technologies with emergency alarm and automatic lighting system were the most popular. The adoption willingness of these technologies was still indecisive. Regarding the use of smart home technologies, factors such as lack of human responders, user friendliness of the device and the need of learning new technology were most concerned.

Smart home technologies seem to be favour in elderly care. Although now people may feel uncertainty in the adoption of these new technologies, it is believed that by giving them real experiences of smart home devices, their usefulness and effectiveness should be more appreciated.

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