AN APPROACH TO EVALUATING GESTURE BASED INTERACTION WITHIN THE SMART HOME FOR AN ELDERLY POPULATION

By

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Abstract

With the development of technology, people are about to usher in artificial intelligence life. The use of innovative products can make people's lives more convenient, but new innovations often result in the creation of problems. The elderly face obstacles to the use of smart homes due to physical and cognitive aging. Gestural interaction as a new means of interaction can solve this problem. This thesis explores the factors that affect the elderly's understanding of gestures through interviews and finally finds suitable gesture commands set through group comparisons.

The research of this thesis will finally propose a set of gesture commands suitable for the elderly and provide research methods and guidelines for future gesture system design.

Acknowledgments

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Thanks to my parents, they have always supported my study financially and emotionally. Thank my friends, who have been with me through the difficulties. Because of these people's help, I complete the research in the past two years successfully.

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Chapter 1 Introduction

1.1 Problem statement

There has been a technological revolution in this era; emerging technologies such as the Internet of Things, quantum communications, and artificial intelligence are all thriving in the past ten years. These technologies are driving the development of intelligence and automation of household products. In such an environment of rapid technological development, the technical capability of companies determines their future development prospects. Therefore, many companies put most of their energy and financial resources into technology research and development in order to seize market share. In this process, the real needs of users and the emotional aspect of consumers are often ignored by the company, especially the needs of special groups like older adults. High-technology solutions have not brought them convenience but have added more obstacles because many products interact in ways that are beyond the reach of the elderly. For example, many elderly cannot adapt to the way that vending machines use mobile phones to pay, so they cannot buy what they want.

According to data from the 2020 World Census, most countries currently have problems that relate to their aging population. With the continuous improvement of the proportion of the elderly population and people's retirement benefits, the proportion of wealth occupied by the aged population will significantly increase, and older adults will become the largest consumer group in the future. However, in the case of smart home products, the existing products often lack consideration of the living habits of the elderly. The operation modes of many products are typically only designed to match the application of high-tech and are not truly human-centered and intelligent. Moreover, the most mainstream interactive modes in the current market have many obstacles for the elderly to operate. They may find it challenging to use such products due to age-induced declines in physical function or the deterioration of learning ability. Taking voice control as an example, most older adults in China only speak dialects rather than Mandarin, so it is difficult for them to use voice-assisted products smoothly. Furthermore, from a psychological point of view, the communication between humans and a machine is not reflective of human nature, and it can be incredibly difficult for the elderly to overcome.

In general, the elderly over 65 years old are a group of users who urgently need smart products to assist their lives, but to date, there few examples of interactive modes that meet the use habits of the elderly, allowing them to learn and use products.

1.2 Need for study

Since entering the industrial age, product iterations have been developing in a user-friendly direction relying on rapid technological innovation. In the article "Designing Calm Technology," published in 1995, a concept called calm interaction was mentioned (Weiser & Brown). The idea is that the process of human-computer interaction will gradually become hidden and invisible. Today, the research of product interaction is also gradually developing around this concept. In recent years, high technology solution such as VR and AR have gradually entered our lives. Gesture recognition and speech recognition, two of the most important control methods, have also been recognized by the public. The picture below (Figure 1) is the most representative product on the market, Leap Motion, that can use sensors to capture the user's hand movements to assist people in operating the computer. This technology has laid the foundation for gesture operations to be used with a broader range of hardware.

Figure1, Leap motion

Compared with the voice control mode, which was first introduced on the market, gesture interaction can achieve more hidden effects, allowing users to complete the interaction process naturally. Moreover, in terms of the life cycle of technology, because gesture interaction will still be in the embryonic stage of development for a long time, it still needs much time to innovate and improve, so there is a huge vacancy in the current market for gesture-based products. And in the future, gesture interaction mode will become one of the mainstream methods of human-computer interaction.

In all industries, the smart home is an essential field of gesture interaction technology applications. "Smart home" denotes the use of technical systems, automated processes, and connected remote-controlled devices in apartments and houses to improve the home's quality of life and convenience. Furthermore, gesture interaction technology can simplify the product's operation process and make the home more intelligent. According to the smart home user group data, the proportion of elderly users accounted for 8.1% of all consumers. Due to the decline in the physiological functions of the elderly, their learning ability is weaker than that of the young, and they cannot easily adapt to the use of high-technology products. This has led to the fact that smart products that could assist the elderly in life cannot be used by the elderly. And according to another survey, more than 80% of the elderly over 65 live alone or with their partners. Aging and living independently will become a new challenge, so smart home products will play an essential role in their life. For instance intelligence products will replace nursing staff to take care of the elderly. In the smart home market, the elderly will be a significantly large potential user group, and how to design a product operation method suitable for the elderly will be a topic worth exploring.

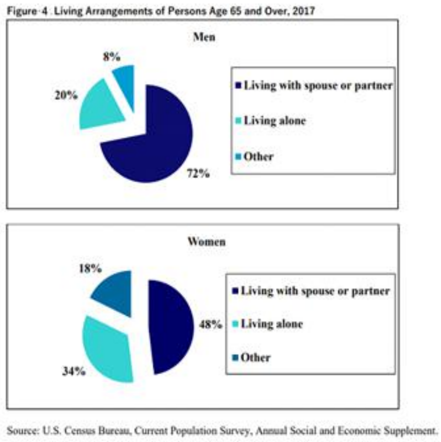


Figure 2, Living arrangement of persons age 65 and over

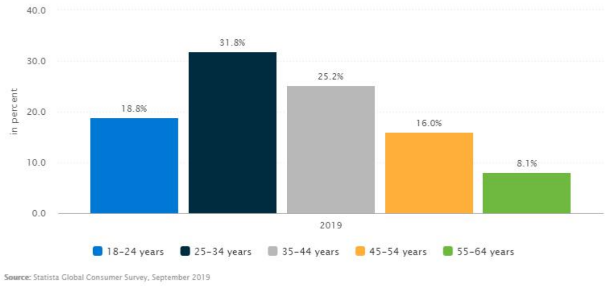


Figure 3, The smart home user group data

1.3 Objectives of study

This research focuses on the gesture control of smart devices to customize the most suitable gesture commands for the elderly. It will focus on the characteristics of the mental cognition of the elderly and the development trend of smart devices. Finally, an effective research method for gesture command selection will be proposed. In the future, researchers can evaluate the pros and cons of gesture commands based on the theory presented in this article.

1.4 Assumptions

This study involves a number of assumptions, detailed as follows. First of all, it is assumed that gesture interaction will become mainstream in the future, and the technology of gesture recognition will be innovated. The system can recognize all human gesture behaviors.

Secondly, people's cognition of gestures will be affected by many different factors such as age, life experience, and family. This study will only focus on a few of these factors and will not consider multiple factors' combined influence.

Finally, it is assumed that the published literature and government statistics are legitimate. And the results of this research can provide designers with references when designing smart products' interactive mode.

1.5 Scope and Limits

The focus of this research is the use of natural gestures in smart home products. Because results maybe affected by regional culture and other factors, the concept proposed in this research is only useful for smart home products used by the older adult in East Asia. Besides, since the interaction model of the product will be affected by the environment, there will be different interaction processes. For example, the interaction inside the car is entirely different from the interaction in the home environment. Therefore, this research only focuses on the research and design of gesture commands for smart home products (including entertainment, security, and lighting).

1.6 Anticipated outcome

This research will identify influencing factors that affect the elderly's understanding of gestures and propose a set of gestures suitable for the elderly. The study will also propose the criteria for selecting gestures in human-computer interaction and will propose a research method for the effective identification of gestures for interaction control of smart devices.

Chapter2 Literature review

2.1 Older adults

2.1.1 Demographics for older adults

The world's population is aging. According to the World Health Organization, people over 60 are described as “elderly”. Virtually every country in the world is experiencing growth in the number and proportion of older persons in their population (United Nations, 2019). The impact of population aging will become a challenge that all countries most face in the 21st century. Globally, the population of persons aged 60 and over is growing faster than all other age groups. Between 2015 and 2050, the proportion of the world's population over 60 years will nearly double from 12% to 22% (World Health Organization, 2018). It is projected that the combined senior and geriatric population will reach 2.1 billion by 2050 (Chucks, 2010).

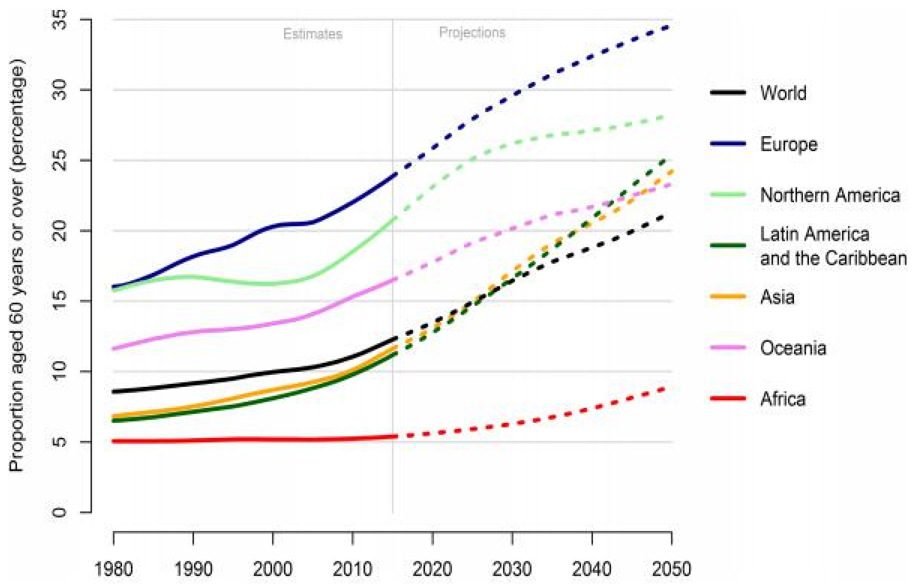


Figure 4, Percentage of population aged 60 years or over by region, from 1980 to 2050

According to the World Population Aging Report released by the United Nations in 2017, the global elderly population's proportion was 11% in 2010. The ratio of the elderly is expected to rise to 21% by 2050. The balance of adults over 60 years old in China is expected to exceed 35% in 2050, which is slightly higher than the 27.8% proportion of the elderly in the United States in 2050 (Demographic indicators related to population aging from World Population Prospects，2017).

According to the World Bank's statistics on old-age dependency ratio, the average world ratio in 2019 is 13.9%, while the ratio in the United States has reached 25% and China has exceeded 16% (World Bank, 2019). This value not only represents the degree of aging but also indicates that the burden of aging on families is increasing in developed countries.

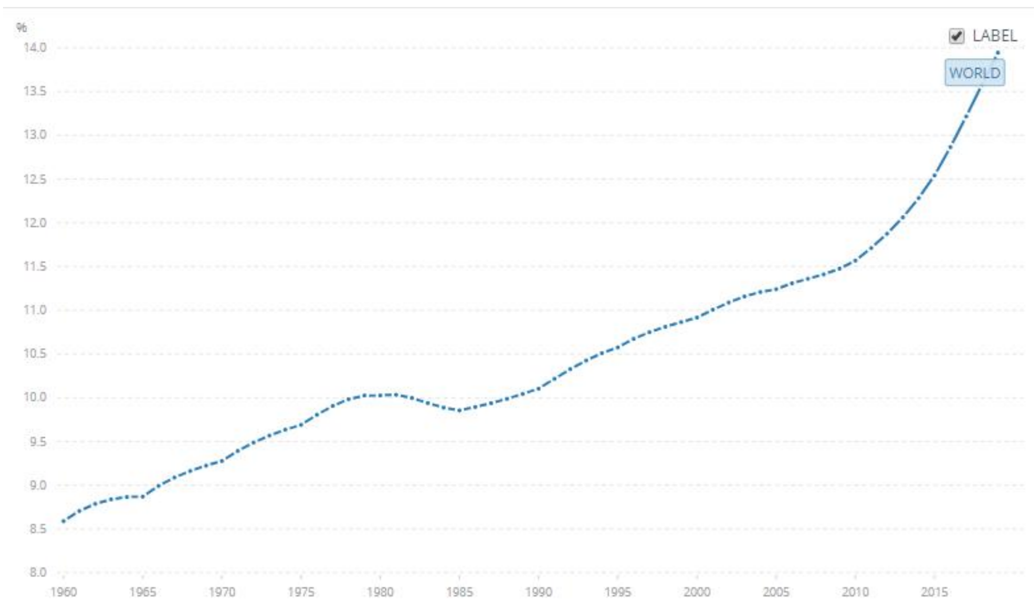


Figure 5, World Bank staff estimates based on age distributions of United Nations Population Division's World Population Prospects: 2019 Revision.

2.1.2 Issues related to an aging population

Based on the above data, it can be predicted that a pension problem will bring difficulties to the family and even society in 2050. Low fertility and increased life expectancy are the two main reasons for the aging population in China and other industrialized countries. According to the United Nations' 2017 World Population Prospects study, due to the improvement of medical treatment in various countries and the improvement of the quality of life of the elderly, the life expectancy of the global population will reach seventy years or more by 2050. The average life expectancy of people in Asia, such as China has increased by nearly thirty years since 1950, and this trend will not be changed in the next forty years (United Nations, 2017). The increase in average life expectancy is an essential factor in society's aging. However, at the same time, low fertility rates also lead to an aging society. In recent years, in Europe, Japan, and other regions, due to the decline in fertility expectations, all countries' birth rate has dropped below 1% (World Bank, 2019). These factors contribute to an increasing old-age dependency ratio and consequently can pose serious economic, budgetary and social challenges in the future (Steg, Strese, Loroff, Hull & Schmidt, 2006).

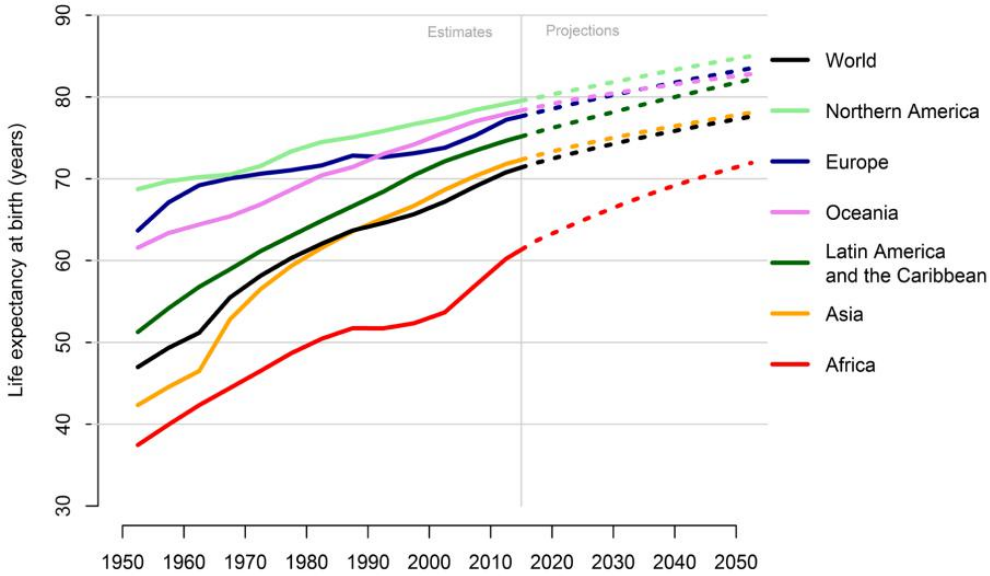


Figure 6, Life expectancy at birth by region, both sexes combined, from 1950 to 2050

To solve the pension problems caused by aging, the government has been making unremitting efforts to this end, such as the Ambient Assisted Living (AAL) program established in 2008. AAL is a European program funding innovation that keeps us connected, healthy, active and happy into our old age. Moreover, it provides a system comprising smart devices, medical sensors, wireless networks, computer and software applications for healthcare monitoring (Muhammad, 2018). A new AARP survey of adults shows that 3 out of 4 adults age 50 and older want to stay in their homes and communities as they age. However, in order for the AAL project to develop and expand its influence, designers need to create auxiliary products that cater to the living habits of the elderly (design for aging). For this reason, the remainder of this section will discuss and analyze changes in the physical and psychological characteristics of the elderly.

2.1.3 Age-related changes

As computing devices continue to become more heavily integrated into our lives, the design of Human-Computer Interaction (HCI) will face more and more difficulties (Williams, Alam, Ahamed & Chu, 2013). An efficient and practical human-computer interaction method requires designers to consider operating habits of different ages and identities of users. Today, the design of HCI is developed and improved around young users. Many older users experience difficulty using digital products. For the elderly user community to effectively use the latest "smart" products, the designer must understand the age-related changes to human sensory, motor and cognitive systems.

The following sections will discuss the changing physical and psychological characteristics of the elderly and their impact on the interaction design.

2.1.3.1 Physical Changes

Vision

The human eye exhibits age-related changes in performance as we age — particularly at sixty years of age and beyond (OD,2019). The change in visual ability affects our daily life, and many activities become challenging due to the deterioration of vision. Table 1 lists the age-related vision changes, the affected vision abilities that are most relevant to the HCI process, and some design recommendations to minimize their impact. Each section of the table is discussed in detail below.

Ability	Age-related change	Design recommendation
Color vision	lose the ability to distinguish specific colors clearly	Avoid using colors with similar hues, especially purples, blues, and greens.
Contrast sensitivity	The ability to recognize the boundaries of objects becomes weak.	The interface uses high-contrast colors
Visual acuity	Decline in ability to resolve small details.	Ensure that the font size is above 12
Glare sensitivity	Increased susceptibility to glare.	Select lights and materials that can avoid producing glare
Temporal resolution	Decline in ability to track stimulus change.	Use rates that are slower than 10 Hz for modulating stimuli
Visual search	The ability to obtain critical information from a large amount of data is decreased.	put important information in the most obvious place

Table 1 Vision degeneration and design recommendations (compiled by the author)

Color vision

A recent study found that with age, many people lose the ability to distinguish specific colors clearly. This loss usually starts around the age of 70 and will get worse over time (Dotinga, 2014). When they are over 70, their eyes' lens may turn yellow, which makes them look through a yellow filter. This will destroy their "blue-yellow" vision, making them unable to distinguish between blue and purple, yellow and green in some cases. In one study, researchers conducted color vision tests on nearly 900 people between 58 and 102 years of age. Color-vision problems in the blue-yellow spectrum affected 45 percent of people in their mid-70s, and that proportion rose to two-thirds by the time people reached their mid-90s (Dotinga,2014).

"Deterioration of color vision is as inevitable as death and taxes" stated Stephen Dain (Dotinga,2014), who studies color vision as a professor with the School of Optometry and Vision Science at the University of New South Wales, in Sydney, Australia.

Contrast sensitivity

Contrast is the difference between two colors, shades or tones. When we discuss vision, contrast is an important part that enables us to recognize and distinguish objects from the scene in which they are located (Sorensen, 2015). For example, when people are standing on the side of the road and waiting for a car, people will see a black car passing by on the road. People can accurately determine the car's position through the color difference between the car and the road. Even when the object moves at high speed, the human eye can accurately distinguish it by color difference.

Healthy visual perception can ensure that people accurately identify objects, but unfortunately, contrast sensitivity is most likely to disappear with age. For example, cataract is a common disease of the elderly. Because of the protein disease in the eyes, the visual contrast of the elderly will be affected, making it difficult for the elderly to perceive the surrounding details and increases the probability of accidents. However, it is a pity that there is very little research in this area overall. Designers can only rely on the small amount of literature they have to consider smart devices' color usage. In choosing product colors for the elderly, designers will try their best to use tones with a stronger contrast, especially in interactive nodes such as buttons and touch screens.

Visual search

The visual area where valid information can be obtained by monocular gaze is called “The useful field of view”. This area will gradually become smaller with age, which means the ability of visual search is weakened (Ball& Beard,1989). Furthermore, older adults will have more difficulty selecting target information in a stimulus display when the number of items to be searched increases (Plude & DoussardRoosevelt, 1989). For example, irregularly stacking a large amount of information in the layout design of a book will cause reading troubles for readers of all ages and significantly impact the elderly. Therefore, the effective visual range arrangement is the key to whether users can quickly understand how the product is used. In one study, Kline and Scialfa (1997) recommend that the object of focus should be presented with consideration to the primary fixation point, be made salient in terms of conspicuity by reducing competing stimulus clutter, and be of high contrast. The product's interactive model can also follow the above suggestions, simplify the interactive information, and present it most conspicuously when facing elderly users to improve the product's usability.

Conclusion

“Vision impairment and blindness are among the top five causes of disability in older adults,” says Dr. Cynthia Owsley, an eye researcher at the University of

Alabama at Birmingham (cited in Wein, 2017). Therefore, products designed for the elderly must take into account the problem of visual decline. The other four human perceptions can compensate for the defects of visual perception in the product interaction process. The following sections will discuss other perception methods of the elderly and their psychological characteristics.

Hearing

Hearing loss is one of the most widespread issues among older adults (Cavanaugh & Blanchard-Fields, 2006). One in 3 adults over age 65 exhibits some level of hearing loss ("Age-Related Hearing Loss", 2018). Degradation of hearing will be inconvenient to the life of the elderly. They will experience obstacles in communication with family and friends, and gradually they will be separated from society. In more serious cases, loss of hearing can result in loss of independence, social isolation, irritation, paranoia, and depression among older adults (Cavanaugh &Blanchard-Fields, 2006). Hearing loss is typically a slow developing process. After 60 years of age, hearing typically declines by about 1 dB annually. 80% of the elderly over 80 have hearing loss (Eyken, Camp & Laer, 2007) and men's probability of hearing problems is often higher than that of women (Matthews, 2005). Therefore, smart devices need to increase the decibel of playing sounds, use low-frequency sound waves when facing elderly users, or use visual cues to help guide actions.

Conclusion

Hearing loss is the most serious in the process of human aging. The weakening of hearing makes the elderly unable to receive voice prompts and unable to quickly perceive the dangers in life.

Although hearing is not directly related to gesture-based interaction, it can guide designers in developing more inclusive user interaction modes. Therefore, designing an interactive method based on the hearing ability of the elderly needs to be considered by the designer.

Touch

Tactile processes are the way people feel temperature, pressure, pain, and vibration. There are countless nerve endings in the skin, muscles, and internal organs. These nerves are responsible for receiving external stimuli and transmitting information to the brain through the center ("Aging changes in the senses", 2020). With age, the nervous system's sensitivity will also decline, and tactile perception will degrade like vision and hearing (Wickremaratchi & Llewelyn, 2006).

Kenshalo (1986) compared the sensitivity of the elderly and the young from six aspects. The study uses a quantitative assessment method finding that the elderly are significantly degraded compared to the young in the four aspects of perceptual acuity. The pain perception does not change due to age, because the signals of pain perception are all transmitted by C fibres, and the function of this tissue will not be affected when people get old. Therefore, the perception of pain by the elderly is the same as that of the young (Chakour et al., 1996). However, the elderly's perception of temperature and vibration will be affected by skin hydration, which will reduce the perception of the skin surface (Gerontol, 1992). For example, the elderly can pick up hot dishes with their hands during cooking, and the elderly often fail to notice the vibration of a mobile phone. Such situations are signs of deterioration of the elderly's skin perception. Besides, studies have also found that the degree of sensory degradation in different parts of the elderly is different. Their fingertips are the most severely degraded part of the sense of touch (Verrillo, Bolanowski & Checkoski, 1998). Therefore, the feedback of product interaction in human-computer interaction is worth discussing. Feedback should consider the elderly's degradation of vibration and tactile sensation. The interaction process may need to increase vibration frequency or use physical buttons to enhance the feedback's prompt information.

Implications

Product interaction models designed for the elderly need to consider the particularities of the elderly in various aspects. This section lists the changes that the elderly have experienced as they age in the visual, auditory and tactile senses. With the increase of age, the physical functions of the elderly are degraded, even affecting daily life. The design of auxiliary products that consider the physical conditions of the elderly is what society needs.

While a gesture-based interaction is about designing gestures, it also needs to consider the body of the elderly in comprehensive way. Combining visual, tactile, and auditory perception can better serve the gesture interaction system.

2.1.3.2 Cognitive changes

Cognition and interaction design are closely related. In many cases, the interaction mode may meet the needs of the elderly's hearing and vision capabilities, but users may not understand its use logic. Moreover, people's cognitive abilities will decline with age (Anstey & Low, 2004). After several age changes, some products suitable for young people may not be accepted by older users.

The cognitive abilities related to interaction design are attention, working memory, long-term memory and spatial cognition.

Attention

"Attention refers to our limited capacity to process information" (Fisk et al., 2009, p. 22). Attention is a basic but complex cognitive process. It has multiple sub-processes dedicated to different aspects of the attention process (Riddle, 2007). Researchers divide it according to different methods. This article uses the most commonly used classification method in aging research, and it divides into "selective attention", "sustained attention", "divided attention" and "attention switching".

Firstly, selective attention refers to the ability to attend to some stimuli while disregarding others that are irrelevant to the task at hand (Riddle, 2007). Firstly, selective attention refers to the ability to attend to some stimuli while disregarding others that are irrelevant to the task at hand (Riddle, 2007). In an experiment, researchers write words on paper that do not correspond to the font color, for example, BLUE, RED, GREEN. The subject needs to answer the correct color in the first reaction. In this process, the subjects need to ignore the interference factors and filter out useful information, but because the interference is given by the word information they often make mistakes. The final experiment results show that generally speaking, the number of errors and reaction time of the elderly is longer than that of the young. As they age, it will take longer on average for them to process the same information.

Next, sustained attention refers to the ability to focus on an activity or stimulation for a long time. This ability helps us focus on completing specific tasks and activities even when we are disturbed by the outside world (Williams & Saunders, 1997). This may be a problem for the elderly because studies have shown that they are more likely to be distracted by factors unrelated to the task, and they are slower when they complete tasks which take longer than five minutes.

Lastly, the primary manifestation of attention degradation with age is divided attention and attention switching (Riddle, 2007). Studies have shown that older people are more affected by attention's division than younger people, especially when both tasks' attention needs are high. When dealing with multiple important tasks, older people seem to be unable to allocate resources appropriately. These results cannot be entirely attributed to the slowing down of their information processing speed. However, they may be due to the overall decline in the processing resources caused by normal aging. When this limited resource is over-utilized, attention cannot satisfy the allocation between two or more tasks. Similarly, when attention must be shifted from one task to another, the performance of the elderly is much slower than that of the young.

The elderly's attention will be disturbed by many stimuli, so the product's interaction should be direct and straightforward. Designers need to avoid clutter and remove redundant information when designing interactive modes.

Memory

Working memory

Not all types of memory are affected by age, and the performance of age-related changes in some memories is more remarkable than other types (Fisk et al., 2009). Among them, working memory is considered to be the fundamental source of age-related memory decline. It is a multi-dimensional cognitive structure, including long-term memory, language, problem-solving, and decision making (Riddle, 2007). In a sense, working memory is a cognitive activity that requires the brain to maintain short-term memory while distracting from other tasks.

Researchers designed an experiment for the working memory of the elderly (Miller, 1956). They arranged a phone number irregularly to allow the elderly to remember. In a short period, the elderly can memorize 7 ± 2 numbers. This experiment results are similar to those of the young, which shows that the working memory of the elderly has not deteriorated due to age. However, when older adults are asked to reorganize numbers and perform more operations, their performance is far worse than young people. As mentioned in the previous section, when the elderly need to perform two tasks simultaneously or need to switch between tasks, the elderly will be more affected by the division of attention than the young, and their reaction speed will be affected by age.

Therefore, the decline of working memory will significantly impact life, such as language, semantic understanding, problem-solving, etc. In order to cope with the problem of working memory decline. Pak and McLaughlin (2010) suggest providing elderly users with all the necessary information when they perform operations, instead of expecting users to memorize the operation mode, to avoid using working memory.

Long-term memory

In the normal aging process, long-term memory may be of the most concern. Many people worry that they will forget the past when they get old. Long-term memory includes episodic memory, semantic memory, autobiographical memory and procedural memory. Among them, only episodic memory and autobiographical memory will become less accurate with age.

Episodic memory refers to an event that happened at a specific time and in a specific place in the past. It is most affected by normal aging (Riddle, 2007). For example, an older adult may remember scenes from a previous college graduation, but their memories of graduation become more and more blurred as time goes by. This is a manifestation of episodic memory aging. Autobiographical memory is the same, except that it represents memories from a period in the past, which will also be affected by aging.

Procedural memory is responsible for storing automatic processes required to perform certain tasks (Pak & McLaughlin, 2010), such as typing, cycling, etc. These skills will not be forgotten with age. However, it is difficult for the elderly to learn and develop a new automatic process (Fisk et al., 2009).

Therefore in the design project, it is best to use the existing knowledge reserves of the elderly to formulate operation methods to not bring more memory burden to them.

Spatial cognition

Spatial cognition generally refers to people's cognitive process judging their position through the surrounding environment's information. It generally includes four areas: visuospatial perception, mental imagery, memory and navigation. With age, visuospatial perception and mental imagery are not significantly affected, but spatial memory and spatial navigation will worsen (Després, Klencklen & Dufour, 2011), and usually spatial navigation and product interaction design are closely related.

In a 2001 study, researchers asked testers to find specific targets in a virtual navigation (mobile phone interface). The results of this study show that older adults are more likely to make spatial memory errors when searching for targets, and it takes longer for them to find the target file, compared with young people. Moreover, research has found that the elderly’s defects in planning and integrating routes are the main reason for the decline in their spatial navigation capabilities (Després, Klencklen & Dufour, 2011). Therefore, in the interactive mode, older adults prefer shallow navigation systems for online navigation. If the designer sets overly complicated commands and menu items, it may be difficult for the elderly to understand and operate.

Psychological and social changes

As discussed above, with physiological and cognitive changes, daily life will face more challenges as we age. These challenges will change the social habits and emotions of the elderly.

First of all, “Socioemotional selectivity theory maintains that motivation changes as people age and time horizons shrink”（Carstensen， 2006）. Young and healthy people usually think that the future is vast. When people think that time and space are endless, they prioritize their goals and focus on acquiring new knowledge and information to prepare for a long and fuzzy future. However, as people age and when life is limited, goals increasingly emphasize emotion and meaning. People are becoming more aware of the gains and losses related to age, so they tend to choose more realistic and short-term achievable goals. The natural interaction methods that conform to the habits of the elderly can sufficiently meet their needs. The elderly can rely on advanced technology to most conveniently achieve their goals, helping the elderly relieve time anxiety and increase contact with society.

Besides, life experience will also change the elderly's ability to deal with problems (Blanchard-Fields, 2007). Compared with young people, they have more life experience to regulate their emotions better, but when encountering unpredictable pain, the advantage of the elderly's ability to regulate will disappear or even reverse (Leclerc & Hess, 2007). In social cognition, the elderly are often defined as a group with loneliness, depression, and cognitive deficits (American Psychological Association, 2012). This concept also affects the self-perception of the elderly, so when performing specific tasks, especially in the learning of new knowledge, the elderly will often be unconfident and anxious, and they will think that they are too old to use the new technology (Turner, Turner, & Van De Walle, 2007). However, studies have shown that teaching and demonstrating the superiority of new technologies to the elderly can change their stereotypes (Czaja & Sharit, 1998). In many cases, the elderly do not like to use high technology products because of fear of the unknown and fear of making mistakes. Therefore, the following chapters will focus on smart home technology and its connection with the elderly.

2.2 Smart homes and older people

This section provides some background information to support this design research, including the definition of smart home and its connection with the elderly. By understanding the history of smart home and analyzing current products, scholars summarized the design trend of smart home, which guides these research projects' promotion.

2.2.1 History of smart home

How to define the smart home? The term "smart" has always lacked a measurement system (Blumendorf, 2013), so everyone has a different understanding of "smart". The concept of the so-called “smart home” has not been accurately defined until recently, and has become more widely recognized by the public. People generally think that all products connected to the Internet and can be controlled through mobile phones are called "smart products, " but this is not the most accurate definition. The definition of smart products needs to be considered from multiple aspects such as users and technology. Other scholars have previously proposed that "smart homes" can be defined as homes equipped with computers and information technology (Richard Harper, 2003). Some scholars also believe that any home can be a smart home, whether it is a studio apartment or a mansion. It is the powerful connections that make it smart (Josh Hendrickson, 2019). These concepts are correct, and they all have one thing in common: they all emphasize similar smart technology, but the user experience is indispensable in defining smart home. "Make people's lives more comfortable" is the most crucial purpose of smart homes. Therefore, the following content will mainly explore the meaning of smart home in history and explore the potential connection between the development of smart home and the lives of the elderly.

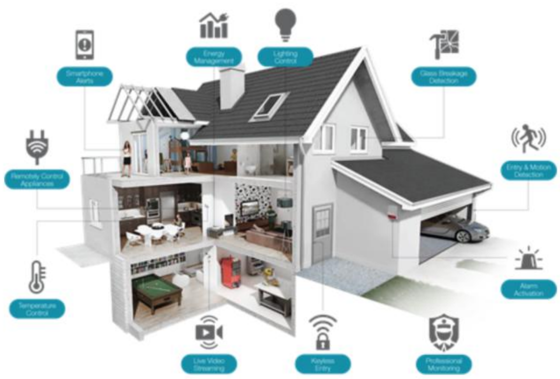


Figure 7, Smart home

Initially, the smart home concept was just a fantasy about the future. It was closer to the subject matter of science fiction than the actual structure. For example, *The Jetson's*, an animated cartoon broadcast on ABC-TV in the United States in 1962, described the Jetson family's story of living in a world full of high-tech products.

There are exquisite robots, spaceships, aliens and various whimsical inventions. Perhaps due to technical limitations, this could only appear in the public eye in the form of animation, but with the development of the technology, some concepts are being realized, and the concept of the smart home is gradually formed from an illusory idea.

Figure 8, The Jetson’s

1901-1940 The invention of various electrical appliances laid the foundation for the smart home's emergence. The emergence of household appliances began in the early 20th century. The American Richard Jones invented the electric iron in a coincidence. When this product was put on the market, it was warmly welcomed. Since then, it has opened the door to household appliances and led a wave of household appliance inventions. In 1907, a vacuum cleaner which served as a prototype of a modern product came out. In 1910, electric washing machines and compressor-type household refrigerators came out one after another. The electric stove appeared in 1914. In 1930, room air conditioners came out. In 1937, the fully automatic washing machine was successfully developed. Since then, the output of electrical products has proliferated, and the variety has been continuously increased and updated.

ECHO IV was the first device recognizable as the concept of the smart home. It was created in 1966. Its appearance heralded the development of the smart home in real life. Through the ECHO IV, users can perform simple operations, such as turning on the TV and setting the alarm clock. It was apparent that this technology was revolutionary in the 1960s. Then in 1969, Neiman Marcus put forward the concept of the kitchen computer (figure 9). Users only need to press the button to get a delicious lunch, which saves the complicated cooking process and puts delicious food at their fingertips. This was just an idea that had not yet been realized, but this idea has taken the smart home a big step forward.

Figure 9, The kitchen computer

By 1980, the American business community was very interested in home automation and established an organization called "Smart House" to promote technology integration into the construction field. Important developments included the replacement of electromechanical switches with digital switches and the establishment of new communication networks. Under this high degree of attention, smart home technology has been dramatically developed in construction, electrical appliances, and energy control. In 1984, the first smart house in history appeared in

Connecticut, USA. It controlled the air-conditioning, lighting and other equipment of the entire building through a computer, and provided information services such as voice communication and email. Its original definition is: Using home bus technology (HBS) to connect various information-related communication equipment, household appliances, and home security devices in the house to an intelligent home system to control and manage, and also maintain these home facilities and residences harmony and coordination of the environment.

In the 1990s, the emergence of the Internet made smart homes enter popular culture. Smart homes were frequently being mentioned by some popular magazines. More film and television works continue to appear. For example, Disney's smart home in 1999 described a series of interesting stories about a genius child and his stern mother after he won a smart house. These phenomena all reflect the popularity of the smart home concept at the end of the 20th century. The development of the Internet in the 1990s also gave support to smart home technology and concepts. Researchers developed AUDREY 3com at the end of the 20th century. AUDREY 3com is an internet application device that users can use to connect to the Internet to receive mail. Don Fotsch and Ray Winninger's original intention in designing AUDREY 3com was to realize a vision of household appliances that "Every appliance is designed for a specific room in the house." Similarly, the Ergo brand also wants to convey this concept: "The appliances are in the kitchen, so it is designed that way" (Hudson, n.d.).

This concept emphasizes the particularity of products in different spaces, and it has a guiding role in the improvement of product humanized design.

It can be said that the 90s was birthed today’s era of smart home. From the fantasy that existed in people's minds to the real entry of smart homes into our real lives, the concept of smart homes was formed after 50 years. In 1998, *Home Energy* magazine gave a new definition of smart home: Advanced home control systems have several names, including smart home, home automation and integrated home system. However, all systems allow people to conveniently control home electronic devices, including video, TV, network, security systems and household appliances. The control system can also provide information and report the house status to users regularly, such as energy consumption and house safety information. And this system also has the function of remote control. Users can give operation commands to home appliances on the way from getting off work (*Home Energy Magazine Online* May/June 1998).

If the 20th century is the budding of the smart home, then the beginning of the 21st century is the pioneering smart home period. The concept of the smart home has been changing with technological innovation. In the original concept of home automation, designers hoped that users could adapt to machines and learn various electrical appliances' operating procedures. In the late 1990s, due to the internet's invention, smart home designers paid more attention to the connection between objects and controlled the air-conditioning, lighting, and communications equipment inside the house through wired networks. The objective of smart homes in the 21st century is to explore what users might want and to combine existing science and technology. Designers will focus more on users' perspectives to make houses smarter and people's lives more comfortable.

Figure 10, Smart home devices

In February 2001, Orange, the UK mobile network operator, announced the'Orange at Home' project. This is a 50-year-old house, it has been connected via the Internet, and a server controls the local area network. Users can control home equipment through WAP, SNS, etc. In this project, the researchers found that sometimes a successful technical case in a work environment will have problems when applied to the home environment. This is not a technical problem, but the environment's difference leads to various users' needs (Harper, 2011). Moreover, this also coincides with the concepts of Don Fotsch and Ray Winninger (2001). Sometimes the best technology is not the highest technology. User needs are the first consideration, and the use environment determines whether the technology is applicable. For example, in recent years, AR\VR home entertainment equipment has attracted much attention, but it also needs to be set up in a proper environment for use. If it is placed in the living room or bedroom, it can play a good home entertainment function, allowing users to relax. However, it is unreasonable to install it in the kitchen or study room. The wrong environment will inhibit the user's demand and cause it to lose its function. "Appropriate" is one of the keywords in smart home design.

The development of the smart home concept is still in its infancy. In today's market, only a few smart houses are built and sold; a big reason for this is that they are costly. So energy-saving and material-saving have become another major trend in the development of smart homes. Gann (1999) has proposed several reasons for the slow popularization of smart home technologies. He pointed out that smart homes are expensive because users need to purchase a series of new smart products and equipment to realize home intelligence. Secondly, most of the current intelligentization of houses is based on the renovation of old houses, which causes users to spend high prices on house wiring. Of course, this problem is partly solved with wireless networks and Bluetooth technology, but it comes with the increase in the probability of equipment failure due to the complexity of the technology, and users need to pay expensive maintenance costs. Moreover, manufacturers are obsessed with technology to promote the intelligentization of houses while ignoring the user experience. Consumers want to use the system to facilitate operation, simplify the use process, save energy, and reduce costs (Meyer & Schulze, 1996), not just using the latest technology.

On the other hand, smart homes' failure to develop rapidly is also due to people's fear of the unknown in the future. Users are unsure whether to introduce smart technology into their homes, a fear illustrated by movies such as *Demon Seed* released in 1977 and the *Dream House* (1998). These movies tell the story of smart houses taking control over its occupants. Although the movies use exaggerated art techniques, this also reflects people's worries about new technologies at that time. "How smart does the bed in your house have to be before you are afraid to go to sleep at night?" This fear has not disappeared even today. The sci-fi TV series *Weird City* released in early 2019 included absurd stories about the murder of several residents by smart houses. Most people still have a sense of distance with technology, especially the elderly user groups. Another possibility is that they will feel inferior and think that they have been out of society, so they reject the development of new things.

In summary, smart home is an intelligent system based on household appliances and smart technology to make it easier for users to control products. Like the concept of calm technology mentioned in the previous article, smart home systems' development trend has always been around the human-centred concept, using hidden and invisible operation methods to save users' learning costs as much as possible and complete operation commands under people's natural actions. This will become the future development direction of the smart home.

2.2.2 Current product analysis

The first voice-recognition smart home device was released in 2015. Smart devices based on voice control have become the mainstream of the market. Amazon Echo is the most representative smart device among them. The features of the device include voice interaction, music playback, making to-do lists, setting alarms, streaming podcasts, and playing audiobooks, in addition to providing weather, traffic and other real-time information. It can also control several smart devices, acting as a home automation hub (Amazon.com, 2015).

Figure 11, Amazon Echo

This product is connected to other devices via Bluetooth or wifi. When using Echo, users need to turn on the device through a "wake word", say "Alexa", and then give Echo a voice command. For the elderly, language functions belong to procedural memory. This article has pointed out that procedural memory will not degenerate with age. Therefore, using voice commands as the primary control method can significantly reduce learning difficulty for the elderly. Furthermore, Echo's remote control interface only has five buttons and uses high-contrast prompt symbols. Compared with traditional remote controls' complicated button settings, Echo's products are easier to use and avoid user's misoperation in actual use.

Echo uses voice mode instead of the traditional touch interface and physical switches to create a more comfortable experience for the elderly, but it still has some shortcomings. First, research shows that the short-term memory of the elderly will be greatly affected as they age, and they will encounter difficulties when they need to remember long passwords. Especially older people with particular diseases such as Alzheimer's disease patients, they cannot remember a complete voice command, so they may not be able to use this product.

Secondly, current speech recognition technology is not mature. The Echo device currently only supports English and German, and Echo is still unable to distinguish some homophones and modal particles such as "umms" and "ahhs". (Allison, 2017) Besides, many older adults will become blurred due to illness and other reasons, which will bring more significant challenges to intelligent voice assistants. After all, a smart device is a machine. It cannot understand the user's tone and deep meaning. Under current technical conditions, it is impossible to communicate with it without obstacles.

Further, some users have suggested that Echo sometimes automatically plays songs late at night, which is a terrifying experience. The elderly maybe afraid of such technology. Some unexpected situations may make them feel that the product is unknown and uncontrollable, and they will feel resistance to such products.

In summary, taking Echo products as an example, there are always some smart homes problems under the current voice control system. Due to the deterioration of the physiological functions of the elderly, these problems will become more serious. Therefore, some scholars put forward the concept of silent interaction. They believe that the operation method formulated through natural behavior will replace voice control and become the mainstream in the future (Kevin, 2019).

Hayo is a virtual control terminal. It connects to your favorite smart home platforms and products (like IFTTT, Wink, Sonos, Nest) and gives you the ability to control them with simple hand motions.

Figure 12, Hayo

The listing of Hayo's product confirms that silent interaction will become the future development trend, and it also fits with the "calm design" concept I mentioned before. The use of calm technology is paired with ubiquitous computing as a way to minimize the perceptible invasiveness of computers in everyday life (Alexandru , 2004). Hayo collects information in the room through three 3D sensors. The user only needs to set the gesture and position of the trigger function through the app. Through simple actions, people can control the switch and adjustment of smart home appliances. In this mode, users set gesture commands through their habits, making the whole use process more smooth.

In the design involving elderly users, because the cognition of the elderly group is different from that of the young people, and the memory function declines due to age, smart products' operation requires them to overcome huge obstacles. The concept of "calm design" emphasizes "that which informs but does not demand our focus or attention" (Weiser&Brown, 1995). This allows the user to complete the operation in their subconscious action, and gestures based on natural behavior also can better reduce the difficulty of the elderly.

Figure 13, The selected gesture set(Song, Wang, & Chen,etl., 2019)

The gesture-based system allows people to operate products more conveniently, but it is more prone to misoperation due to the lack of visual cues. As shown in the figure above, the meaning of some gestures may vary in different countries and regions, and different people have a different understanding of gestures. Designers need to find gestures that people have reached a consensus on and integrate those gestures into the smart home's control system to achieve the purpose of silent interaction. Taking volume adjustment as an example, people usually assign "right and upward" a positive meaning. Therefore, when designing volume adjustment gestures, pointing up with a finger represents increasing the volume. However, the old people's impression of the volume adjustment action is generally controlled by the knob, so in the interactive mode for the elderly, the volume adjustment method must be adjusted. In order to adapt to the cognitive structure of different groups of people, the settings of the gesture system need to be changed accordingly.

Finding a series of common gestures is the basis for smart homes to move towards silent interaction. This article will summarize a set of gesture models that conform to the living habits of the elderly. The next section will focus on analyzing smart products' interaction methods, especially free hands gesture-based interaction. Products that can be used without learning are the smart homes that the elderly dream of.

2.2.3 Potential benefits and disadvantages of smart home for older adults

Smart homes obviously can make life easier and more convenient, but technology also brings new difficulties to life. This section will analyze the security system, lighting, and entertainment of the smart home.

1) **Security system**

Housing safety is essential for both the elderly and the young. The smart home security system provides the homeowner with security protection functions such as image monitoring, detection and alarm, and automation assistance. When there is a hidden danger in the house, the homeowner can get early warning information, thereby reducing losses. The security hardware includes doors, locks, alarm systems, lighting, motion detectors, and security camera systems. Taking smart door locks as an example, according to an FBI report, 58.3% of burglaries in the United States involved forcible entry ("Burglary" FBI, 2016). If the smart door lock has an alarm function, it can warn the intruder and remind the homeowner to defend, effectively protecting the personal safety of the homeowner. In addition, smart door locks replace traditional keys with fingerprints or passwords, which fundamentally solve the problem of people forgetting to bring their keys or losing them when they go out. Moreover, in the future, the design of door locks will be combined and developed in tandem with voice recognition, face recognition and other technologies. Users can also make more custom settings to ensure home safety.

However, the current market feedback shows that the elderly users do not like smart locks very much, mainly because the current recognition technology of smart door locks is not accurate enough to support the elderly users with severe skin wear, so the elderly cannot use the fingerprint recognition function usually. Secondly, using a password to unlock is a more significant challenge for the elderly. Even young people will forget passwords with more than six digits. Moreover, the memory of the elderly has begun to decline, and password unlocking is not suitable for the elderly. So taking smart locks as an example, such products can improve people's quality of life, but at the same time, there are many obstacles to popularizing it to users of all ages.

2) Lighting

Smart lighting is a lighting technology designed for energy efficiency, convenience and security, and there are wall panel units for controlling lighting and other functions. The system uses a touch panel to replace traditional physical switches. It also adds the brightness adjustment and memory function to provide a more comfortable lighting environment for the elderly. The *Chinese People's Daily* article pointed out that the elderly have many requirements for lighting: 1. They prefer a single warm light source; 2. Due to the degradation of the visual system, the brightness of home lighting is brighter than that of young people; 3. They will go to the bathroom many times at night, so the assistance of smart night lights is also needed; 4. The most important thing is that they need an easy-to-operate switch mode (Dong, 2017). The control panel of lighting system unit stores multiple lighting modes. The elderly can easily control the home lighting by tapping the touchpad, and the brightness adjustment function can also meet the needs of the elderly at different periods. However, the smart panel also has some shortcomings. For example, the touch panel's feedback is not as direct as the physical switch, so the elderly occasionally misuse it, but this does not affect the improvement of the life of the elderly brought by smart technology.

3) Entertainment

You should never stop having fun however old you are. According to a survey by *People's Daily Online*, the favorite entertainment of 88.9% of the elderly in China is watching TV dramas. Their entertainment activities are relatively simple. The entertainment system of the smart home can provide them with various audio-visual facilities and entertainment methods. For example, the somatosensory game produced by Nintendo is simple to operate and can also provide an opportunity to exercise. The elderly can play with friends and family, which makes their home life more fun. Intelligent audio-visual equipment has given the elderly more entertainment projects and created a more comfortable leisure environment. However, the entertainment system also faces two problems: the first is that the high price is not affordable for all users, and the second is that users may be afraid of the unknown of technology, a tendency that makes the elderly avoid smart products.

There is no doubt that a smart home provides a more comfortable life for the elderly, but every coin has two sides. The new operation of smart products and the unknown brought by technology discourages the elderly from using them and sometimes the technology even hinders their lives, making them feel like they have been separated from society. Therefore, an operating system suitable for the elderly is in urgent need of development.

2.3 Smart home interaction

With smart home technology development, people are also making various attempts to interact with smart devices. Currently, smart home products mostly revolve around keyboards or touch screens for interaction. However, as technology advances, more possibilities are waiting to be developed, such as gesture-based interaction methods.

This section uses the interactive method as the classification standard to divide the smart home into two categories: device-centric interaction methods and user-centric interaction methods.

Device-centric interaction generally refers to an interactive mode in which users control smart homes or virtual objects through physical products such as mobile phones and remote controls. In this mode, the user uses the device as a magic wand to perform various command instructions (Brown 2017). People are familiar with this control method. People would use remote controls to control TV sets and use switches to control lights in the past. Nowadays, people use mobile phones to control home appliances and every smart product. Device-centric interaction methods are the most popular interaction mode in household products. They have been used since the invention of home appliances. This section will analyze them based on the types of interactive media.

Controlling household appliances through the keypad is the most primitive method of operation. In 1898, American inventor Nikola Tesla invented the earliest remote control, called "Method of and Apparatus for Controlling Mechanism of Moving Vehicle or Vehicles". The invention of the remote control provides people with a way to control the product machine from a distance, and it combines all the product functions in one panel, which brings much convenience to people's lives (Chandler, 2011)

Figure 14, Remote control, Peter Ha. (2010).

However, with the increase of product functions, the remote control interface can no longer carry more buttons. The complicated button layout has caused the user's learning cost to rise, and many user groups have difficulty mastering the remote control. Take the following product in figure 15 as an example. This is a standard TV remote control. In this small plane, it gathers fifty-two buttons and adopts an eight-color button design. Such a complicated interface is a great challenge for many people, especially for special groups such as the elderly. Due to the degradation of visual perception and memory loss, they will encounter more significant challenges when using such products.

Figure 15, TV remote control

In general, the interactive mode of keyboard input has accompanied home appliances for nearly a hundred years, so most people are familiar with this method's use, but with the development of the times, product features are becoming more and more abundant. As the user's learning time continues to increase, the remote control can no longer meet the user's needs. After 2010, the button control mode has been gradually replaced by the touch screen. The touch screen of the smart home uses IoT technology to interconnect home appliances. One screen can carry the switches and adjustments of all home appliances, and users can also customize various function buttons on the screen. Compared with the button panel, the touch screen provides more detailed control on the basis of multi-layer hierarchical menus. Although the touch screen's feedback is not as direct as the traditional switch, the high efficiency and fast characteristics of the touch screen have made it contemporary and mainstream.

Figure 16, Touch screen control

The current product model established with mobile phones or tablet computers as the medium is the core of the market. In recent years, augmented reality (AR) technology has developed rapidly. Mobile phones have become a carrier connecting virtual and reality. The real world is connected to another parallel world.

Figure 17, Pokémon Go

Pokémon Go is a 2016 augmented reality (AR) mobile game developed and published by Niantic. In this software, the mobile phone is no longer a substitute for the remote control to control home appliances' function. It is the connection portal between the 3D world and the Pokémon world. Pokémon is put into our world and communicates with characters based on a series of specific interactive gestures. In AR scene interactive applications like this, smart devices expand our perception (vision), and mobile phones become our "other eye, " allowing us to see characters and scenes in comics. With smart devices' help, the integration of the interaction between virtual and real scenes will be the direction of the future development of device-centric interaction.

In general, the era of keyboard input has passed, touch screen input has occupied the mainstream of the market, and more technology will be used in interactive design in the future. The device-centric interaction for mobile AR, especially like some Tangible User Interfaces (TUIs), can give the user vibrative and tactile feedback to provide a clearer understanding of the operation status (Huidong, 2016). However, this interaction mode forces users to learn new input methods every time, which is more difficult for the elderly. On the contrary, user-centric interaction methods will be easier to learn and use, and their operations are closer to people's habits.

Unlike the device-centric interaction methods that heavily rely on the device as an intermediary, user-centric interaction directly accepts the user’s natural behaviors, like free-hand gesture, gaze or speech, as input signals (Bai,2016). This type of interaction method formulates command sets based on users' natural behaviors, making the process of human-computer interaction more natural, convenient, and efficient.

Hand gestures are an important modality for human computer interaction. Gesture is an important nonverbal medium of communication. Gesture can not only assist language communication but also has independent communication attribute. In daily communication, gestures have the function of explaining and emphasizing emotions. It often occurs naturally with language. It has the characteristics of unconsciousness and implicitness. Novack and Goldin-Meadow (2015) pointed out that the thought information conveyed by communicator's gestures is not a repetitive expression of language information, which is beyond the scope of the information of the language. The communicator's gestures often reveal new information outside of certain languages, and this new information is difficult to express in language. As an independent expression, gestures can express abstract thought processes through body movements more intuitive and convey meaning accurately. In a real communication situation, both parties can usually capture gestures and decode them accurately. Therefore, gesture-based interaction modes are often more intuitive and convenient than language and help reduce communication's cognitive load (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). In gesture interaction, users can use the most direct actions to issue commands to the product to simplify the interaction process, and studies have shown that even blind people who have never seen any gesture expression will also use gestures in communication. The gesture is an integral part of language communication, and it is also the most efficient mode of human-computer interaction (Iverson & Goldin-Meadow 1998; Kang, Tversky, & Black, 2015; Novack & Goldin-Meadow, 2016; Weinberg, Fukawa-Conolly, & Wiesner, 2015).

The gestural commands for smart products can be characterized along three dimensions: Cognitive aspects, Articulatory aspects and Technological aspects. Cognitive aspects refer to how easy commands are to learn and to remember. All gesture commands should be natural and intuitive, and the meaning of gestures needs to be easy to understand, whether for young or old. Compared with gestures in people's language communication, gesture commands aimed at manipulating devices are less affected by culture and background. People from different cultural backgrounds have similar cognition of basic gestures such as opening and closing. However, the generation gap between the elderly due to limited learning ability and different ages will cause differences in understanding gestures. For example, taking the gesture of making a phone call as an example, people used to use landline phones, so the gestures also imitate the shape of the receiver of the landline phone. With the iterative development of mobile phones, children nowadays have the most daily contact with smart phones, so they will tend to use a gesture like the right side of Figure 18 when they make a call. The changes brought about by the development of the times affect people's lives and indirectly change people's habits.

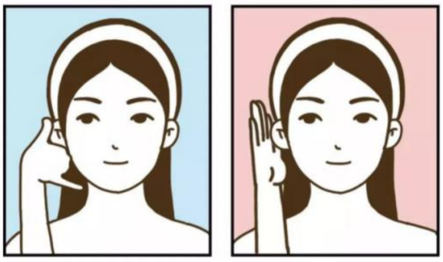


Figure 18, Differences in gesture habits

Gesture commands need to be natural. Easy-to-understand and natural gestures can make the interaction process more smooth. "Natural gestures" require designers to make a trade-off between multi-task manipulation and ease of gesture learning based on Articulatory aspects. Articulatory aspects refer to how easy gestures are to perform, and how tiring they are for the user. Generally speaking, gestures need to avoid complicated hand or finger postures, because they are difficult to articulate and might even be impossible to perform for older adult. From a technical analysis, the Leap Motion product can be used as an example. It is based on The Computer Vision System; it can track and recognize the hand poses, but recognizing complex gestures, overlapping or crossing the fingers will cause errors in its calculations. Also, complex gestures require a long time raising and moving the arm. If the elderly are the user group, they will likely experience fatigue.

Finally, technical aspects refer to the fact that the system be appropriate for practical use, and not only in visionary scenarios and controlled laboratory situations. The practical application of gesture commands will face many technical difficulties, such as distance, angle, light and background interference of gesture recognition. In 2018, Baidu released a public gesture recognition technology test, which included 24 kinds of gesture recognition and dynamic gesture capture. In the test, when the hand's distance is too far (more than 3m), the gesture image is too small, which will lead to inaccurate positioning and recognition. When the hand's angle is tilted, or something obstructs it, it will also affect the system's recognition. Moreover, in an environment without lights at night, gesture recognition accuracy will also be affected. These problems show that many factors still plague the development of gesture interaction.

In conclusion, the most significant advantages of gesture interaction are natural, convenient and intuitive. In the face of special people like the elderly, it can play the greatest role to eliminate the contradiction between the elderly and modern technology. However, the use of natural gestures for human-computer interaction still faces many technical and social factors. Therefore, this paper proposes that the basis for the future development of gesture interaction is finding the factors affecting the cognitive differences between the elderly and the young and establishing a basic gesture commands set. These gestures need not be natural but could be developed for the situation. This set of gesture commands for the elderly will include all basic operations, such as adjustment, opening, closing, and switching. It is based on the gesture recognition of the elderly, and it can also develop with changes in the environment or user groups.

Chapter 3 Methodology

In the previous chapters, the literature review enhanced understanding of (1) the older adult age-relative change including physical changes, cognitive changes, psychological and social changes; (2) smart home history and potential benefits and disadvantages of smart home for older adults; and (3) the most common smart home interaction methods. This chapter will propose a methodology for designing gesture interaction for future designers to study.

The research on gesture interaction is divided into two stages. In the first stage, the researcher needs to determine the research goals and scenarios and preset a set of basic gestures; the second stage is to compare different gestures through user interviews and finally choose the best gesture solution.

3.1 Stage one: Research preparation

In the first stage of research, designers need to determine the usage scenarios and user groups. As highlighted in Chapter 2.3, scholars point out that people will use different gestures reflecting their different cultural backgrounds and on different contexts.

First of all, gesture interaction can be used in a variety of usage scenarios. The main application areas are smart homes, AR&VR applications and intelligent automotive systems (Figure 19). When a gesture command with the same meaning is used in different scenarios, the user's understanding and needs for the command are different. For example, the application of the gesture command "switch songs" is different in each usage scenario. In smart home scenarios, users generally choose two-handed actions to interact with smart products (Figure 20). However, in the application of intelligent automotive systems, to minimize the interference of gestures on driving the vehicle, the users need a more intuitive and straightforward gesture. And in VR applications, gesture commands are often used in combination with the controller so that the operation method will be different from other usage scenarios. Therefore, before researchers design gestures, they need to determine the scenes used in gesture interaction and then study the design of gesture commands according to the differences and limitations of different scenes.

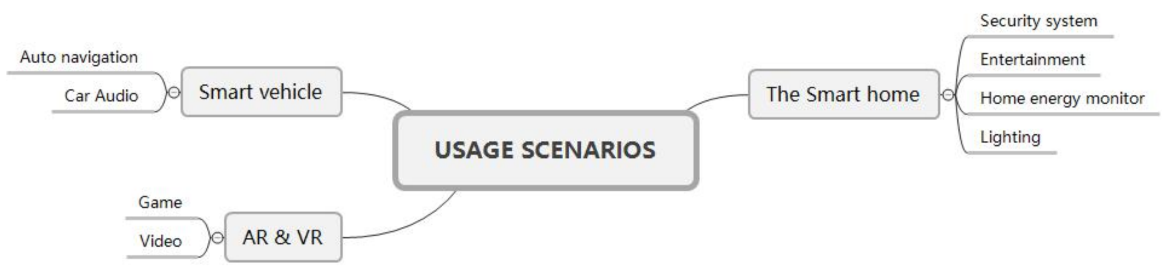


Figure 19, Mind map of usage scenarios

Figure 20, “Switch songs”

Secondly, the designer needs to define the user group of the research. Designers can classify people based on the two elements of age and cultural background.

According to the age division of the United Nations, researchers can roughly divide the population into three categories according to age: minors from 0 to 17 years old; young people from 18 to 65 years old; and middle-aged and elderly people over 66 years old. And the researcher should define the user group according to the user's cultural background. This can be divided according to the country where the target population is located, such as China, Japan, the United States, etc., and can also be divided according to broader regional cultures, such as East Asian cultural regions, and Islamic cultural regions. The definition of user population can help designers select interviewees, and it also makes research more targeted. Furthermore, designers should select healthy persons without cognitive impairments as the research respondents and select multiple groups of people with differences to set up multiple control groups for comparison and reference.

After completing the definition of the user and the scene, the designer needs to design a set of primary gesture commands for subsequent research. According to the definition of the usage scenario, the designer needs to classify the types of commands in the scenario. The designer can get several basic command types (Figure 21) based on this classification and use this as the basis of the design to help researchers plan the gesture command research. In this process, designers should reference existing literature (such as Figure 22) and into observations to create a preliminary gesture set. And designers can use these basic gestures as a basis to develop new gesture commands in the future.

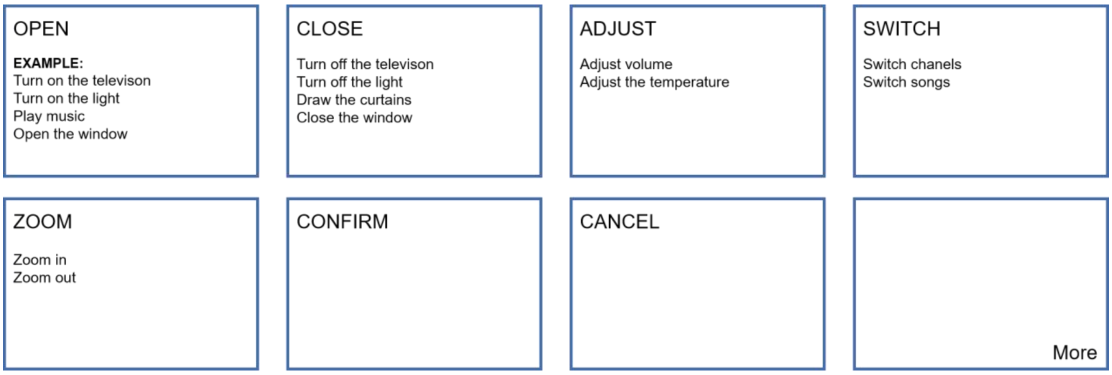


Figure21, Command classification

Figure 22, The selected gesture set(Song, Wang, & Chen,etl., 2019)

The following is the 3D gesture design guideline, which combines the physiological characteristics of the elderly mentioned in chapter 2.1 and proposes a gesture design criterion based on the existing interaction mode. Designers need to consider the following three conditions when designing the preset gesture group.

1. Simple and Intuitive Use

The use of the design needs to be easy to understand. According to chapter 2.1.3, the physiological functions of the elderly will degenerate with age, especially the visual and auditory senses. The degradation of these two senses brings much inconvenience to life. Therefore, the gestures used in the life of the elderly should be concise and natural. Unlike the interaction method of voice recognition and touch screen, gesture interaction is not limited to language, vision, and learning ability, so gesture interaction only needs to meet the two conditions of easy understanding and easy operation. In order to study the elderly's perception of gestures, designers can also obtain information through interviews. In the following, I will introduce the user research method and use it to help designers study the advantages and disadvantages of different gestures.

2. Flexibility in Use

The gesture design accommodates a wide range of individual preferences and abilities. In section 2.3 above, it is proposed that people's habit of using gestures is different. Before conducting the interview, the researcher needs to put forward hypotheses to predict the factors that affect user cognition. These factors may be age, education level, and life experience. In the interview, the researcher can collect relevant information around the hypothesis and rely on data analysis to verify the hypothesis. This process can determine the reasons for the differences in user perception and ensure that the gesture actions selected in the selection of gestures are universal. In short, it is necessary to compare gestures and look for the kind of motion for which the public has reached a consensus in the gesture system's design.

3. Low Physical Effort

According to the information mentioned in Chapter 2, all aspects of the human body's abilities will inevitably degenerate as we age. Gesture control methods should avoid the use of commands that require complex hand movements. Furthermore, older adults are less accustomed to both hand movements, so it is better to choose one-handed operation mode for gesture design. Under the gesture interaction system, the design should be used efficiently and comfortably and with a minimum of fatigue.

The interview process： After finding the interviewee, make an appointment for the interview. The interview can choose online meetings or face-to-face conversation. The interview is divided into three steps: Recognize and classify gestures， Recognition of gestures，and Learnability of gesture. These three steps will be used to collect user data and do feasibility testing. In the next section, we will introduce the process of each step in detail.

3.2 Stage two: Research and analysis

The second phase of gesture research aims to compare the pros and cons of different gestures and find gesture commands that are more suitable for the elderly. The research will focus on people's cognition of gestures and the habit of using gestures to conduct grouping experiments. Based on the pre-defined gestures in the early stage, this stage requires the designer to collect data for gesture evaluation through user interviews. The work will be divided into three distinct phases of research as follow：

Phase one: Recognize and classify gestures

The first phase is to collect the characteristics of the target population for gesture recognition. Designers need to conduct one-on-one interviews with users. For the purpose of this research, the researcher will mainly adopt the research method of card sorting, allowing users to classify different gesture commands and collect relevant data. Card sorting is a technique in user experience design in which a person tests a group of subject experts or users to generate a dendrogram (category tree) or folksonomy. Card sorting uses a relatively low-tech approach. The person conducting the test (usability analyst, user experience designer, etc.) first identifies key concepts and writes them on index cards or Post-it notes. Test subjects, individually or sometimes as a group, then arrange the cards to represent how they see the structure and relationships of the information (Jakob, 1995). In the study of gestures, designers need to demonstrate preset gesture commands for users one by one. After each command is performed twice, the interviewees need to make judgments. They need to choose among the types of commands summarized in stage one. In this process, designers should look for users with different identities to increase the versatility of experimental results. And in the interview process, the researcher needs to collect the user's background information, such as age, educational background, living area, life experience, etc. According to the interviewee's performance in the interview, the designer can put forward some hypotheses about the factors that may affect people's gesture recognition and use them as a reference to filter the types of gestures in the final.

Phase two: Recognition of gestures

The second step is to allow users to recognize gestures. The process of recognizing in psychology is a method of testing memory and cognition. The purpose of this process in gesture research is to test the user's understanding and certainty of the meaning of commands. The designer needs to demonstrate the preset gesture commands to the user again and sort them again. By comparing the collected results with the first step, the designer can confirm whether the user can understand these gesture commands. After completing the classification task, the interviewees were asked to rate the degree of conformity between the gesture and its meaning (1=not conforming, 5=very conforming). By comparing the scores of gestures, designers can get the user's certainty in understanding gestures.

After completing the first two steps, the designer can obtain the data for gesture screening. First, the designer needs to determine the priority of each data comparison. The following is the process of gesture screening:

STEP1. The first thing to consider when choosing gestures is the degree of consensus among the target group on gesture commands. Summarize the interviewee's classification of gestures, analyze the selective distribution of each gesture, and select several gesture commands that more people reach a consensus as candidates.

STEP2. The interviewees were grouped and compared according to the influencing factors assumed in phase one. For example, the designer found that academic qualifications may have an impact on human cognition, then the designer can divide the user population into high school degree and below high school degree. And the two groups of data are integrated and put into the one chart for analysis. If the choices of the two groups of people are mostly the same, then this factor can be excluded from the screening conditions; on the contrary, if the answers of the two groups of people are different, then the designer has to find commands with more minor differences as candidate commands. The designer needs to verify every possible influencing factor and complete the second round of screening.

STEP3. Examine whether the user's cognition of gesture is clear. Based on the score in the second phase, the designer needs to filter the gesture again according to the score from high to low.

STEP4. Considering the versatility of gesture commands, the choice of gestures also needs to take into account groups other than the target population. Compare the understanding of this gesture between different groups, and find the gesture with the minimum difference as the best choice.

Phase three: Learnability of gesture

Phase three is to verify the feasibility of gestures. After screening, the designer can obtain a set of candidate gesture commands. Let the interviewees try to operate these gestures for testing, the researcher will teach them and record the time spent on learning. In this process, the researcher needs to show the gestures in the form of pictures to the respondents first and let them imitate the gesture. If the respondents is not able to make gestures smoothly, the researcher will conduct a step-by-step demonstration and record the time spent on learning. Finally, researchers can evaluate the difficulty of using each gesture command based on the performance of the users. With phase three's experimental results, researchers can select and optimize the gesture commands set.

3.3 Conclusion

This chapter provides a design method for evaluating gestures. Designers can use the above process to research gesture interaction for different groups of people. According to the specific conditions of different projects, designers can make adjustments to the above process and help users find the most suitable gestures.

Chapter 4 Application

4.1 Introduction

With the development of the Internet of Things technology, smart homes have officially entered ordinary households. These kinds of intelligent products need to meet practicality, safety, economy and ease of use. Among them, ease of use is the most crucial part (Zuo, 2017). In the previous smart home system, people still rely on hardware input to control the system. The cost of learning this model is relatively high. The interactive mode in the future smart home environment is bound to develop in somatosensory interaction and "calm technology". In some studies, after scholars collected the participants' cognitions about the operating commands of household products, they found that using 3D gesture commands can significantly improve usability and practicability. Moreover, the study found that subjects with different backgrounds have very different understandings of gestures and demand for smart products (Wang&Zhang, 2016). Therefore, the proposed methodology will be used to study gesture design, recognize relevant differences between the elderly response and the designers intent, and recognition of factors influencing this difference.

4.2 Research preparation

Firstly, according to the method proposed in chapter 3.1, the designer needs to decide the application scenarios and product types of gesture interaction design. This research selects the smart home system as the research object. And according to the smart home classification (Figure 21) mentioned in the literature review, the application area of the gesture control system will be selected.

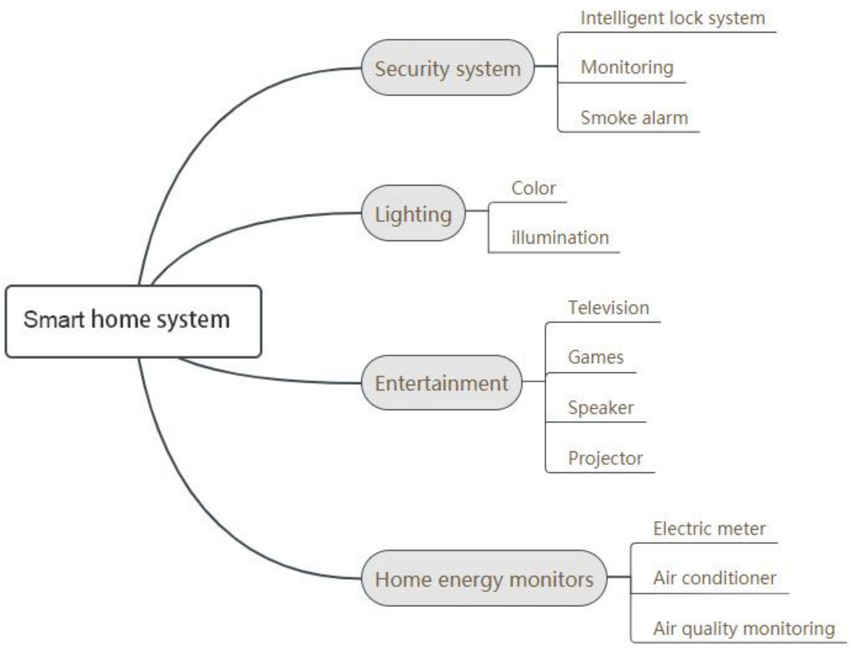


Figure 23, Mind map of smart home system

According to the "Questionnaire Survey of Chinese Residents' Cultural Consumption Tendency," Chinese people are very dependent on television. Among the 6,443 respondents, "Watching TV" ranked first with a support rate of 62.6%. In 2011, the "Survey Report on the Living Conditions of the Elderly in Xi'an" pointed out that 96.3% of the elderly ranked "watching TV" in their daily entertainment, and they "watched it at least once a day." Watching TV is a major pastime for the elderly. Moreover, the TV control includes all the types of commands in this research, so the TV was finally selected as the object to demonstrate the experimental results.

Secondly, cultural differences across countries will affect people's cognitive level, so this design selects the elderly in China as the target group for research. In order to achieve the purpose of the research, this interview selected nine young people (five women, four men), aged between 20 and 35; and nine elderly subjects (four women, five men), between 65 and 75 years old. All participants are in good health and have a clear understanding of things. And this study deliberately selected subjects with different cultural backgrounds and living environments to find various factors that affect cognition.

Finally, the designer needs to design a set of basic gestures before research. In the study of gesture control in the home environment by Christine Kuhnel and others (2011), scholars selected 23 operation commands that achieve the same function but use different objects (Figure 24), for example: "Turn on the TV", "Turn on the lamp "Etc., this operation commands all have the same function realization, but the target carrier objects are different. The researcher collected all the operating commands in this category and summarized them, and finally came up with the most commonly used operating commands in smart home scenarios. In this research, I summarized these commands in combination with the usage scenarios of the smart home (Figure 25). Finally, four general basic gesture commands were determined: "open", "close", "adjust", and "switch" (Figure 26).

Blinds

DOWN

UP

STOP

Lamps

TURN ON

DIM

TURN OFF

TV

TURN ON

NEXT CHANNEL

PREVIOUS CHANNEL

VOLUME DOWN

VOLUME UP

TURN OFF

Electronic Program Guide

SHOW

RECORD MOVIE

SET REMINDER

Video Recorder

SHOW LIST

DELETE MOVIE

PLAY MOVIE

Answering Machine

PLAY MESSAGE

NEXT MESSAGE

PREVIOUS MESSAGE

General

HELP

ABORT

Figure 24, The 23 commands

THE LIST OF COMMANDS

TURN ON THE TELEVISION

TURN OFF THE TELEVISION

SWITCH CHANNELS

ADJUST VOLUME

TURN ON THE AIR CONDITIONING

TURN OFF THE AIR CONDITIONING

ADJUST THE TEMPERATURE

SWITCHING MODES

DREW THE CURTAINS

DREW BACK THE CURTAINS

PLAY MUSIC

SWITCH SONG

TURN ON THE LIGHT

TURN OFF THE LIGHT

ADJUST BRIGHTNESS

OPEN THE WINDOW

CLOSE THE WINDOW

Figure 25, The list of commands

Figure 26, Four basic command types

According to the above classification of commands and the gesture design guideline proposed in Chapter 3: simple and intuitive use, flexibility in use, and low physical effort, this study selected eighteen gesture commands based on the customer habit. Among them are six "open commands", four "close commands", four "regulation commands" and four "switch commands". (see figures below):

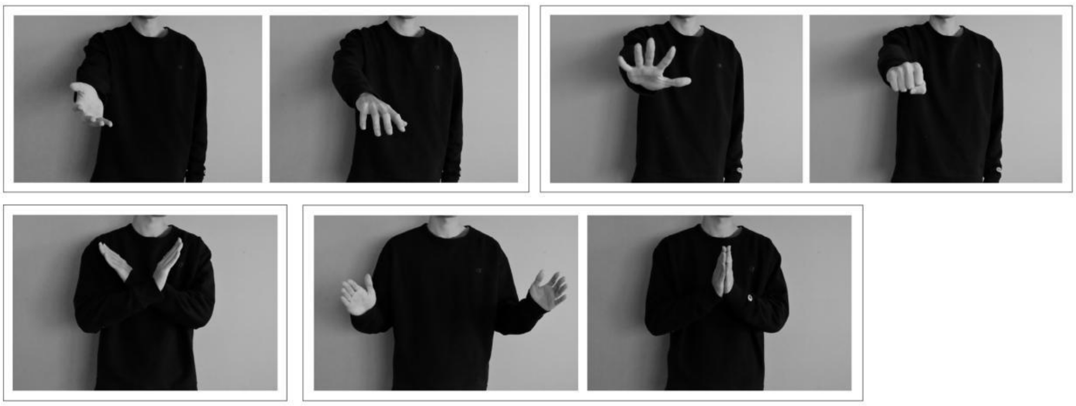


Figure 27 (Group of Close command)

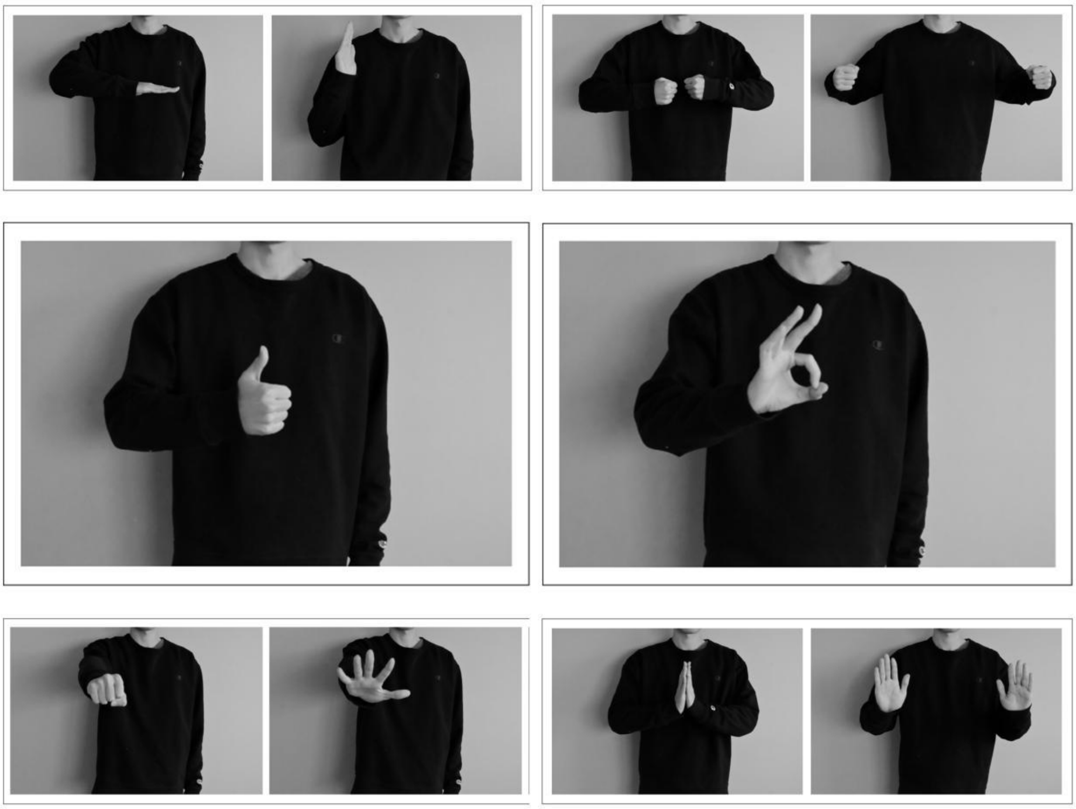


Figure 28 (Group of Open command)

Figure 29 (Group of Switch command)

Figure 30 (Group of Adjust command)

Assumptions

A. Young people and older adults have different perceptions of the same gesture.

B. Young people can learn new gestures faster than older adults.

C. The educational background affects the cognitive level of the elderly.

D. The residential area will affect the elderly's perception of gestures.

E. The elderly’s previous experience in using smart products will affect their cognitive level.

The interview process

The interview is conducted according to the three steps described in the previous chapter. Equipment needed for the interview: a computer connected to the Internet and a notebook.

Interviews were conducted through an online meeting. First of all, the participants needed to watch gestures and classify them. All gestures will be randomly presented to the subjects, and each gesture will be repeated three times. Participants need to choose among the five options of "open, close, adjust, switch, and unknown".

During the selection process, the participant is also required to explain the reason for the choice. Then, the second step is the process of re-recognizing and scoring. Participants can watch all the gestures again and score based on the degree of conformity between the gesture and their answer. In this process, the participants need to try to imitate the operation gesture. If the gesture command operation cannot be performed, the researcher will teach them and evaluate the gesture's learning difficulty. At last, the final selected gesture set will be re-evaluated by the elderly for its feasibility.

4.3 Result and analysis

To study the cognitive differences between the young and the elderly, the researchers divided the final data into control groups of different ages (see figures below):

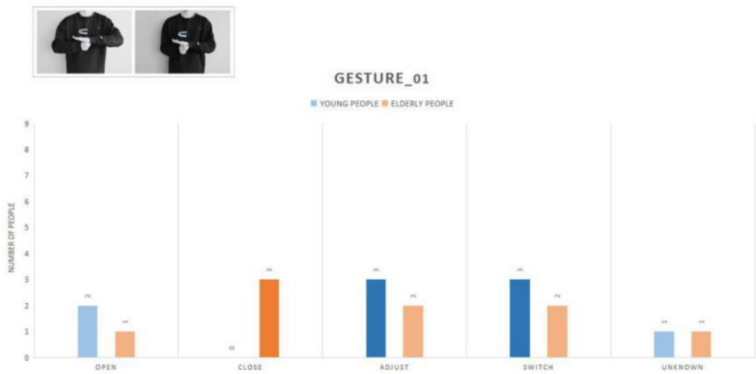


Table2, Experimental results of interviewees of different ages 01

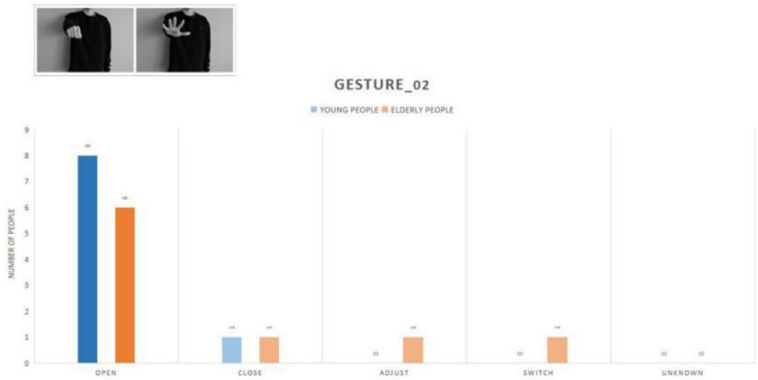


Table3, Experimental results of interviewees of different ages 02

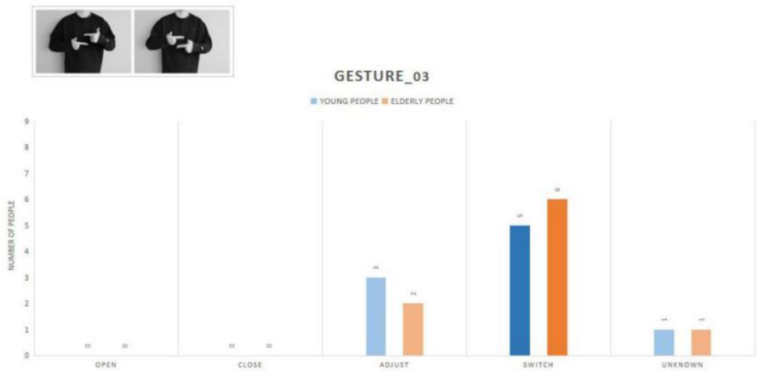


Table4, Experimental results of interviewees of different ages 03

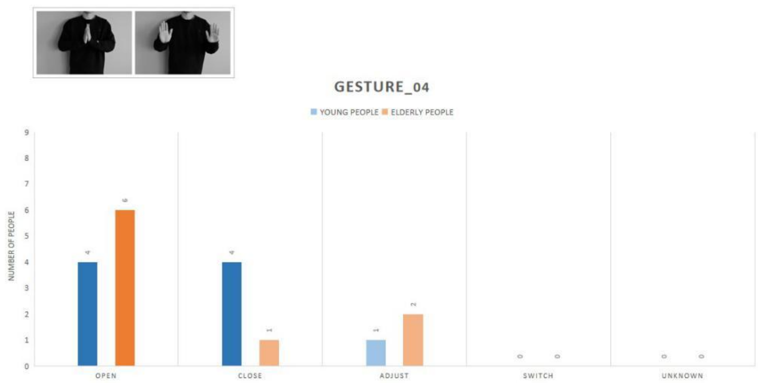


Table5, Experimental results of interviewees of different ages 04

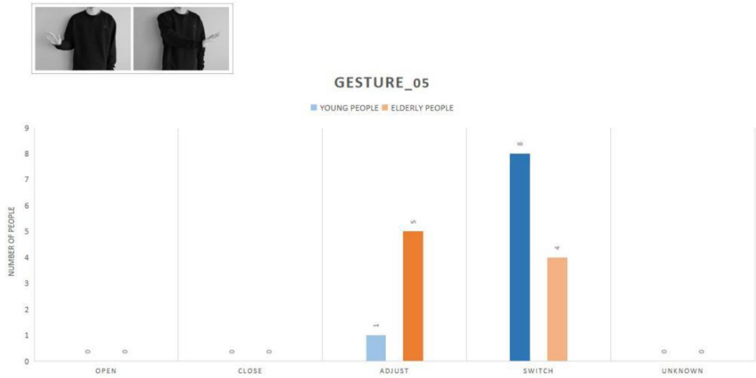


Table6, Experimental results of interviewees of different ages 05

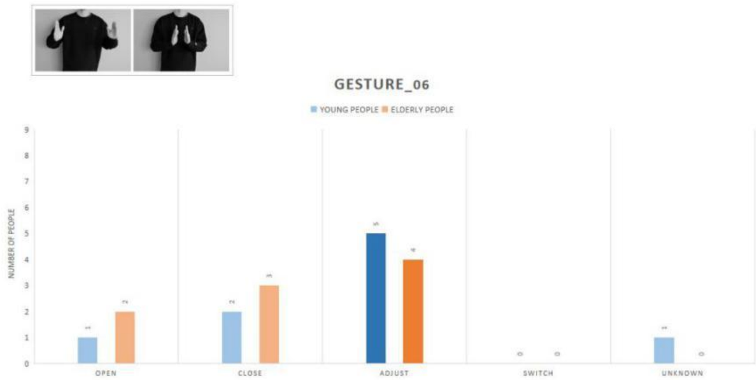


Table7, Experimental results of interviewees of different ages 06

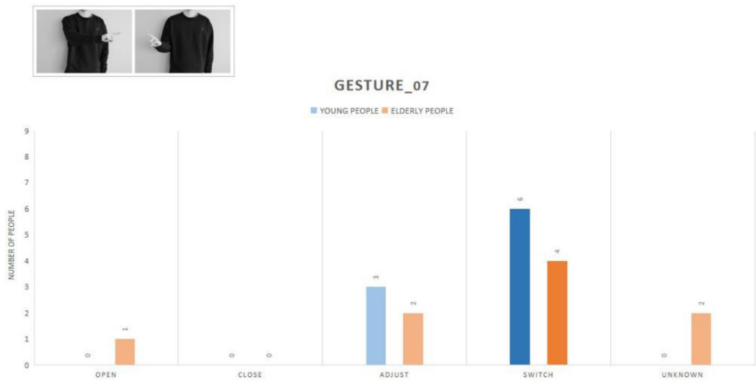


Table8, Experimental results of interviewees of different ages 07

Table9, Experimental results of interviewees of different ages 08

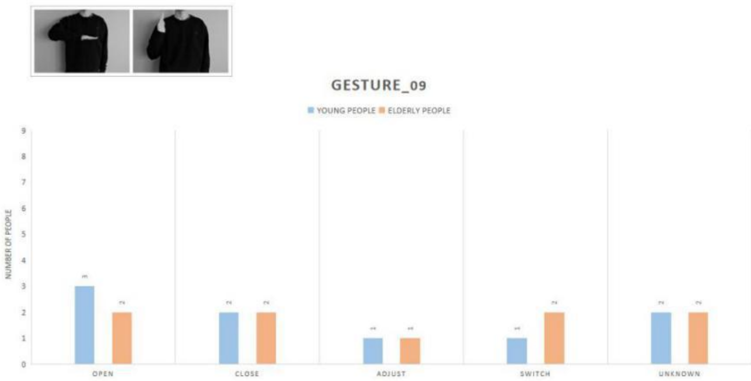


Table10, Experimental results of interviewees of different ages 09

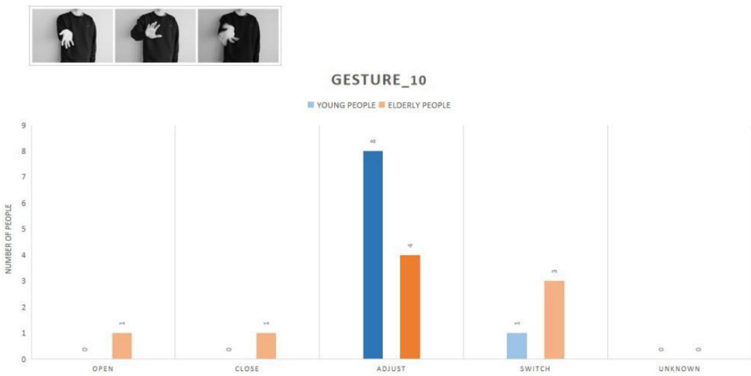


Table11, Experimental results of interviewees of different ages 10

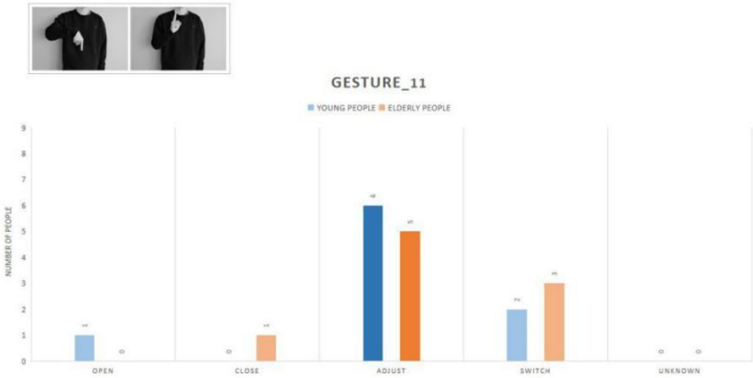


Table12, Experimental results of interviewees of different ages 11

Table13, Experimental results of interviewees of different ages 12

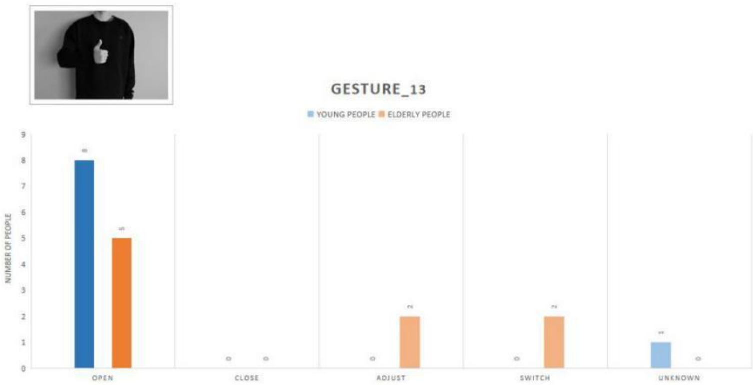


Table14, Experimental results of interviewees of different ages 13

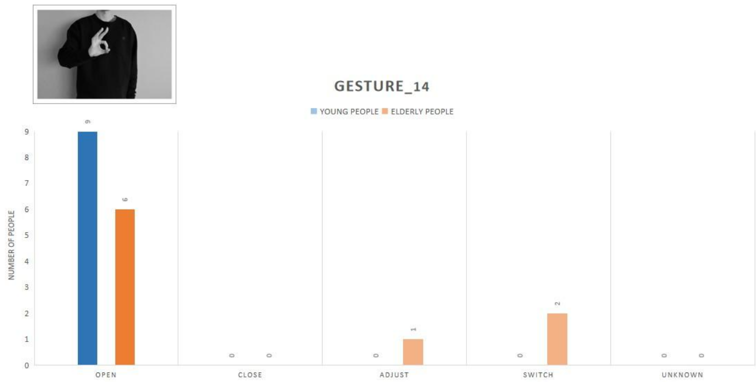


Table15, Experimental results of interviewees of different ages 14

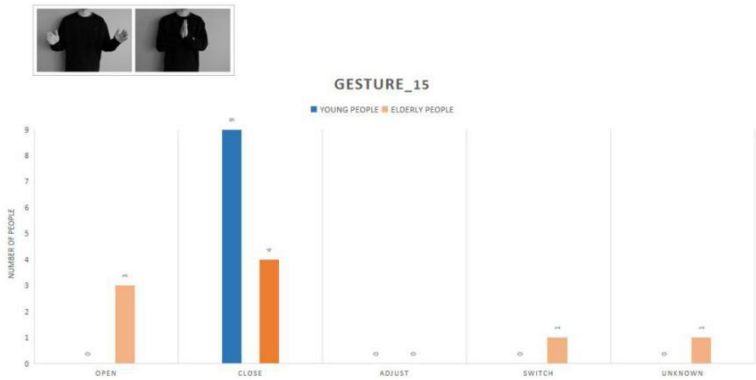


Table16, Experimental results of interviewees of different ages 15

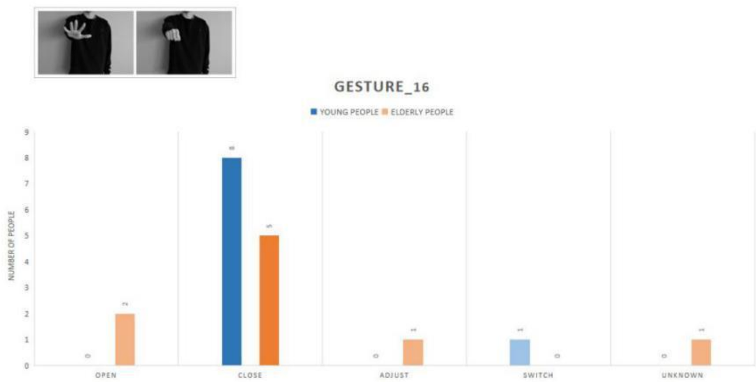


Table17, Experimental results of interviewees of different ages 16

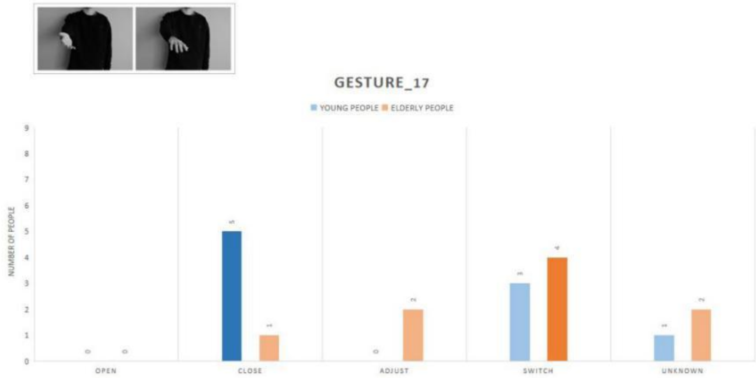


Table18, Experimental results of interviewees of different ages 17

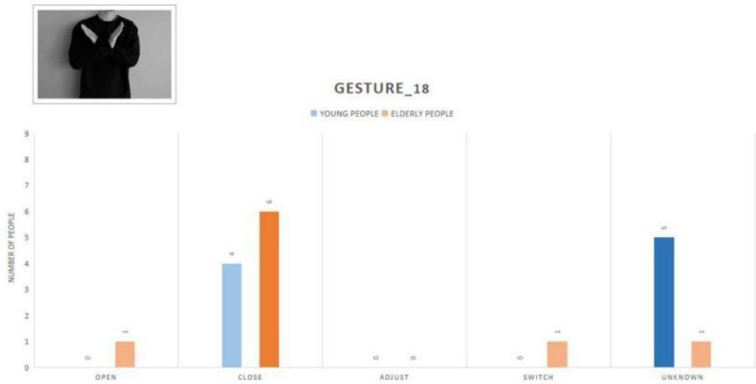


Table19, Experimental results of interviewees of different ages 18

The interviewees this time are nine young people and nine older adults over 65 years old. The above charts show the comparison of the number of people selected for each option of each gesture.

According to the interviewees' overall selection distribution, among the eighteen gestures, fourteen gestures reached a consensus between the elderly and the young for which most people in the two groups chose the same command option. However, from the analysis of the distribution of the number of people who choose each option, young people's choice will be relatively concentrated, especially for the gesture commands they are familiar with.

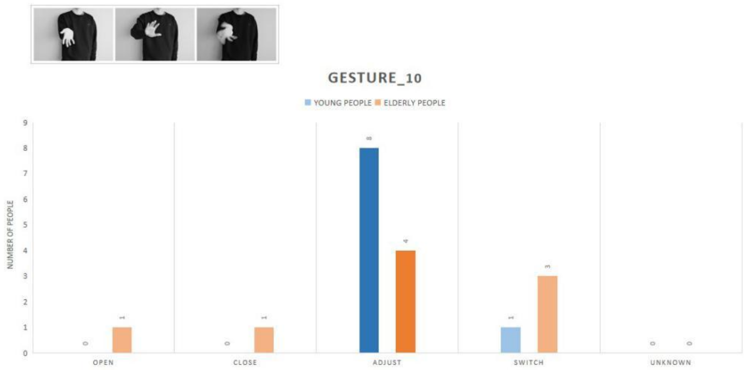


Table 20, Experimental results of interviewees of different ages 10

Take gesture10 as an example. The choices of young people are very uniform, but the older adults are scattered. During the communication, the young people suggested that gesture10's motion is like the operation method of the volume control knob in the car, so they all chose "adjust." Because young people have a wealth of experience in using smart products, they can easily associate gestures with other products. Therefore, their choices in the gesture10 test are uniform, but it is difficult for the elderly to reach a consensus. Even if motions like gesture14 come from daily life, the expression of "OK" is global and regardless of age. However, a small number of older adults interviewed by the research institute still choose different answers, while young people choose an option consistently. Besides, according to the scoring situation, most of the elderly give gesture14 a score of four, and the young people have a score of five for all. The elderly are more likely to hesitate when judging the meaning of gestures, which may be due to different cultural backgrounds. The "OK" gesture is a foreign cultural phenomenon for elderly Chinese people, and they do not use the Internet as frequently as young people to learn about external information. Therefore, they likely do not understand this gesture deeply enough, which leads to a small number of older adults having differences in their choices.

In general, young people and older people can agree on gesture recognition, but because young people are more likely to access information from the outside world, young people's choices will be more concentrated in this test.

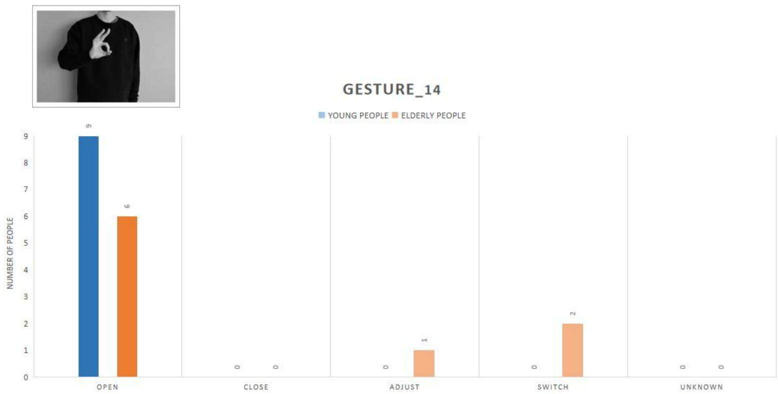


Table 21, Experimental results of interviewees of different ages 14

In addition, comparing the data of various gestures shows that users are easily confused when judging adjusting command and switching command. Taking gesture5 and gesture7 as an example, these two gestures are the meaning of switching and adjusting when they are initially set. However, in the actual interview process, it is difficult for interviewees to distinguish whether they are young or old, and the scores of the two show that most of these two gestures are four points and three points, which also shows that the user's understanding of such gestures is ambiguous. The user can know that this gesture represents switching or adjusting, but it becomes difficult to judge when two options appear at the same time. For example, there are only three options for lighting control, on, off, and brightness adjustment, so the user can accurately use gestures. However, for electrical products such as televisions with both switching and adjusting, distinguishing between these two commands will be the key to the problem.

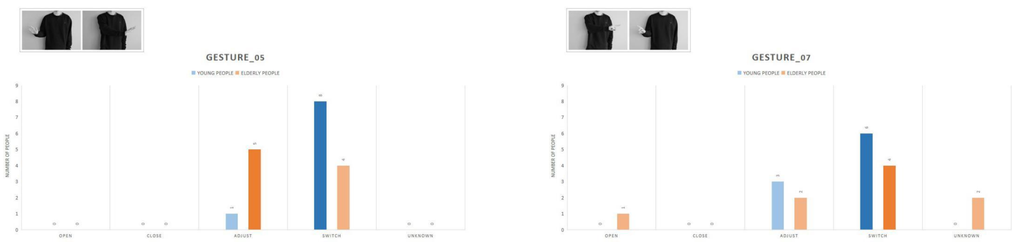


Table 22, Experimental results of interviewees of different ages

Furthermore, from the analysis of the elderly and the young's situation in completing gesture recognition tasks, these two groups of people also have their own advantages and disadvantages. From the interview and task completion time, the average time spent by young people is 326 seconds, while that for the elderly takes 747 seconds. And during the interview, researchers need to explain to the elderly and repeat the meaning of tasks several times, but some older adults still find them incomprehensible. On the other hand, young people can quickly understand the meaning of the question and complete the answer. And according to the data collected in the interview, it can be seen that the proportion of the elderly who choose the “unknown” option is higher than that of the young in most of the questions. It can be perceived that the cognitive ability of the elderly is weaker than that of the young, and the elderly often need more time to complete the same task.

However, in the judgment of some gestures, the young people's previous experience will affect the judgment, and the elderly rarely have this problem. The previous experience in the Gesture10 test helped young people reach a consensus on the choice, but more often, experience will mislead people's choices. For example, gesture4 imitates the action of opening the door, so the pre-set command is to open, but because this gesture is more like the gesture of closing the application in apple mac, four young people in the interview chose to close. Young people have a higher frequency of using smart products than older adults, so that some 2D gesture operation methods will affect their cognition of 3D gestures. They will subconsciously think of a smart phone or computer's operating mode and therefore have different choices. But for the elderly, gesture control is a whole new field, and previous experience will not affect their judgment. Inexperience becomes one of the advantages of the elderly.

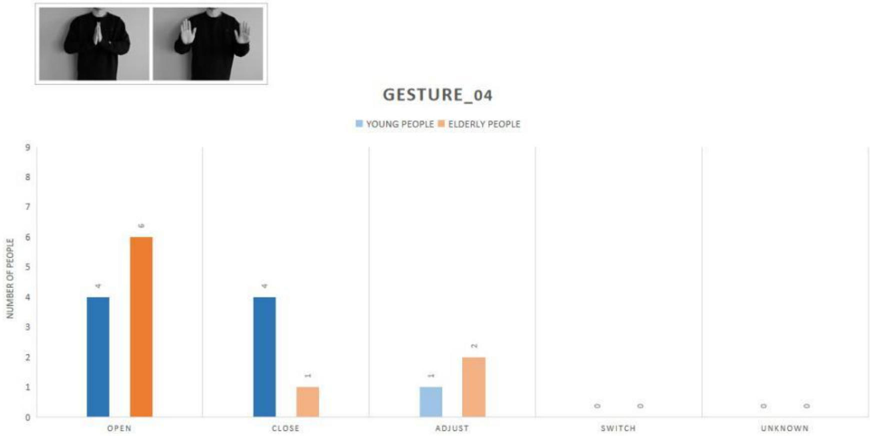
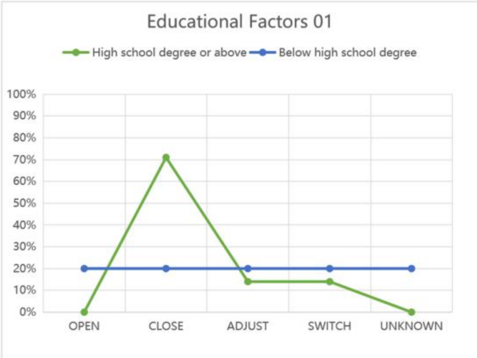


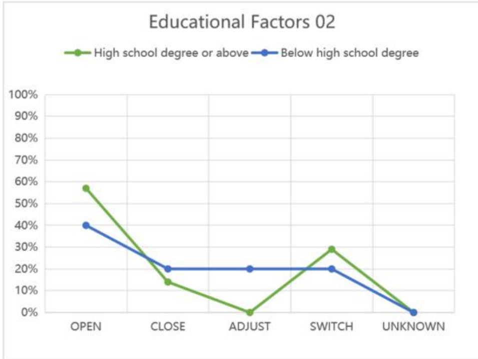
Table 23, Experimental results of interviewees of different ages 04

In general, the elderly and young people can reach a consensus on recognizing 3D gestures, but there are differences. Young people are more determined about the meaning of gestures, and they can reach a better consensus on familiar gestures. On the contrary, the elderly often hesitate and experience difficulty in reaching a complete consensus. Besides, young people are usually better than older adults in quickly recognizing and remembering gestures. But at the same time, young people's experiences will affect the judgment of gestures, while the elderly do not have this interference.

The following subsections will group and compare the older people according to individual differences to find the factors affecting the cognition of the elderly.

In this part of the study, the elderly are grouped and compared according to their education level, area of residence, and whether they have prior experience with smart device.


Educational Factors 01
High school degree or above
Below high school degree
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
OPEN
CLOSE
ADJUST
SWITCH
UNKNOWN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High school degree or above
Below high school degree
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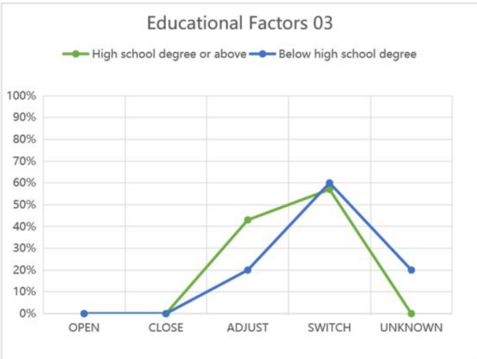
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High school degree or above
Below high school degree
100%
90%
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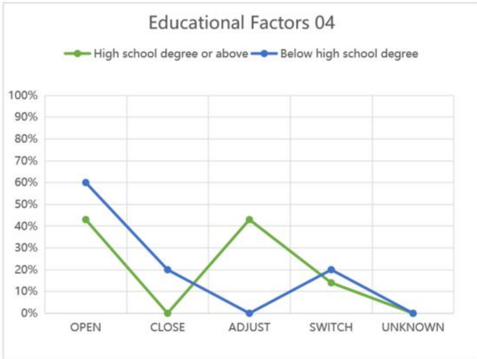
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Below high school degree
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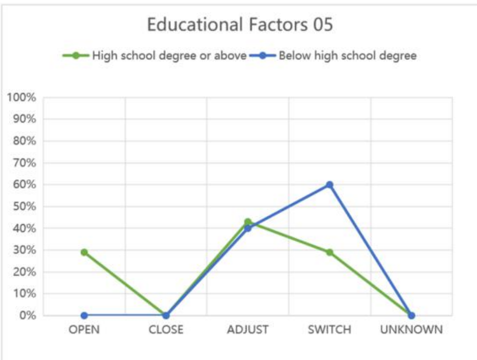
Educational Factors 05
High school degree or above
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100%
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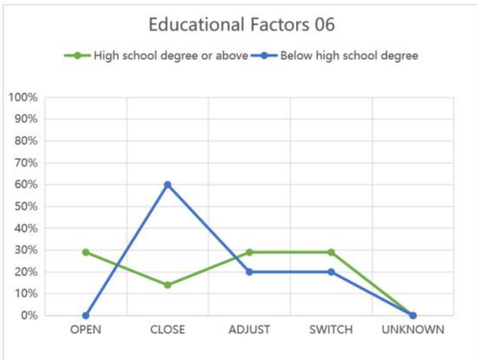
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High school degree or above
Below high school degree
100%
90%
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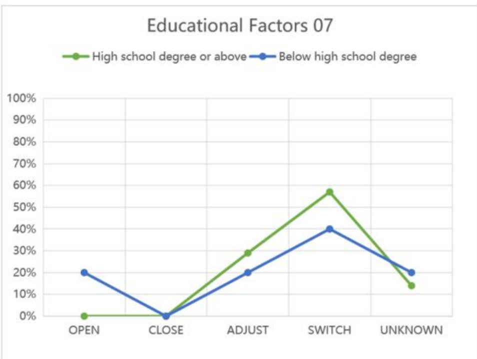
CLOSE
ADJUST
SWITCH
UNKNOWN


Educational Factors 07
High school degree or above
Below high school degree
100%
90%
80%
70%
60%
50%
40%
30%
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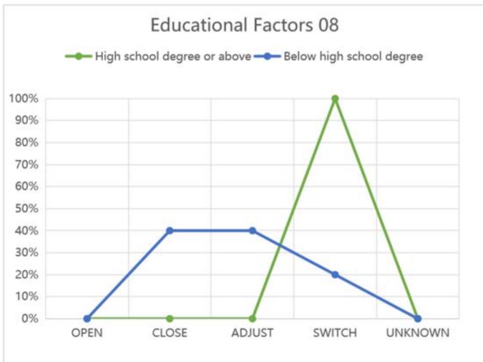
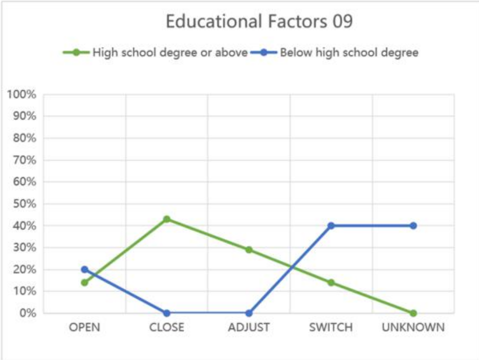
OPEN
CLOSE
ADJUST
SWITCH
UNKNOWN


Educational Factors 08
High school degree or above
Below high school degree
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
OPEN
CLOSE
ADJUST
SWITCH
UNKNOWN


Educational Factors 09
High school degree or above
Below high school degree
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60%
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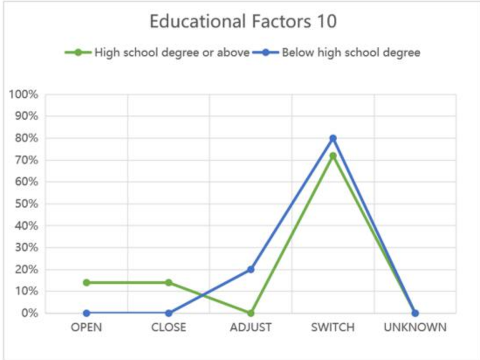
40%
30%
20%
10%
0%
OPEN
CLOSE
ADJUST
SWITCH
UNKNOWN


Educational Factors 10
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Below high school degree
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10%
0%
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CLOSE
ADJUST
SWITCH
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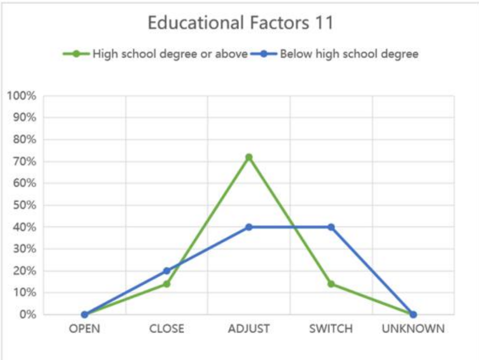
Educational Factors 11
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Below high school degree
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0%
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CLOSE
ADJUST
SWITCH
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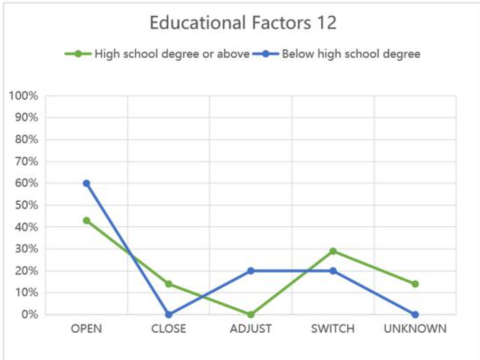
Educational Factors 12
High school degree or above
Below high school degree
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0%
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CLOSE
ADJUST
SWITCH
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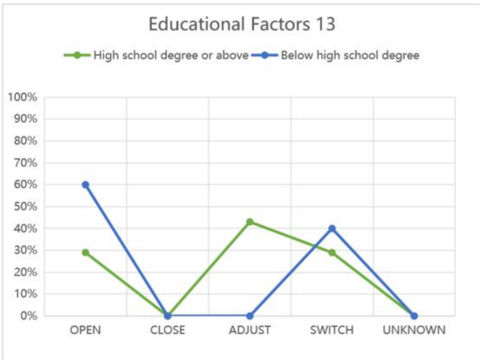
Educational Factors 13
High school degree or above
Below high school degree
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0%
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ADJUST
SWITCH
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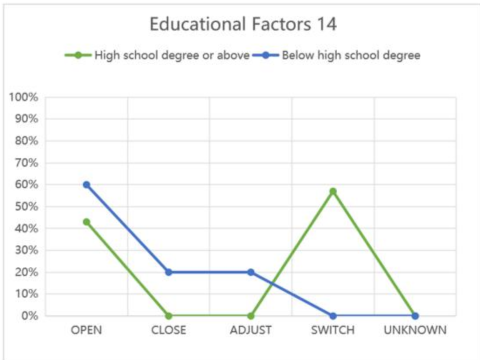
Educational Factors 14
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CLOSE
ADJUST
SWITCH
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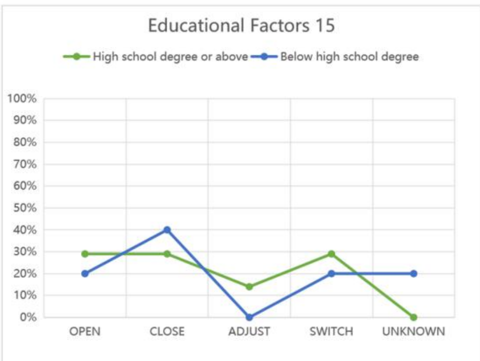
Educational Factors 15
High school degree or above
Below high school degree
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20%
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CLOSE
ADJUST
SWITCH
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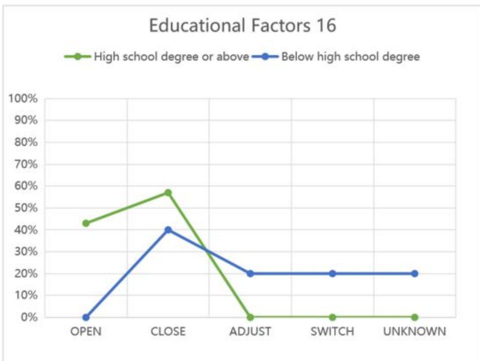
Educational Factors 16
High school degree or above
Below high school degree
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0%
OPEN
CLOSE
ADJUST
SWITCH
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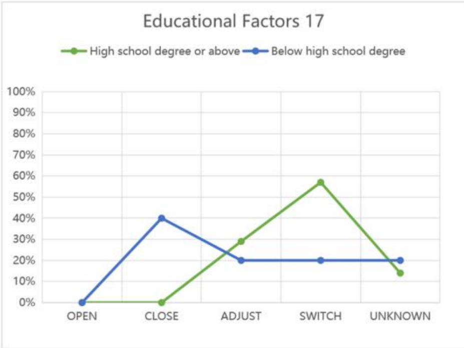


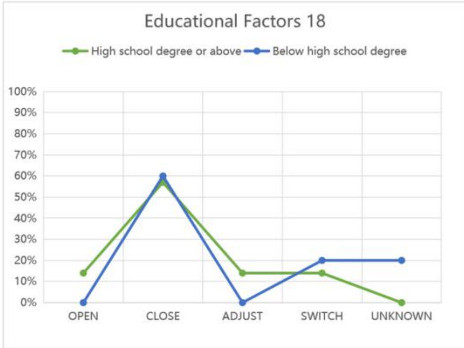


Table 24, Experimental results of interviewees with different educational backgrounds

The first is to classify and compare the interviewees according to their educational background and divide them into two parts based on whether they graduated from high school. Then, the task is to observe the highest value in each chart above, which is the meaning of the gestures selected by the two groups. There are differences in understanding the two groups of older people in 11 gestures out of the 18 gestures. From the results, it can be found that the elderly with higher education are more likely to reach the same opinion in the process of recognizing gestures than other elderly. Taking gesture1 and gesture8 as an example, more than 70% of the elderly with higher education reached an agreement when choosing; on the contrary, other older adults' choices were scattered. Moreover, when interviewing elders with no education, communication becomes very difficult. Researchers need to explain this task many times before they can continue to complete them, and the proportion of them choosing "unknown" is much higher than that of other elderly.

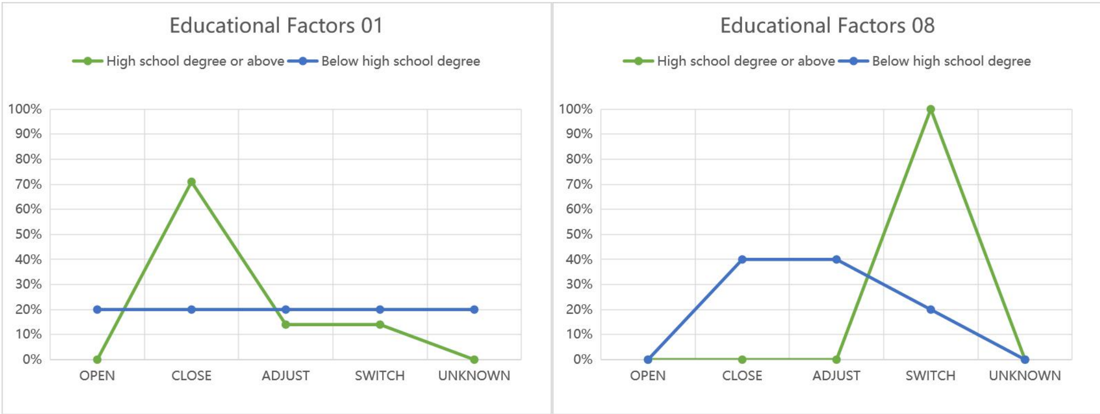
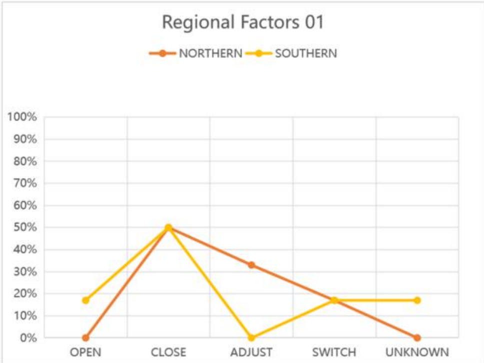


Table 25, Experimental results of interviewees with different educational backgrounds 01,08

In summary, the difference in education level affects the cognition of the elderly. The interaction design is necessary to select gestures that all elderly can understand, such as gesture03, gesture10, and gesture18.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SOUTHERN
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20%
10%
0%
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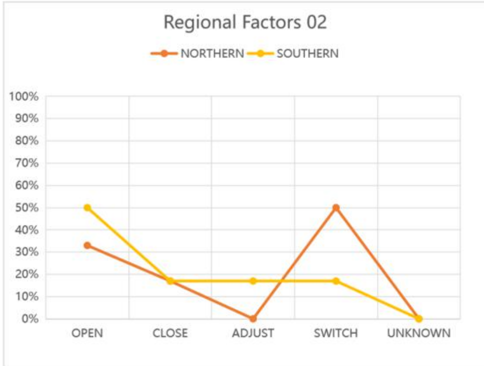
CLOSE
ADJUST
SWITCH
UNKNOWN


Regional Factors 02
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SOUTHERN
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0%
OPEN
CLOSE
ADJUST
SWITCH
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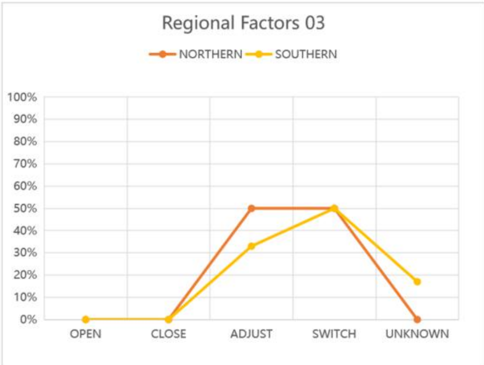
Regional Factors 03
NORTHERN
SOUTHERN
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10%
0%
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ADJUST
SWITCH
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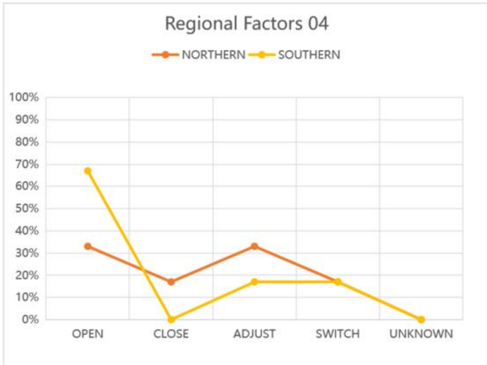
Regional Factors 04
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SOUTHERN
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0%
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CLOSE
ADJUST
SWITCH
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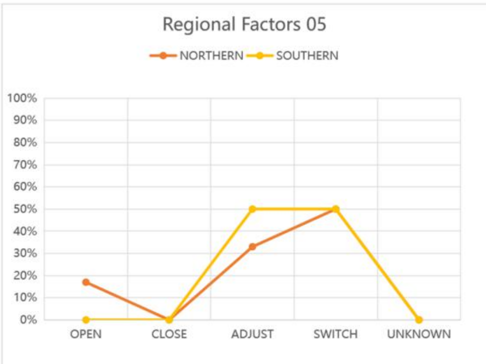
Regional Factors 05
NORTHERN
SOUTHERN
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0%
OPEN
CLOSE
ADJUST
SWITCH
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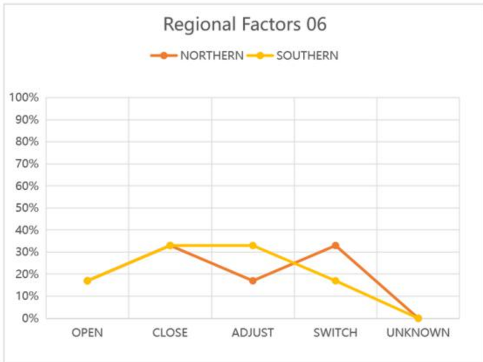
Regional Factors 06
NORTHERN
SOUTHERN
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30%
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10%
0%
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CLOSE
ADJUST
SWITCH
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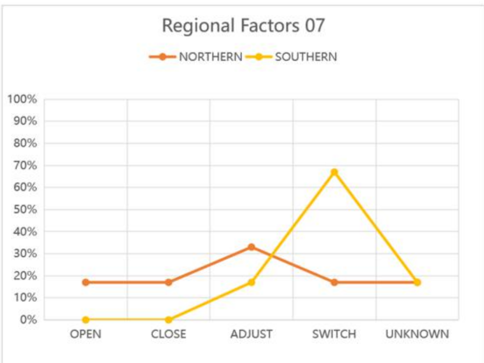
Regional Factors 07
NORTHERN
SOUTHERN
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30%
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0%
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CLOSE
ADJUST
SWITCH
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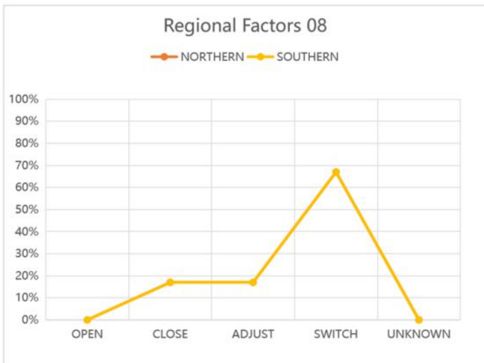
Regional Factors 08
NORTHERN
SOUTHERN
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10%
0%
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CLOSE
ADJUST
SWITCH
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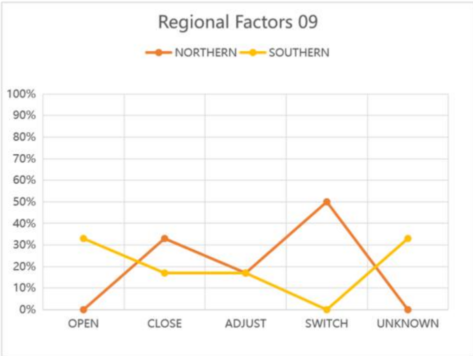
Regional Factors 09
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SOUTHERN
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CLOSE
ADJUST
SWITCH
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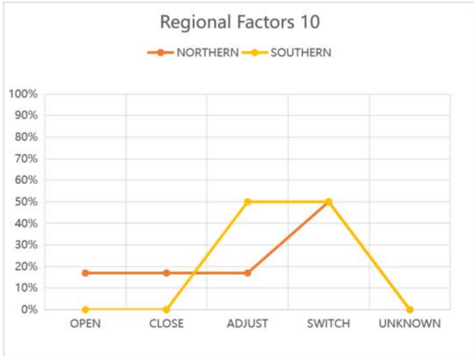
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ADJUST
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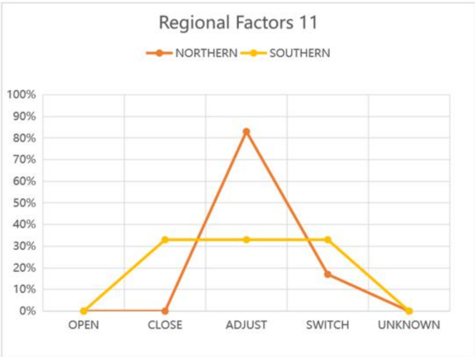
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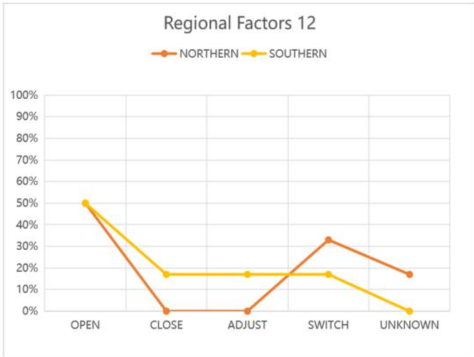
Regional Factors 12
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SOUTHERN
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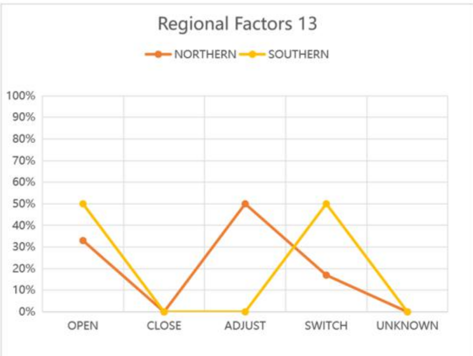
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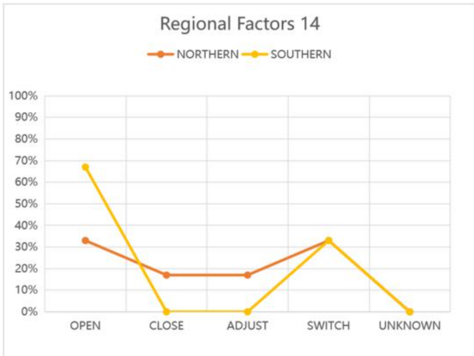
Regional Factors 14
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SOUTHERN
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ADJUST
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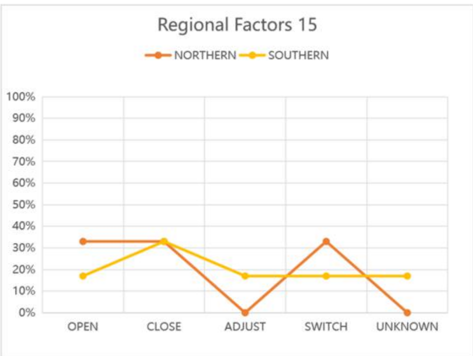
Regional Factors 15
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SOUTHERN
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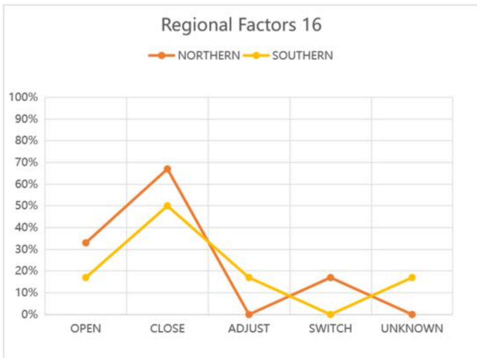
Regional Factors 16
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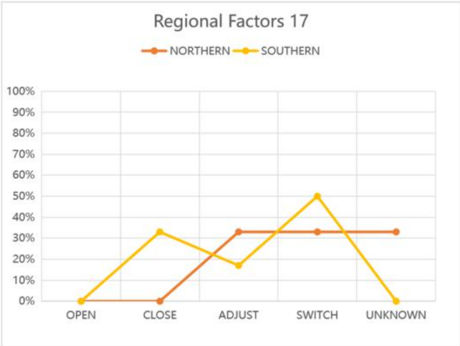


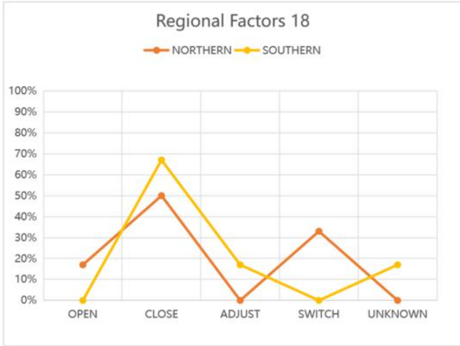
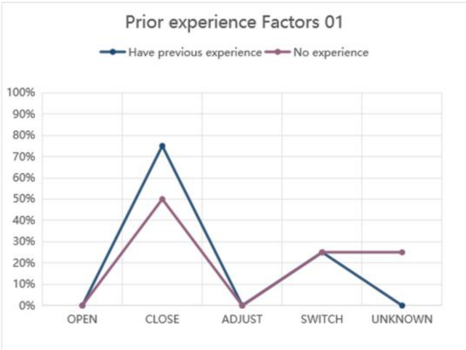


Table26, Experimental results of interviewees from different areas of residence

Secondly, previous research revealed that differences in regions would also affect the elderly’s understanding of gestures. Therefore, the researchers divided the elderly data into the south and the north for comparison. These results show that regardless of southerners or northerners, the cognition of the elderly in each gesture is mostly the same. In the gesture08 interview, the data of the two groups of older people were even completely corresponding. In a total of eighteen types of gestures, only three gestures produce differences between the north and the south. Therefore, it can be concluded that the differences in the areas where the elderly in China live will not lead to differences in the understanding of gestures.

In addition, some older people interviewed by the research came from the same family, but the results they chose were not the same. It can be seen that the elderly are entirely unfamiliar with gesture control, and their living environment will not have a significant influence on their decision. Therefore, the gesture system's design for the elderly in China does not need to consider geographical and family factors.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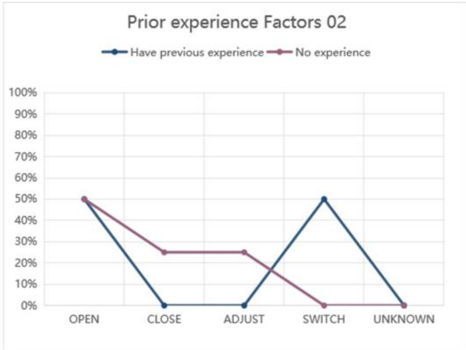
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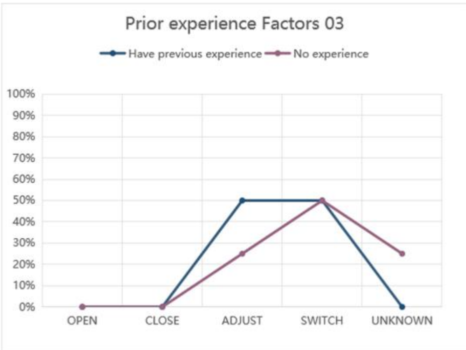
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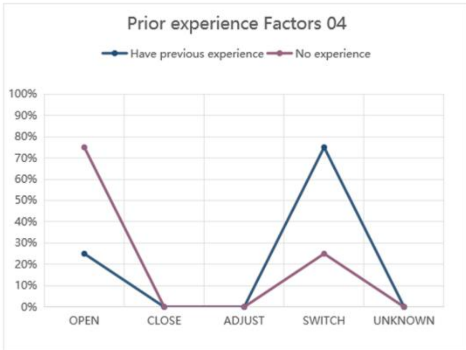
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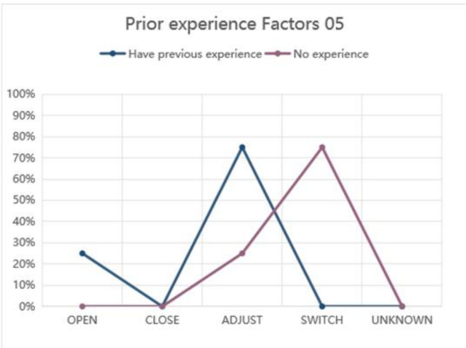
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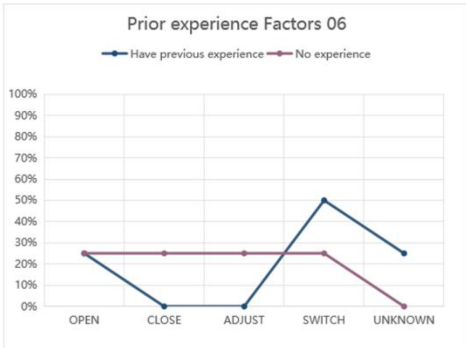
Prior experience Factors 06
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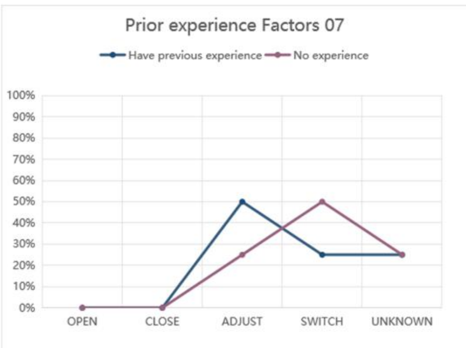
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ADJUST
SWITCH
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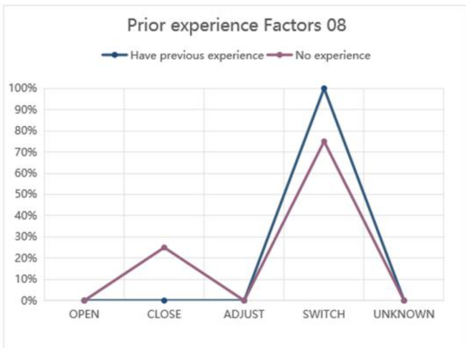
Prior experience Factors 08
Have previous experience
No experience
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CLOSE
ADJUST
SWITCH
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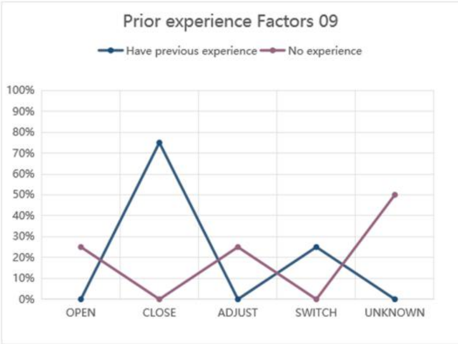
Prior experience Factors 09
Have previous experience
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CLOSE
ADJUST
SWITCH
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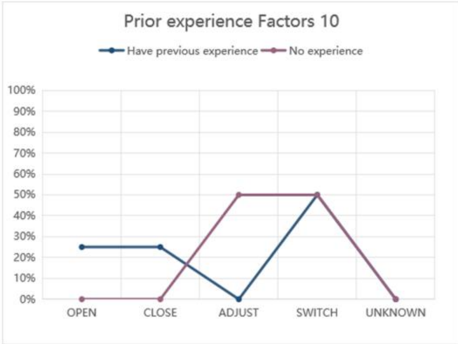
Prior experience Factors 10
Have previous experience
No experience
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ADJUST
SWITCH
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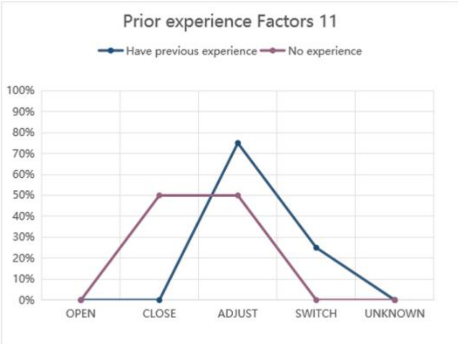
Prior experience Factors 11
Have previous experience
No experience
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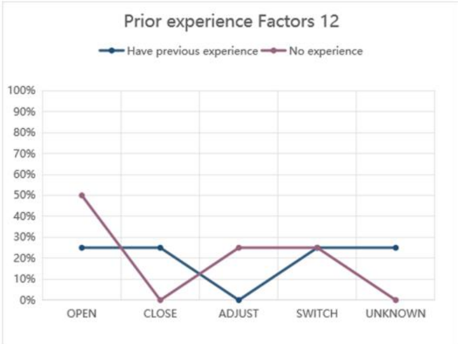
CLOSE
ADJUST
SWITCH
UNKNOWN


Prior experience Factors 12
Have previous experience
No experience
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OPEN
CLOSE
ADJUST
SWITCH
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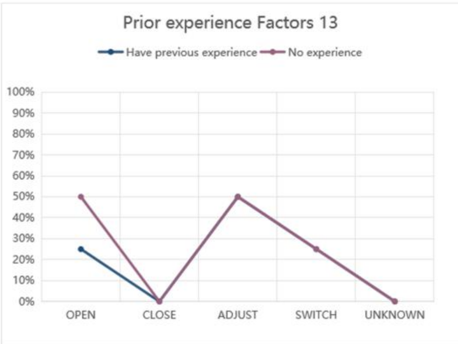
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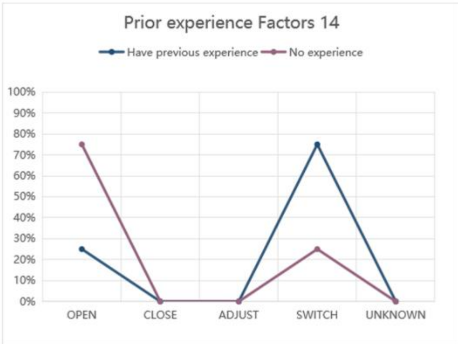
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Have previous experience
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CLOSE
ADJUST
SWITCH
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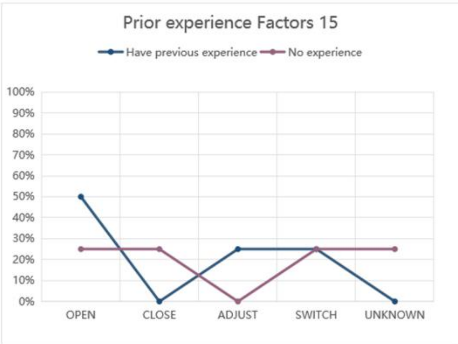
Prior experience Factors 15
Have previous experience
No experience
100%
90%
80%
70%
60%
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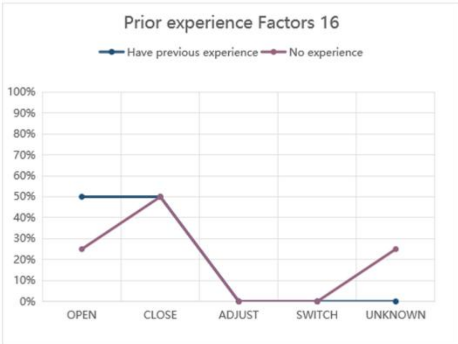
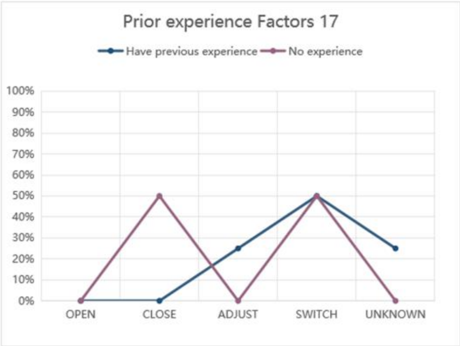
30%
20%
10%
0%
OPEN
CLOSE
ADJUST
SWITCH
UNKNOWN


Prior experience Factors 16
Have previous experience
No experience
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
OPEN
CLOSE
ADJUST
SWITCH
UNKNOWN



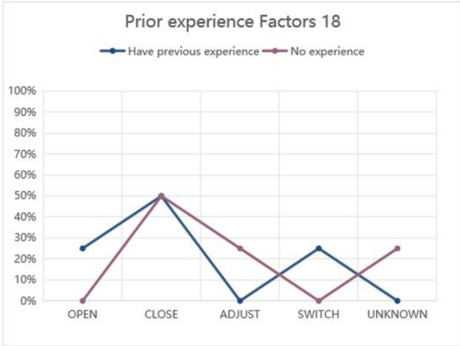


Table 27, Experimental results of interviewees with different experiences of smart devices

Finally, there is research on whether the elderly will be affected by the previous experience of using smart products. The elderly have fewer opportunities to use smart products daily. At present, only 20% of the elderly in China can operate smartphones. In this interview, half of the elderly have used smartphones, but they only use the most basic operations, including phone calls, surfing the Internet, and texting. Fewer elderly people have the experience of using other smart appliances. Moreover, the control of former smart products mostly stayed on buttons and touch screens, and gesture control was rarely used. The frequency of use of products by the elderly is relatively small, so the previous experience should not cause interference to the elderly. However, according to the interview results, there are still differences in understanding between experienced seniors and other seniors, and this difference will change for different types of gestures. For example, the two groups of elderly people almost reached agreement on the understanding of gesture13, but the two groups of elderly people have very different cognitions of gesture09. The cognition of gestures will be affected by prior experience with smart devices, but it depends on the situation.

In conclusion, compared with young people, the gesture system design of the elderly has unique advantages, and their previous experience has little influence on the judgment of the elderly. In terms of gesture selection, designers need to choose easy-to-understand and straightforward gestures, such as gesture 13, and gesture08.

4.4 Proposed Gesture Command Set

Based on user ratings and the cognitive level of different groups of people, this research has summarized the following set of interactive gestures. There are four commands corresponding to these interactive commands: "open", "close", "adjust", and "switch".

The process of judging and selecting gestures is as follows:

STEP1. First, compare the degree of understanding of each gesture within the elderly group. Based on the classification of gestures by the elderly in chapter 4.3, the gesture types that most older adults can reach a consensus are selected as candidates.

STEP2. Study the interference of the two influencing factors mentioned above (Educational level& Experience). In the comparison chart of the research influencing factors in the previous chapter, the designer found the gestures that each group has the same understanding: gestures that have the same answer for each group of people in the classification task. Collect these gestures and screen out better options based on the results of the first step.

STEP3. Screen gestures based on the user's understanding of the meaning of them. Sort the gestures from high to low according to the scores of the elderly (Table 28).

STEP4. Select the gestures in which the elderly and young people choose the same answer in the classification experiment, filter the gestures again, and find the gesture with the minimum difference as the best choice.

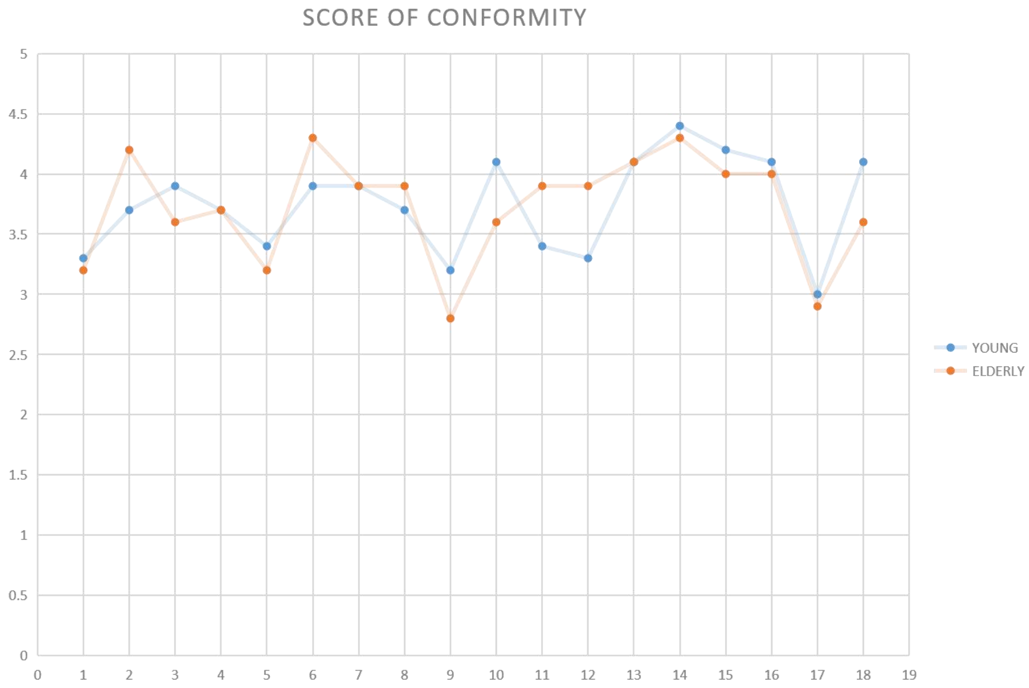
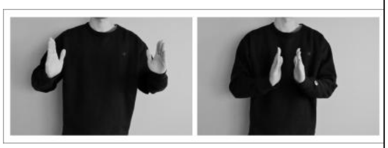
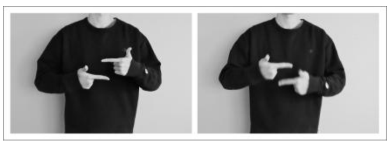


Table 28, Score of conformity

The final result is as follows (table 29):

Command name	**“Open”**	**“Close”**
Best choice	Gesture02 	Gesture16 
Second-choice	Gesture14 	Gesture18 
Command name	**“Adjust”**	**“Switch”**
Best choice	Gesture06 	Gesture08 
Second-choice	Gesture11 	Gesture03 

4.5 The evaluation of results

First of all, after a lapse of 20 days, the researcher found the elderly who had been interviewed before and conducted a second interview. The eight gestures selected above were shown to the elderly again and asked them to classify the gesture. In this process, the elderly can quickly answer the same answer as the first time (Except gesture06). This have proved that the elderly are clear about these eight gestures' meaning. And they do not need to pay attention to the process of recognizing gestures. The meaning of gestures is just like words, which can be understood the first time.

Figure 31, Gesture02, Gesture16

Figure 32, Gesture14, Gesture18

Figure 33, Gesture06, Gesture08

Figure 34, Gesture11, Gesture03

Then, without guidance, the researcher asked the elderly to use these eight gestures.

Figure35, Feasibility experiment (Gesture03)

The elderly encountered difficulties during the operation of Gesture03. The first is that the fingers of the elderly are relatively stiff. This gesture is easy for young people to do, but the elderly will have some obstacles. The second is that gesture03, as a gesture for "switching," is dynamic. It requires two fingers of the elderly to make a rotating trajectory. The older adult's fingers are not flexible, and some movements are not easy for them. Nevertheless, in the end, after the researcher's guidance and teaching, the older man also quickly learned this type of movement.

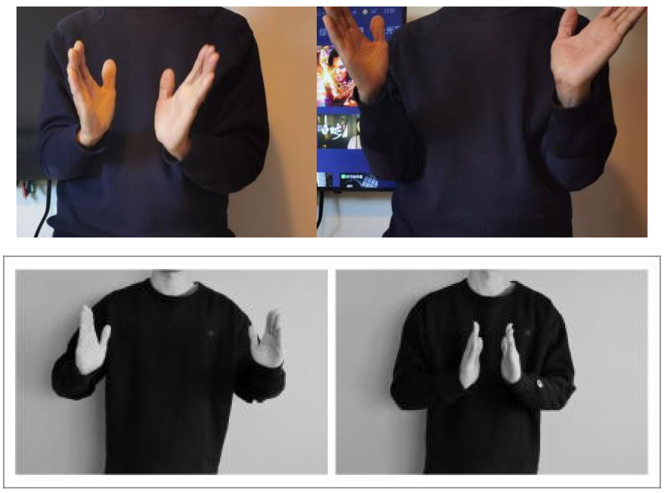


Figure36, Feasibility experiment (Gesture06)

Gesture06 is also a problematic gesture. Controlling the volume by the distance between the palms requires the elderly to hold their hands in the air for a long time. In the communication, the elderly said that doing this action will cause muscle fatigue. Furthermore, this gesture is challenging to keep the hands parallel during the operation, so studies have proved that gesture06 is not the best gesture for adjusting commands.

In addition to the above two gestures, the elderly can understand and learn the other gestures in the first time.

The following is photos of the elderly applying gestures to the TV:

Figure 37, Turn on the TV 01

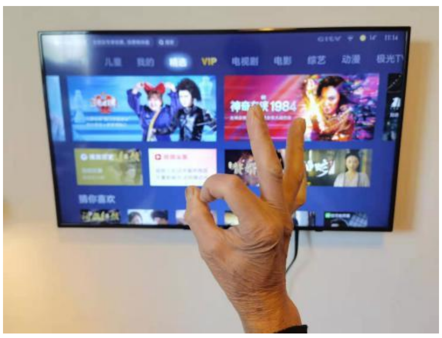


Figure 38, Turn on the TV 02

Figure 39, Turn off the TV 01

Figure 40, Turn off the TV 02

Figure 41, Adjust volume 01

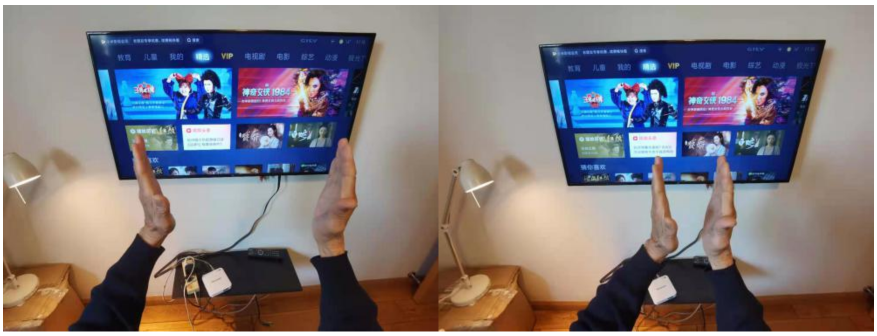


Figure 42, Adjust volume 02

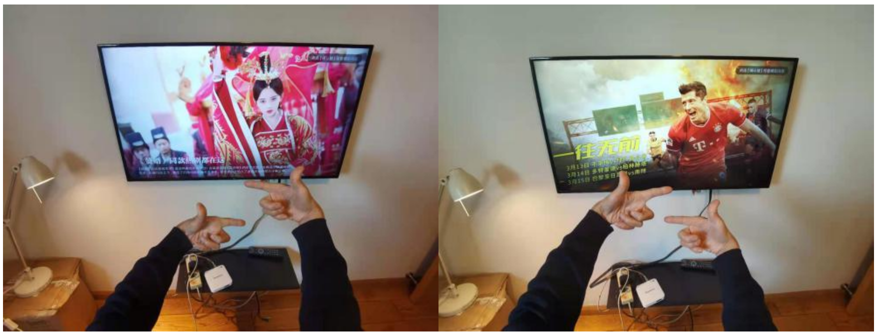


Figure 43, Switch channel 01

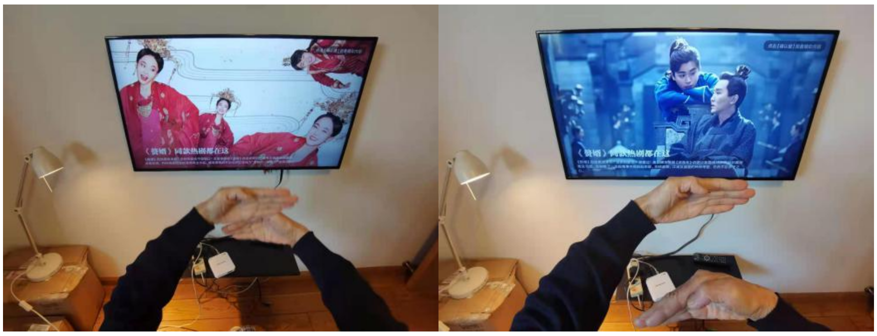


Figure 44, Switch channel 02

The results show that the above eight gestures are suitable for use in smart products for the elderly. This kind of gesture control application can eliminate the barriers for the elderly to use smart home appliances.

The next step is to make adjustments to the previous chapter's conclusions based on the verification at the end of the study. The researcher selected the best motion for each command in the gestures listed in this study based on the previously discussed follow-up research .

Command name	**“Open”**	**“Close”**
Best choice	Gesture02 	Gesture16 
Command name	**“Adjust”**	**“Switch”**
Best choice	Gesture11 	Gesture08 

Table30, The final result of TV control

Chapter 5 Conclusion

Interaction based on natural gestures is an effective way for the user to welcome smart life, and it can bring a better living environment for them. In the research field of gesture interaction, besides the difficulties of recognition technology, the biggest obstacle is to find gesture command actions suitable for the public. In this study, the researcher provided a method for future designers to study gesture interaction. Using this methodology, designers can in-depth study the user's understanding of gesture commands. And based on the analysis, designers can quickly and effectively evaluate a series of gestures. This method helps designers design and screen gestures and finally get gesture interactions suitable for a particular group of people.

However, there are still more aspects that can be further investigated in the next phase. Suggestions for the further research as follows:

1. The research method proposed in this paper is only for gesture interaction design for the elderly. In the future, designers can modify the method according to the research process proposed in Chapter 3 to make this method suitable for other groups of people.

2. In specific applications, many factors affect users' cognition of gestures. Designers can make more profound explorations based on their interview performance.

3. This thesis proposes a method of gesture command design in gesture interaction, the recognition technology of gesture and the feedback mechanism of gesture interaction need more in-depth research in the future.

4. Culture is an essential factor that affects gesture commands. Future research can further study gestures based on the characteristics of different regional cultures.

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