Guidelines for Designing Inclusive Wearable Devices for the Aging Population

by

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Abstract

Wearable technology has rapidly evolved during the past decades and become trendy nowadays. There is a steady increase in wearable devices sales every year; however, unfriendly user experience and high abandonment rates show that the future of wearable devices should be more inclusive and engaging. As a designer, it is a responsibility to design technology products for a better experience to accommodate a wide range of people with different abilities and experience.

Wearable devices have great potential values to benefit the aging population, while the gap between the product value and current usage is quite huge. This thesis aims to help designers to design an inclusive wearable device for promoting health, especially to accommodate older users' needs. Based on user experience design (UX) theory, a series of design guidelines are provided with different design stages to help designers create and evaluate their concepts. The design thinking behind this research is using design to influence user's behavior. Specifically, through inclusive design, UX design, and persuasive design strategy, a designer can understand behavior, enable behavior and finally influence behavior. An ideal inclusive wearable device should not only be accessible to older adults without stigma but should also be attractive to normal consumers because of ease of use.

Acknowledgments

After four months of learning, researching and writing, my thesis finally comes to an end, but my way on design will never stop. I will always passionate to deliver better user experience to users and keep learning new knowledges. The thesis-developing process is stressful but fulfilling, and I would like to express my gratitude to the people who have guided and supported throughout my graduate student life.

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Chapter 1 Introduction

1.1 Problem Statement

With rapid adoption of powerful mobile computing devices, and the development of ubiquitous computing, wearables have gradually become a trend, especially in the health and wellness area. Compared to traditional tracking devices like pedometer, mobile phone and hospital testing, a wearable has several unique advantages in terms of tracking activities: multi-tasking, interactive interface, continuously monitoring and inexpensive. However, despite such potential advantages in health tracking, the current usage of wearable devices among the elderly is poor. According to the US Census Bureau Reports in 2018, 2030 will be a demographic turning point when about 20% of people will be at retirement age (65+) (Vespa, 2018). However, in recent research, the older adults (65+) only account for 4.6% of the wearable users in US (Figure 1.1). This gap indicates that most current wearable devices cannot fulfill older users' needs. Indeed, the younger people are still the largest user group so that the mainstream wearable devices still focus on the youth market; however, the rapidly growing aging population should also be able to enjoy the benefits brought by wearable technologies. There are several wearable devices that specifically focus on older adults which are also not welcome because they shut normal users out, which causes stigma feelings for older adults compared to mainstream products, and such devices are hardly adapted to changes with users of different abilities and preference. Therefore, I propose an inclusive design would be the best and win-win solution, because it can not only satisfy a wider range of potential users' needs but can also maximize the companies' benefit.

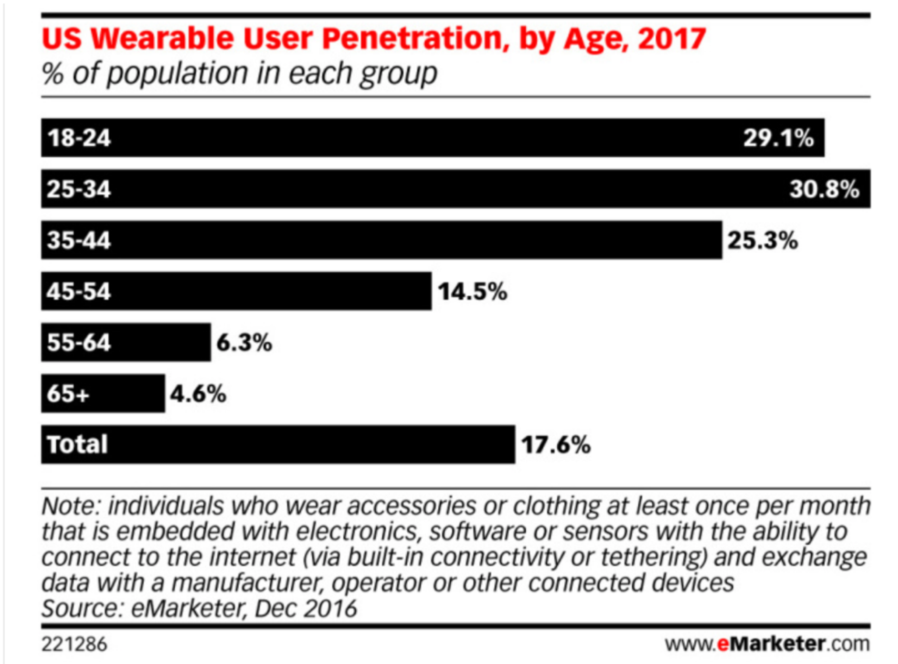


Figure 1.1 US Wearable User Penetration by Age

https://www.emarketer.com

1.2 Need of Study

The advantages of designing wearable devices to accommodate older adults is stated above, but how to apply inclusive strategy to an actual design is still challenging. If a product is inclusive, that means it keeps all elements and features at a great balance to attract both normal users and elderly users. There will be great business success, social benefit and user satisfaction as well. For example, the inclusive and eye-catching style design of the Bradley Tactile Watch (Figure 1.2) can let more people to use it, and in more ways. It is designed for touch when you cannot easily use sight: during a meeting, in a movie theatre, or due to a vision impairment.

Figure 1.2 Bradley Tactile Watch

In order to achieve this goal, we first need to understand potential users and define the exclusion, as design for all is not realistic in most practical design. Keeping inclusivity in mind to understand users' needs and barriers, then we can find ways to address these issues. The second part will use design to enable users to accomplish their tasks. The approach I will apply here is through user experience design process to consider each design element so that the design can deliver a better using experience. The last part is included in the experience design process but focuses on an added value of wearable devices for promoting health. In my research, I found a general challenge for wearable devices in health area is how they can be "actionable", which means from monitoring health to managing health, how can design promote users to a healthier behavior? Therefore, in this thesis, older adults and wearable devices will be firstly introduced. Also, the older adults' expectation, actual usage and barriers will be discussed in the literature reviews. Then the strategies of inclusive design, experience design and persuasive design will be discussed in depth. In turn, a completed design flow with a series of guidelines will be developed for designer to create and evaluate their wearable devices design for promoting health.

1.3 Objective of Study

- To study older adults' needs and age-related changes.

- To identify the usage and challenges of current wearable devices.

- To investigate older adults' attitude and behavior with wearable devices.

- To summarize users' barriers when using wearable devices and their suggestions.

- To study the theories of inclusive design, user experience design and strategies of promoting behavior changes.

- To determine relationships between these design strategies and how to influence user's behavior.

- To develop a design flow chart and guidelines for designers to design and evaluate the design of inclusive wearable devices for older adults.

1.4 Definition of Terms

Evaluation- a systematic determination of a subject's merit, worth and significance, using criteria governed by a set of standards ("Evaluation," n.d.).

Inclusive Design- the design of mainstream products and/or services that are accessible to, and usable by, as many people as reasonably possible ... without the need for special adaptation or specialized design ("Inclusive Design," n.d.).

Persuasive Design- persuasive design is an area of design practice that focuses on influencing human behavior through a product's or service's *characteristics* ("Persuasive Design," n.d.).

User Experience Design- the process of creating products that provide meaningful and relevant experiences to users. This involves the design of the entire process of acquiring and integrating the product, including aspects of branding, design, usability, and function ("User Experience Design," n.d.).

Wearable Technology- is a blanket term for electronics that can be worn on the body, either as an accessory or as part of material used in clothing ("Wearable Technology," n.d.).

1.5 Assumptions of Study

It is assumed that all the theories, research results, methods and statistics I found are correct.

It is assumed that designers do want to their products to accommodate a wider range of people of various abilities and preferences.

It is assumed that technology barriers for older adults can be solved by the design process.

It is assumed that the prices of wearable devices are affordable by potential users.

It is assumed that the technical parts such as accuracy, battery life and data processing will not cause usability problems.

It is assumed that the designers have already acquired a basic product design skill includes ideation sketching, CAD modeling and prototyping.

1.6 Scope and Limitations

Though the design flow chart is a completed process for designers to apply, the design considerations will mainly focus on the user experience of the software sides. The design of a wearable device is typically multi-faceted, including both hardware and a software component; however, as a technological product, the barriers for elderly users mainly happen when they are interacting with the interface. Therefore, I only provide a general guideline for the hardware part in the thesis. The physical problems of current wearable devices will also be discussed in the Literature Review.

Also, only self-monitoring and health management functions will be discussed in the wearable devices design since this is the most popular application field in wearable technologies. Moreover, the aging populations will have exceptional benefits from wearables to promote their health. Another recent topic of wearable technology application is remote health; unfortunately, the current accuracy and compatibility problem are difficult to solve and therefore should not apply directly to medical use. The study focuses on the inclusive design of wearable devices to accommodate older adults, so children will not be considered.

1.7 Procedures and Methodology

Part 1 Concepts overview

Step 1 Introduce the target aging population as well as their situations and needs.

Step 2 Introduce the development of wearable device and its crucial elements

Step 3 Study older people's attitude and experience with the wearable devices from the Literature Review and analyze their barriers and suggestions.

Part2 Theories overview

Step 4 Learn inclusive design theory and existing guidelines, focusing on the elderly inclusive design aspects and the application in the context of wearables.

Step 5 Study the user experience design process, guidelines and key factors, also discussing the application to wearable devices for elderly users.

Step 6 Study the strategies for promoting behavior changes and their applications to wearable devices.

Part3 Guidelines building and application

Step 7 Build a new design flow chart of designing an elderly-friendly inclusive wearable device.

Step 8 Develop a series of design guidelines for each design stages to help designer go through the design and iteration process.

Step 9 Apply the new guidelines to a practical design project.

1.8 Anticipated Outcomes

The primary outcome of this thesis is providing a series of new guidelines for designers to design and evaluate an inclusive wearable device for older adults to promote health. The target aging population and wearable technologies will be studied. The barriers were encountered with wearable devices by elderly users and their recommendations will be summarized from the Literature Review and will be used as a reference in developing the guidelines. The study will also cover the theories of inclusive design, user experience design and strategies of promoting behavior change and how these strategies be applied in the context of wearable devices. Existing design guidelines will also be referred to, organized and edit to build the final new guidelines. A CAD model and corresponding user interfaces will be developed based on the new guidelines.

Chapter 2 Literature Review

2.1 Aging Population

2.1.1 Demographic Structure & Socio-economic Status Change

In the world today, the demographic structure is aging fast, especially in developed countries. It was predicted that 2030 will be a demographic turning point as the baby boomer will be older than 65 years old; also, approximately 20% of the people will join the aging group (65+) (Vespa, 2018). Rather, the social-economic status is gradually changing due to the aging society as the healthcare systems are experiencing severe financial stress (Intille, 2004). Such problems indicated that we should find ways to better fulfill the health needs of the elderly people as well as relieve some of the burdens of the healthcare services.

2.1.2 Independent Living Trend and Desire of Older Adults

From the perspective of the older adults, they generally hold a desire for independence which is aligned with societal trends. Research showed that even while getting older, people in their 50s, 60s and 70s are still active to engage in their communities and determined to remain relevant to the societies in which they live. (Farage M.A., 2012) Many older adults feel years younger than their chronological age. Although they may notice some aspects of diminished capacity, they do not view themselves as old and want to remain independent, productive and socially integrated.

On the other hand, the negative stereotypes about older adults also contribute to their feeling of stigma. (Clarkson, 2013) It is a prejudice and mistake to think of older adults as a wheelchair user or as severely disabled. The truth is older adults are mostly the vast number of people who, in advancing age have little discernible impairment, but have a strong drive to remain independent to contribute to the community, yet sometimes are hampered by inappropriate design. Thus, a better design can play a crucial role in enabling the elderly users to remain physically and mentally active.

2.1.3 Health Monitoring & Management Needs of Older Adults

2.1.3.1 Health Aging

Though the elderly population is more independent than they might seem to be, they still have exceptional expectations and needs in health monitoring and health management than younger groups, looking forward to “Healthy Aging”. The World Report of Aging and Health introduces Healthy Aging as “the process of developing and maintaining the functional ability that enables wellbeing in older age”. (World Health Organization, 2015)

2.1.3.2 Inadequate Physical Activities

For the aging population, physical activity provides innumerous benefits, for example, preventing functional decline and maintaining independence, which can contribute to aging healthier. However, a study displays that more than 70% of older adults are inadequately active. (Arriaza Jones, 1998) The main barriers for the elderly to perform physical activity is the lack of information about their individual capabilities and limitations. (Hirsch, 2000) Using health monitoring technology to help them understand their body and create a proper activity plan is important to achieve Health Aging goal.

2.1.3.3 Prevalence of Chronic Diseases

The prevalence of chronic diseases is another reason for the importance of health monitoring and management. (Zhou, 2018) Also, because of the increasing burdens on healthcare, health monitoring is expected to gradually shift from the hospital to the family or individual-centered environment. Statistics showed that osteoporosis, cardiovascular diseases, diabetes and dementia are the four most common diseases in elderly people (Hentschel, 2016) , and many such geriatric diseases need continuous or frequent monitoring of their parameters to ensure good health. (Kekade, 2018) Therefore, the older adults are more prone to benefits from using wearable technology to monitor and manage their health.

2.1.4 Age-related Changes

When designing technology for older adults, age-related changes in vision, hearing, motor control, cognition, and even the social changes are important considerations. Only by understanding user's behaviors and addressing their barriers can the design be truly inclusive.

2.1.4.1 Vision Changes

In terms of vision, these include changes in visual acuity, color perception, peripheral vision, and dark adaption. (Charness, 2009) For example, as objects move away from central vision into the periphery, it becomes more difficult to resolve their details. Similarly, user interfaces employ pop-ups often appearing on the corners of the screen; however, the information might not be noticed by elderly users. Also, the adaption from a very well illuminated environment to a very poorly one reduces the sensitivity of their vision. (Nunes, 2010)

In order to address the visual difficulties, there are some considerations when designing visual displays for older adults. (Williams, 2013) A proper visual display for elderly should be easily adjustable, with color only used as needed and overly-flashy designs omitted because of their distracting qualities. Consistent brightness would be necessary, and pop-ups might be allocated to a particular part of the screen to avoid overwhelming users. Meaningful icons should be provided to differentiate categories, as text-only listing might be problematic for those with poor vision. In generally, keeping the visual presentation simple and clear enough is the key when designing for older users.

2.1.4.2 Hearing Changes

At the age of 65, about half of the men and 30% of the women suffer from hearing losses on different levels. For instance, older adults face greater difficulty perceiving high-pitched sounds, such as those above 2500Hz, and greater interference from background noise. (Jia, 2015) The audible frequency also decreases with age. Moreover, the hearing loss is worse for consonants than it is for vowels, which makes it difficult to fully understand some words and long sentences. (Nunes, 2010)

Voice interaction is a common way to help products of technology become more accessible and convenient. The success of user interactions with tech-products can be greatly affected by user's ability to hear. Another fact is that elderly users tend to downplay or even deny hearing loss they might have in order to avoid stereotypes (Nunes, 2010), so, systems with sound features should enable users to easily to adjust the volume. Also, when designing speech presentation, the designer should keep an eye on its pace, length, linguistic structure and pauses to facilitate recognition.

2.1.4.3 Motor Changes

Changes in motor control, including increased difficulty with fine motor control, coordination, onset of disease processes such as arthritis, and reduced skin sensitivity, can affect the experience of older adults physically interact with technology. Elderly users often have a more difficult time finding little targets and make less accurate movements. Continuous and rapid movements such as "drag and drop" and "double click" are also difficult to finish. As arthritis is common among older adults, swelled fingers in pain will most likely reduce the speed and accuracy of the intended movement. (Fisk, 2018) Diminished skin sensitivity may cause problems when using physical buttons.

It is important to adapt to the motor impairments when designing elderly-friendly interaction. Bigger buttons and longer intervals of time between clicks are some ways to relieve users' pain and eliminate unnecessarily errors. Also, to address visual impairment problem, some systems utilize an audio display when a user indicates a selection; however, it is not uncommon that elderly users also have hearing problems so they may run the risk of missing the audio output. Haptic response such as simple vibration thus can be very useful in adding user interactions, but the designer needs to make sure that the haptic feedback is noticeable yet unobstructive.

2.1.4.4 Cognition Changes

As aging, cognition is affected as well. Older adults are associated with general slowing of cognitive processes, decreased memory capacity, and decreased attentional control. (Charness, 2009) Memory is an ability that involves complex process such as the storage and retrieval of information in the brain. (Nunes, 2010) If an activity involves multi-tasking, older adults tend to perform at lower levels compared to younger people, especially complex tasks. Problems will occur if complicated inferences are required and connections between ideas are not explicit. Processing speed also declines with age since older adults tend to take longer to process and respond to incoming information.

Attention is our capability of concentrating on one task instead of a number of competing thoughts and stimulus. Noise and details can easily distract elderly users. Fisk also states that "if we do not selectively attend to the stimuli coming into our senses, we would be overload". (2018) When required to execute more than one task at once – like driving and looking for street signs – older adults show more difficulty than younger people. Study also found that older adults are more easily to be distracted by salient events such as flashing and high-intensity lights.

These changes in cognitive function can slow performance and result in a greater number of errors as older adults interact with technology that was not designed with their capabilities in mind. To better design with memory and attention constraints in mind, it is important to require the minimal steps to finish tasks, remove unrelated information and blinking elements that capture user attention. Jargon-free tutorials are required to introduce new features to elderly users. All elements should be designed with in a simple and clear way, and attention-getting components should be sparse.

2.1.4.5 Social Changes

Another major change that happens to older adults is social roles and relationships. (Jia, 2015) In terms of role loss as people age, the elderly people probably start losing roles as active parents, employees, and spouses. This often leads to feelings of loss of control over life. In addition, older people generally have less contact with others, which in turn causes their social networks to shrink.

Consequently, when people do not feel in control of their lives and are isolated, they tend to have lower life satisfaction and well-being. So, design to promote the older adults' positive attitudes, self-efficacy, and encouragement to maintain their social networks could be extremely valuable.

2.1.4.6 Defining "Older Adults"

With age comes inherent biological changes that often lead to health impairments; however, there is no such thing as "the typical older adult". There are, instead, several trajectories of age, defined not only by impairment, but also by the ability of the individuals to cope with those impairments. (Cabrita, 2018) Design and development of technology should not be geared towards the factor "age", but rather should focus on specific abilities or impairments.

It is important to recognize that older adults as the target group are very heterogeneous and individual differences are very prevalent throughout the life course. (Czaja, 2005) Aging is a highly individualized process, which means older adults vary considerably in their abilities, skills and experiences. When designing age-technology interaction, designers should use age as an index of potential physical and behavioral changes that occur with adulthood.

Czaja (2009) defined "older adult" as those individuals who are 60 years of age and older in his book; however, he also admitted that such classification is not always so straightforward. For example, the detection threshold for the normal range of human speech goes through a rapid decline after the age of 60, while accommodation is severely limited in vision by the age of 65. Generally, although demonstrating individual differences, older adults do have much in common in terms of the biological, psychological, and social dimensions. As designers, when we are considering inclusive design, we are focusing on those similarities that allow us to optimize the design.

2.1.5 Family & Care Provider Connection

For older adults, close connections are important to Healthy Aging. However, the reality is most elderly participants do not live with their children according to research. (Fang, 2016) Also, most of them had different levels of chronic diseases such as hypertension or diabetes and one of the main reasons why they welcomed a wearable device was its function for continuously monitoring their health and informing their family members or care providers about the health condition so that can ease their concern and worry. A sharing information system is expected to connect between older adults and their family members or care providers.

2.2 Development of Wearables

2.2.1 Wearables Became the Trend

Wearable technology, also called wearable gadgets, is defined as a category of technology devices that can be worn by a consumer and often include tracking information related to health and fitness. (Sazonov, 2014) Wearable devices refer to small electronic devices that are used as accessories that enable processing of personalized information.

Due to rapid adoption of powerful and affordable mobile computing device as well as the emergence of real-time context-ware computing, wearable devices are so popular and prevalent nowadays; while a reliable 24 hours a day measurement and recording of the physical activity in daily life from video to smart homes remains either intrusive or expensive. (Tedesco, 2017) Therefore, the user of micro sensors worn by elderly people to analyze body movements seems the most acceptable solution for the individuals and their caregivers. The massive diffusion of micro electromechanical systems makes those micro sensors highly available, miniaturized, and low-cost. Many big technology companies launch new wearable products every year (Figure 2.1), which proves that the wearable device is absolutely an irresistible trend in the current market and the near future.

The development of wearable technology is just started. There is a general description of the future direction of wearable devices that they will be even smaller, lighter, inexpensive, and available in a variety of convenient form factors. (Intille, 2004) Such trends can also be implied from the figure below (Figure 2.2) about how consumers predict wearable technology.

(a) Apple Watch Series **(b) HUAWEI Watch** **(c) Garmin Vivoactive 3** **(d) Misfit Vapor 2**

(e) Samsung Gear Fit 2 **(f) Fitbit Charge 3** **(g) Xiaomi Mi Band 3** **(h) Sony SmartWatch 3**

Figure 2.1 Mainstream Wearable Devices in Current Market

Figure 2.2 Prediction of Wearable Technology on Consumers' Perspectives

2.2.2 Classification of Wearables

The evolution of wearables is so quick that many innovative forms and functions of wearables have been created these years. Though there is not an authoritative standard of wearables classification, the International Electrotechnical Committee (IEC) generally divided wearables into four types which are near-body electronics, on-body electronics, in-body electronics and electronic textiles (Figure 2.3). Also, a more specific classification of wearable devices is created by TESLASUIT team (Figure 2.4). I will only focus on the design of accessary type devices showed in the Phase 1 of Figure 2.3, since this category is the most popular and acceptable by older adults. Also, design considerations will include the wearable systems like applications on mobile phones and websites.

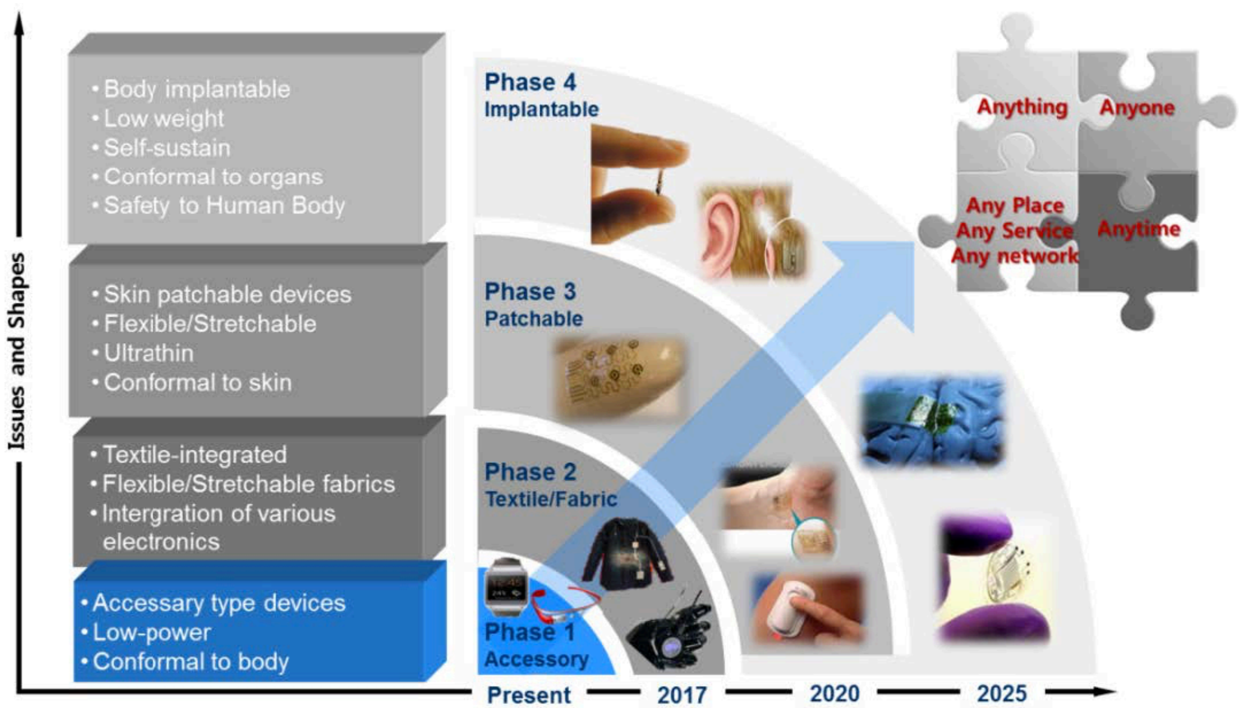


Figure 2.3 Classification of Wearables by IEC

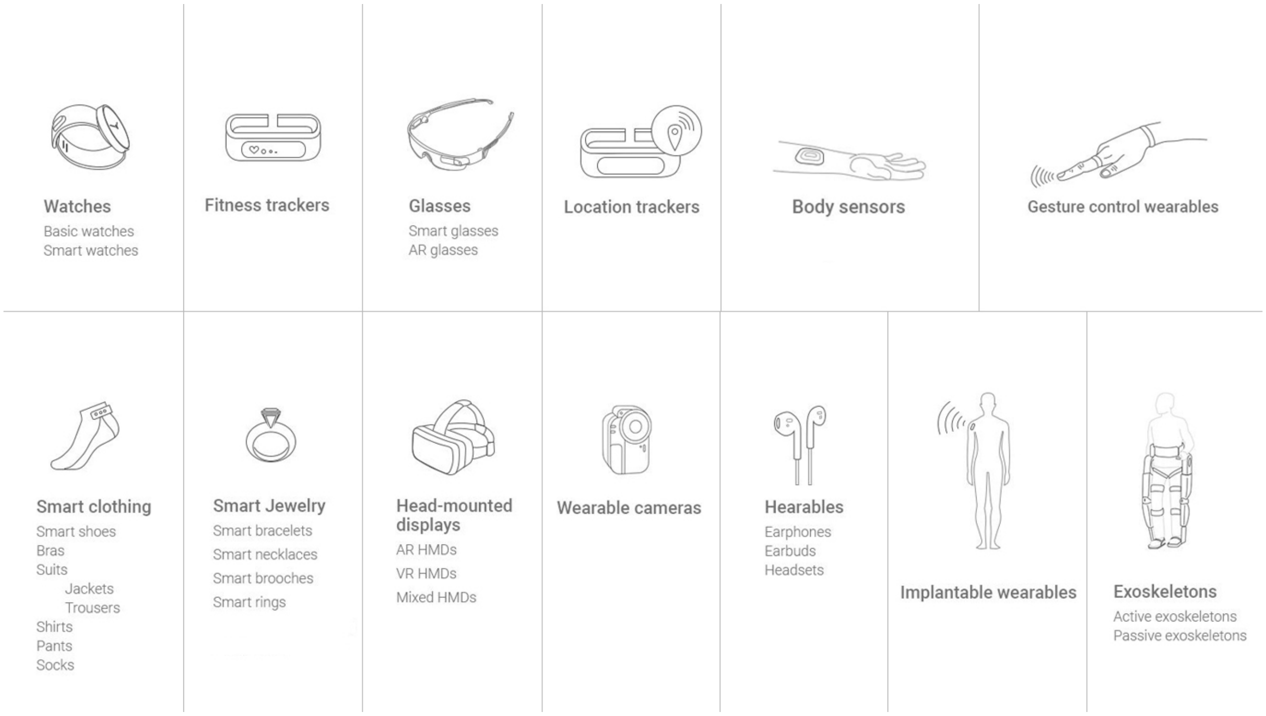


Figure 2.4 Classification of Wearable Devices by TESLASUIT Team

2.2.3 Technologies of Wearables

The most crucial technology applied on wearable devices is sensor technology, which realize the main function of tracking activities. Features of sensors used in wearable devices can be divided into four major groups: environmental sensors, biosensors, location tracking sensors and other sensors. (Mardonova, 2018)

Environmental sensors. Environmental sensors are used for measuring, monitoring, and recording environmental conditions or properties, such as barometric pressure, relative humidity, luminosity, temperature, dust, and water level.

Biosensors. These sensors allow people to be aware of their health status at all times and are used by healthcare professionals in the early diagnosis and prevention of disease. Examples include body temperature sensors, heart rate monitoring sensors, electrocardiogram (ECG) sensors, electroencephalography (EEG) sensors, electromyography (EMG) sensors, blood pressure sensors, and glucose level sensors.

Location sensors. Location and position tracking sensors such as GPS, altimeter, magnetometer, compasses, and accelerometers are the most common types of sensors on wearable devices.

Other sensors. Other sensors include a variety if detectors and sensors available on the market, usually found on consumer wearable devices. Wearable cameras and smart glasses are often described together with camera sensors as the main part of these devices. Communication sensor modules (i.e. Bluetooth, Radio-Frequency Identification, Wi-Fi, etc.) provide communication and data exchange features to wearable devices. Motion sensors, speed sensors, inertial measurement unit (IMU) sensors, ultrasonic sensors, and infrared receiver (IR) sensors are also used as electronic components of wearable devices.

Several methods for physical activity monitoring and assessment was discussed in a study, finding a wearable motion detector is the best tradeoff. (Tedesco, 2017) For example, self-report is too subjective and indirect to be referred as reliable information. Video-recording is not practicable for great amount of resources. Smart home and ambient assisted living are too expensive to be widely used; also, privacy concerns and limited indoors application could be another hindering factor. Though the method of doubly labeled water is the most accurate tool used for measuring energy expenditure, it is expensive and requires specialized training and rigid environment. Polysomnography is also quite accurate, but its use of electrical wires attached to the body may disturb sleep.

Regarding accuracy of wearable devices, several studies showed similar points that current wearable devices generally have good accuracy for health monitoring as a health indicator and disease prevention, however, not enough for medical use. (Piwek, 2016), (Godfrey, 2017), (Hentschel, 2016) That is also the reason my research will focus on health monitoring and management.

Other supportive technologies include display tech, chip tech, operating system, power support, and cloud tech together cooperating and bringing wearable technology to benefit our lives. With knowledge of wearable technology, designers can better determine the functional limitations and possibilities of their wearable designs.

2.2.4 Functions of Wearables

2.2.4.1 Health Monitoring

There are a wide range of applications of wearable technology, including embodied tangible interaction, sport and health tracking and remote medical, etc. In terms of health application, health monitoring is the key function in supporting healthy aging in two areas: monitoring of the body and monitoring of the minds. (Cabrita, 2018)

Physical health. Physical health is essential to the complete health of an individual; this includes everything from overall well-being to physical fitness. In adults, typical ways of collecting data on physical activity are by self-administrated questionnaires, or by some forms of direct measurement movement. (Barton, 2017) Regarding the method of questionnaire, it can fulfill the same task but lacks objectivity and accuracy as it relies on the recall ability of the respondents. In fact, large differences between self-reported and objectively measured levels of physical activity among older adults have been found. (Wild, 2016). Furthermore, their repetitive use can be bothersome to the individual, often leading abandonment. Therefore, more objective, and less obtrusive ways of monitoring physical activity in daily life are needed.

Activity-tracking devices monitor can monitor the number of steps, minutes of activity, calories burned, and distance traveled quite accurately. Some of the trackers are also able to record heart rate, sleep habits, or number of stairs climbed. (Steinert A. H.-T., 2018) For visualization of the collected data, additional websites, mobile applications, or the devices themselves are used (Figure 2.5). Within the accompanying platforms and applications, the users are able to track, record, learn their data, and even can share their data with others in the online community (Figure 2.6)

Figure 2.5 Wearable Device with Accompanying App on Mobile Phone and Website

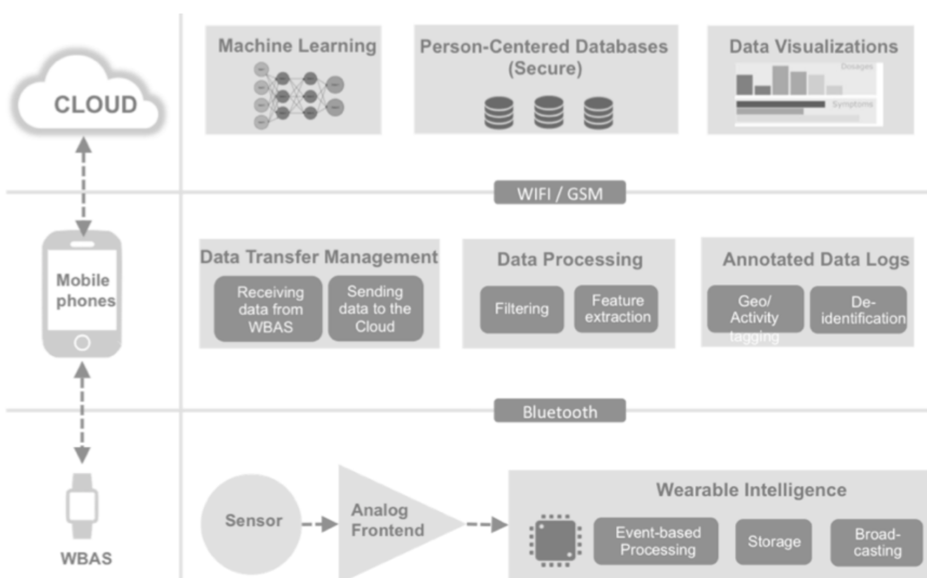
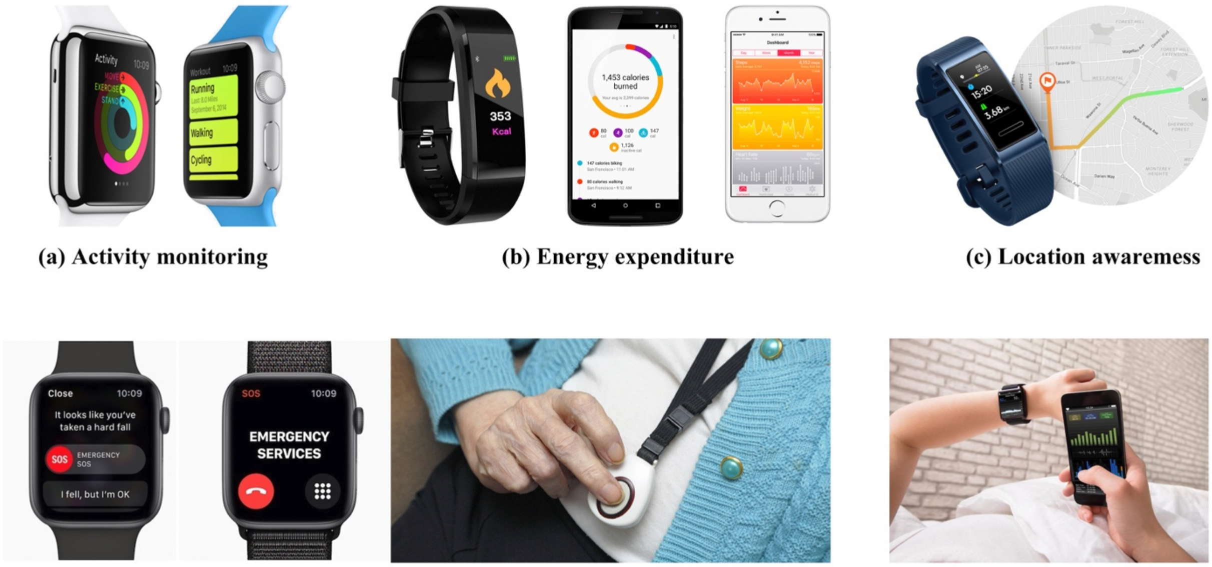


Figure 2.6 Example of Workflow of Wearable System

There are mainly five physical activity indicators (Figure 2.7).



(a) Activity monitoring **(b) Energy expenditure** **(c) Location awaremess**

(d) Fall detection and emergency call (built-in and stand-alone) **(e) Sleep monitoring**

Figure 2.7 Examples of Physical Activity Indicators in Applications

Activity monitoring (a). Activity monitoring is beneficial to help people understand their exercise better and encourage people to be active. Sedentary behavior is a dominant behavior nowadays, which is connected to a high risk of developing chronic disease. It has been also reported that the amount of time spent sedentary may be an important health risk factor for all-cause mortality. (Van der Ploeg, 2012)

Energy expenditure (b). Energy expenditure is expended as a result of physical activity and is extremely important in lowering the rate of obesity, type 2 diabetes mellitus, and other diseases, and has been known to be one of the factors impacting the risk of falling events, especially in older adults. (Morrison, 2016)

Location awareness (c). The availability of contextual information, like location, can be incorporated with the other indicators to provide the ability to assess the indoor and outdoor location of physical activity and sedentary behavior. GPS, wearable cameras, and wireless communication technologies can be used for this purpose. (Tedesco, 2017)

Fall detection and gait/balance analysis (d). Fall-related injuries can rapidly deteriorate the health and functional status of elderly people, leading to loss of independence and higher risk of morbidity and mortality (Yang, 2010). Statistics display that more than 30% of people older than 65 suffer a fall at least once a year. (Morrison, 2016) Detection of falling events thus have the potential to mitigate the adverse consequences of a fall and can have a direct impact on the reduction in the fear of falling and the rapid provision of assistance. Including such features could be an added value to the older adults.

Sleep monitoring (e). Sleep disturbances are also very common in older adults. Those sleep disorders decrease the quality of life and can be linked with premature death. (Tedesco, 2017)

Mental health. The emotional wellness of individuals emphasizes the importance of a positive outlook towards life circumstances, the capability to cope with stress and ability to maintain fulfilling relationship with others. WHO also defines the mental health of individuals as an equally contributing part of overall wellness of an individual and considers emotional wellness as one of the most important and overlooked parts of overall health. (World Health Organization, 2010)

In the year 2015, the annual cost of stress in the US alone is estimated to be 300 billion; similarly, a huge market of meditation, yoga, addiction treatment and depression treatment indicated the overall mental health are getting worse in our modern life. (Bradford, 2017) In recent years, there is also a significant increase in efforts by individuals and healthcare sectors to promote digital solutions to increase emotional health. However, the digital intervention to improve the emotional wellness of older adults is still an under-explored area. (Warraich U. R., 2017) With age, several factors contribute towards the emotional wellness of an individuals, such as loneliness and isolation. In addition, deteriorating health conditions may add extra stress to older adults. It has been proved that emotional self-regulation can help improve the quality of life in patients with different medical problems, like diabetes, immune diseases, etc. (McCraty, 2000) In order to promote the mental wellness of older adults, wearable technology can be the ideal intervention.

Firstly, different physiological signs (e.g. facial muscle tension, blood volume pressure, skin conductance which measures electro-dermal activity, etc.) can be collected using wearables and sensors. These data can be interpreted as emotional data and analyzed to provide recommendations to improve emotional wellness. (Picard, 2001) Secondly, using such wearables and sensors to track emotions have a convincing accuracy. In a research conducted by MIT lab, they claimed to detect emotions as happiness, sadness, or anger with 87% accuracy using reflections on the human body emitted by a wireless router to detect heartbeat and breath. (Zhao M. A., 2016) There is a very promising future and a long way to achieve the goal that emotional detection can manage users' mental health effectively.

Indeed, there are some wearable devices are mainly designed to measure emotions: like (a) Spire Stone, (b) Muse, (c) Feel, (d) Bellabeat Leaf Urban, and (e) Pip (Figure 2.8). However, there is an obvious research gap in research for wearables that address emotional wellness for older adults.

Figure 2.8 Examples of Wearable Devices for Emotional Health

Another challenge for wearable devices to monitor health is that the current commercial wearable devices are only reliable in measuring the basic indicators (e.g. number of steps, distance), which can be referred as a health assessment. However, the accuracy of measurement in relatively complex activities, ECG, and sleep quality are still inadequate (Figure 2.9).

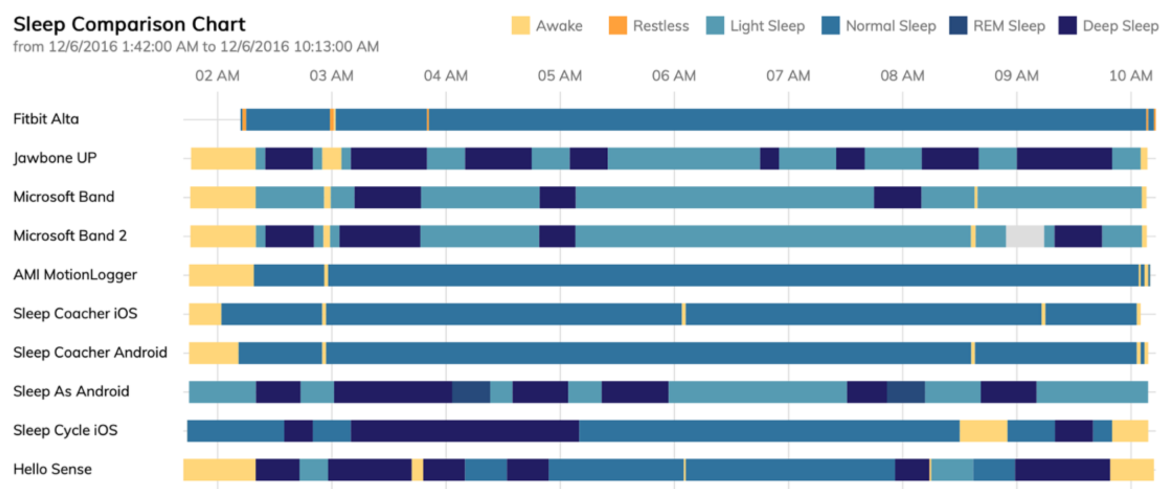


Figure 2.9 A Sleep Measurement Comparison Chart from Ten Mainstream Wearables

2.2.4.2 Health Management

Health monitoring, as the primary health function of a wearable device has been discussed above. Turning to health management, this is an actionable feature that should be with the monitoring process to help people change toward a healthier behavior, which unfortunately absent in many wearable devices' design.

Taking a sedentary lifestyle as an example, physical inactivity is the fourth leading cause of mortality, behind only hypertension, tobacco use, and high blood glucose. The prevalence of sedentary behavior is increasing, and it has been identified as a major risk factor for breast and colon cancers, diabetes, and heart disease. (Mercer, 2016) Increased exercise can reduce frailty, lower blood pressure, and lead to a longer independent life. If we can use wearable technology to help users better understand their bodies and persuade them to develop a healthier behavior change, that is the real value of these products.

Unfortunately, many studies conclude that the biggest obstacles to manage people's health is unreasonable data processing and presentation. (Cabrita, 2018) Firstly, through monitoring, we can collect real-time data in daily life. However, most of times the data collected is meaningless in its raw, or unprocessed form. A smart reasoning and proper display of such data thus important to bring a wealth of meaningful and understandable information regarding the user's context and behavior. Secondly, another crucial step is to turn this information into meaningful actions to promote behavior change: coaching. By doing that, persuasive technology can provide coaching in (near) real-time to motivate, adapt to changes, and finally can maintain the healthier behavior changes of the user.

2.2.4.3 Fall Detection

Emerging detection is one of the most important functions of wearable devices for older adults. Falling can be a frequent and dangerous event for elderly people. It is estimated that over a third of adults age 65 years old fall each year, making it the leading cause of nonfatal injury for that age group. (Hornbrook, 1994) There are a pile of related research works and products design on wearable devices for elderly fall detection which can be referred. (Pierleoni, 2015) If appropriate, including a fall detection function could be of great value to older adults.

2.2.5 Human Factors of Wearables

Human factors considerations involve both hardware and software aspects of wearable devices should not be neglected when designing a wearable device. There are several points we need to consider carefully in design practice.

Location. Although there exist a lot of innovative wearable forms, the placement of the wearable device does have some rules to follow. In order to acquire better accuracy, a research analyzes different parts of the body that suitable for wearable computers: (Fang, 2016) neck, upper back, upper arms, waist, wrists, tights, calves, and ankles (Figure 2.10). In the same research, wrist device received the highest acceptance, which provides the best viewing angle for information reading and a natural way for interacting. (Figure 2.11)

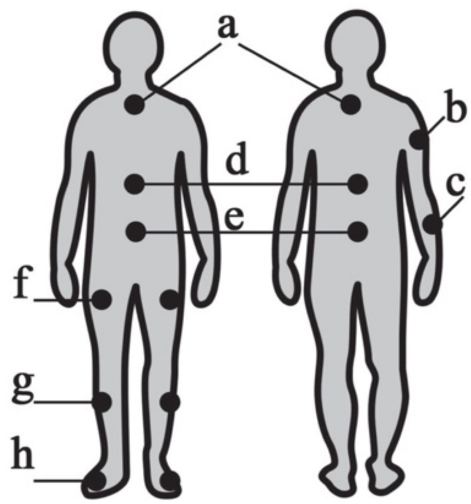


Figure 2.10 The Parts of Human Bodies Suitable for Wearables

Figure 2.11 Wrist Device Gives the Best Viewing Angle and Natural Interaction

Wearability. Wearability is a key factor for success of a wearable devices which considers the physical shape of objects and their active relationship with the human body. Ergonomics and wear comfort are two main aspects here. The former regards the respects to the body anatomy, its constraints and how users perceive it; The latter concerns the freedom from discomfort and pain. For example, ergonomic design considerations such as grab ability (proper shaping of the user's hand), ease of use (intuitive controlling), coherence (coherent logic of the device), and limited conditions of using the device (wearing gloves). Comfort involves an acceptable temperature, texture, shape, weight, and tightness and a comfortable device fit user enabling normal movements, without physical or psychological constraints. Flexible materials for instance, permit normal joint movements. Smaller form factors and more convenient sensor locations on the body can aid to ensure comfort.

A research compares four belt wearables for measuring HR and ECG for elderly, showed some wear manner and comfort concerns. (Ehmen, 2012) For example, there is a potential usability problem if the belt lacks length-adjustment function. Also, elderly people are looking for a more comfortable manner to put on the wearables through a proper closing and locking mechanism (e.g. Velcro and magnetic are better than snap closure and putting the pin into a small hole). They are sometimes confused if they are positioning the sensors correctly (e.g. sensors are not centered, putting upside-down). If a wearing manner requires a high order of the fine motor skill, there will another impediment. Also, uncomfortable material (e.g. too narrow width, non-breathable coating of sensors, too hard and inflexible, rough and constrictive) will dramatically upset the older adults.

Ease of Use. A straightforward, simple and intuitive interface enhances the usability levels of the device, aiding to increase the engagement levels of users. Intuitiveness concerns the immediate understanding of how the interaction occurs, e.g. regarding existing buttons, icons, commands, and features, can facilitate user's access to the device. User friendliness can facilitate the user interactions with device, especially for older adults. Research, among a group of elderly users using an activity tracker with only one button to interact with, found it is difficult and annoying to use because they had some problems feeling the button under the silicon wristband sue to diminished sensibility. (Rasche, 2016) Using an obvious button design or applying multimodal interactions could be a solution. Also, size was found important to wearable devices, in both software and hardware sides. The older adults mainly prefer a larger screen for better information presentation, but a compact device for portability. (Fang, 2016)

Reliability. It refers to the level of confidence and trust that users have of the device, concerning safety (no harm to the user), precision (provide faithful, accurate data), and effectiveness (expected responses).

Subtlety. Subtlety refers to transparent communication and unobtrusiveness of the device. Users are often concerned with excessively attracting other's attention. For example, notifications or speech intended for the owner of the device should not disturb other people nearby. A subtle approach ensures more privacy and discretion to users.

Customization. Humans considerably vary in shape, size, dimension, and ability, and also in their preferences, interests, and wishes. To engage users, designer could allow customization in size, color and appearance aids users to feel more comfortable and confidence wearing the device and to integrate it to their normal outfit.

Be thoughtful. Always keeping users in mind with empathy is the key to design a considerate product for people with different abilities and preferences. For instance, displays as well as the visualization of the displayed information should be suitable for both wearing position (e.g. left-hand and right-hand users).

Aesthetics. Aesthetics consideration mainly associated with its attractiveness – an attractive design tends to improve the desirability of the device. Although wearable device's value mainly depends on how good the tracking function performs, aesthetics was also raised by many elderly participants as an important consideration. They desire for the wearable to look like a mainstream device primary location mentioned were the wrist, a ring, and a necklace/lanyard. (Ye, 2014) The reasons behind these choices included ease of use, social comfort, and discrete use. The older adult's appearance preference may also be affected by gender and previous life experience.

2.2.6 Challenges of Wearables

Indeed, the rapid development of wearable technology benefits people in many aspects. There are still challenges that need to be faced and space to grow for this market. The study of Ledger and McCaffrey showed that 6 months after buying or receiving an activity-tracking device, one-third of US consumers had stopped using the device. (Hornbrook, 1994) Such high abandon rate indicated other than some technical limitations, a better user experience needs to be provided through design.

Another issue is that the wearables market tends to focus on the younger populations, whilst overlooking a great potential need in the health of older adults. However, a good sign is that some famous wearables makers like Apple and Fitbit have started adding health monitoring features that appeal to elderly consumers (Figure 2.12), like fall detection, ECG monitoring, wheelchair monitoring, and sleep apnea detection.

(a) ECG monitoring **(b) Wheelchair detection** **(c) Fitbit SpO2 sensor** **(d) sleep apnea detection**

Figure 2.12 Example of Health Monitoring Features to Appeal Older Adults

2.3 Aging Seniors and Wearable Devices

2.3.1 Acceptance & Prospection

In overview, if applying wearable technology properly, wearable devices will greatly benefit and transform the process of healthy aging. However, what is the relationship between aging seniors and wearable devices at this stage?

Regarding technology and the elderly, the people's attitude towards technical products is a crucial factor. Survey results showed that very few older adults were currently using a wearable device, while more than 60% of them were interested in the future use of wearable devices to improve physical and mental health. (Kekade, 2018) The limited use of technology but a willingness to change one's behavior for a healthier life provides a good opportunity for digital intervention to improve the elderly people's overall wellness. Similarly, a study by Endeavor Partners consulting firm showed that, in 2013, 10% of US adults consumers owned an activity-tracking device. Only 16% of activity devices owners were 55-64 years old and merely 7% of those were 65 years old or older. (Partners, 2014) Among this age distribution, the wearable devices were primarily used by younger adults. Several determining factors lay behind this situation.

The determinants of the accessibility of the use of information and technological products for elderly users are predominantly reflected in the following six aspects: (1) Perceived usefulness, impact and relevance (Melenhorst, 2006); (2) Perceived ease of use (Zhao L. L., 2016); (3) Issues associated with the technology (Selwyn, 2003); (4) Personal traits (Bhattacharjee, 2017); (5) Social issues (Renaud, 2008); and (6) Facilitation issues (Steele, 2009).

Another study also concluded elements of the most impact of older adults' acceptance. (Puri, 2017) Firstly, elderly people prefer smartphones as facilitators of wearable activity trackers.

Secondly, against the author's estimation, privacy is less of a concern for wearable devices to self-tracking. Thirdly, senses of self-awareness and motivation contribute to their acceptance. Besides, a composite factor of subjective norm, social support, and sense of independence will determine how the elderly feel about wearable technology. Lastly, the equipment characteristics do matter, including performance of display, battery, comfort, and aesthetics.

This available research indicates that older adults are not "technophobic" and are willing and able to use technology such as computers. However, the nature of their experience with technology, available support and the perceived usefulness of technology applications are important determinants of attitudes, confidence, and comfort using technology and ultimately technology adoption. As a designer, we can do little on the technical improvement, but with more friendly designs in appearance, human-computer interaction, educational tools, and visual presentation, we can build confidence and enhance user experience of the older adults when using wearable technology.

Moreover, high adoption of smartphone and computer imply a promising future between wearable technology and older adults. According to a recent survey, 85% of elderly people owned a cellphone in 2018, including about half with a smartphone, while in the age of 50-64, 94% of those own a cellphone, about three fourths of which are smartphones. (Pew Research Center, 2018) Also, the National Institute of Aging (2001) stated that people over 60 years old today constitute one of the fastest growing groups of web users. Such statistics are able to give insight into the future prevalence of wearable technology.

Not only the positive attitude towards wearable technology, but the learning capacities of older adults are also higher than common expression. In user research, participants aged more than 60 years old appeared to be receptive to use wearable activity trackers and learned to use them quite easily. (O'brien, 2015) The results from another research study also showed that although older adults may be initially wary of fitness technology, after consistent use, they reported they find the technology useful and acceptable, while also advised of needs to help setting up the device and how to interpret the data at the early stages of use.

"Ease of use" and "non-obtrusiveness" are the striking features which older adults are most concerned for health monitoring system according to a questionnaire research. (Nicolle, 2014) System should use similar language with existing devices which elderly users are familiar with to meet their prospection.

Last but not the least, even if older adults do with some impairments, most of them do not want to have their age regarded as a disability. Therefore, a mainstream-looking device with built-in accessibility can contribute to remove the stigma of special aids or modifications.

2.3.2 Benefits

How a product can benefit the users is the key criteria of the value of the product. Wearable devices such as smartwatches and the corresponding apps are well suited for supporting a safe and self-determined life of elderly people. (Lutze, 2018) These devices generally have four decisive advantages: (1) They are typically worn during the whole day for continuous tracking. (2) They are functional inside the home and also on the way. (3) They are compact and non-stigmatizing devices in contrast to dedicated emergency buttons of whatever form. (4) They are widely accepted and cost efficient. Other advantages include the immediate detection of tumbles and falls which is exceptional helpful for elderly people.

A positive result also found after using activity trackers, the older adults reported they had a better understanding of their own health and were willing to take some measures to promote their own health in the next stage, and also had grown accustomed to using the wearable devices. (Zhou,

2018) Most elderly participants perceived an added value and proved that wearable devices can help them become more aware of their daily activities.

In addition to the physical benefits, wearable technology also has a great potential benefit to facilitate mental health. For older adults, the technology could prevent or relieve their loneliness and isolation by increasing their social capital and expanding their social networks.

2.3.3 Barriers

Understanding users' barriers first is essential to ease user experience later. In terms of human factors, certain drawbacks are indicated, such as discomfort, itching, and sweating materials, irritation of wearing difficulties, hampered monitoring due to sensitivity, and short battery life, etc. (Kekade, 2018) Besides, perceived disgrace and awkwardness might discourage elderly people from utilizing certain assistive technology system, especially in public environments. (Hirsch, 2000) Designers should keep in mind that despite the numerous benefits that older adults can gain from the system, acceptance could be hindered if the product looks awkward or unpleasant. Elderly people like to use assistive systems that not only provide support for practical necessities but are also aesthetically pleasing.

The importance of ease of use has never been overstressed. A recent survey, which conducted three assigned tasks to test with elderly users, found a wide variety of the problems that cannot be neglected. (Steinert A. H.-T., 2018) The hardware side had issues such as putting pins in holes, risk of losing, trap skin, too firm wristband, reddened skin and sweating materials, hard to press and hold small button. Software side issues include lack description of measurement and data, no support for real-time synchronization, etc. The synchronization and navigating in the application were shown to be quite difficult for elderly participants in a comparative usability evaluation. (Pak, 2014)

Studies also found that when most older adults encounter information technology, the biggest problem so far is lack of confidence. (Alm, 2002) Negative stereotyping of elderly people can be the main reason. However, they later found once confidence levels are built up, rapid progress can be made. Difficulty to remember a large number of details in order to accomplish tasks can seriously upset the older adults. A proper guidance or instruction applied at an early stage can contribute to establishing their confidence. Similarly, a high mental effort for installing the app because of a lack of training can also shut the door to elderly users. (Rasche, 2016) Design considerations to simplify the tasks and relieve user's memory load is significant to accommodate the elderly users.

When designing for the elderly users, several common HCI challenges need special consideration. For example, older adults are less able to block out distractions or irrelevant stimuli on the interface and they tend to focus their attention on the center of the screen due to their reduced width of visual field (Sharma, 2016). Common age-related changes in abilities were discussed in (Hawthorn, 2000), and a set of guidelines were also created correspondently to each ability categories, including bigger texts on the screen, greater spacing between different control elements, higher color contrast, prolonged backlight, and stronger feedback, etc. Based on the web interactions, Kurniawan and Zaphiris (2005) came up with a set of 38 guidelines grouped under 11 distinct categories from navigation and the use of graphics to use of color, background and text design for elderly users. Points such as avoiding deep menu structure and scroll bars and maintaining consistency in screen layout are great insights. The lack of adaptable design is one reasons that prohibited the people with impairments from adopting wearable technology in their daily life. Moreover, the increasing and complex functions on these gadgets are also creating huge psychological burdens for older adults.

Although a relatively reliable tracking accuracy was claimed in the previous section, consumer fitness trackers have greater estimation errors for older adults with health problems or slow walking speed, and rather, some of the different results could also be due to variations in algorithms across devices. (Lauritzen, 2013)

The drawback of data accuracy may be hard to solve by design, but the improper displays of data can be improved by better design. In research (Choe, 2014), a word cloud illustrated the most pleasing data visualization types from users: line charts, bar charts, and custom visualization (Figure 2.13), which can help to determine ways of data presentation. However, this still left an open challenge of difficulty in data interpretation. With wearable technology, the body data is valueless to users unless users can understand and leverage it.

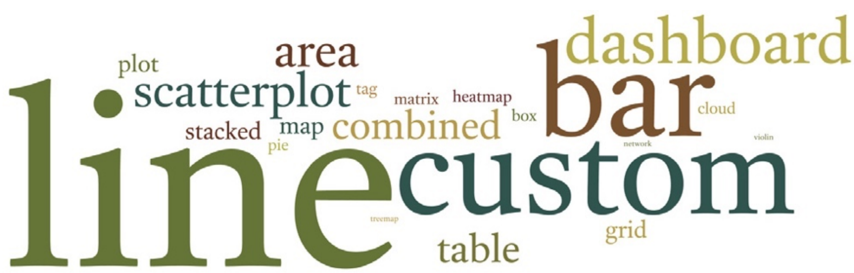


Figure 2.13 Word Cloud about User Preference of Visualization Types

2.3.4 Recommendations

A great number of research has been conducted to seek solutions to address those barriers that hampered the elderly use of wearable devices. A recommendation of a simple, clear, consistent, and straight-forward interface was offered. (Sharma, 2016) In order to exploit the capability of mobile and wireless innovations, research needs to consider the effect of visual density and cognitive capacity of the users to avoid confusion and information overload. Managing complexity is an important aspect of design for the older adults.

Besides, design of technology should consider the emotional or affective aspects in terms of feel, value, sensitivity, and appeal. (Lee, 2015) Wearable technology should be able to allow the elderly users to be self-reliant and can enhance their self-efficacy and confidence to live on their own with personal freedom and individuality.

In a successful wearable system, effective and accessible educational tools or instructions is a must-have, especially for older adults who have less experience with technology. A case study aiming to lowering the technology threshold among elderly users, developed and tested a system with an educational tool in a form of card sets, which was proved to be satisfied and promising. (Figure 2.14) (Jia, 2015) The elderly participants valued the possibility to keep the cards to later remember what they have learned. Also, from the feasibility consideration, it is a low-cost solution and requires no additional learning curve.

Figure 2.14 Card Sets as Educational Tool for Elderly Users

There is also a set of practical and detailed guidelines for creating senior-friendly product instructions (Table 2.1), which can be a great reference when designing learning materials for older adults.

Guidelines for Creating Senior-Friendly Product Instructions
1. Provide an overview of the elements that will be used later.
2. Increase the legibility of all content.
3. Create instructions as self-contained steps.
4. Include all the information that is relevant at each step.
5. Remove irrelevant content.
6. Include the goal for any steps that have sub-steps.
7. Establish & use consistent language.
8. Label key elements in image figures.
9. Explain technical terms and concepts using plain language.
10. Show the post-action state for every step.
11. Provide references to similar tasks before the instructions.

Table 2.1 Guidelines for Creating Senior-Friendly Product Instructions

Peer support in learning is a well-established general principle and is particularly effective for older adults learning technology. (Alm, 2002) Being taught, coached, or supported by another elderly person avoids the embarrassment the learner might feel with a younger person (Figure 2.15).

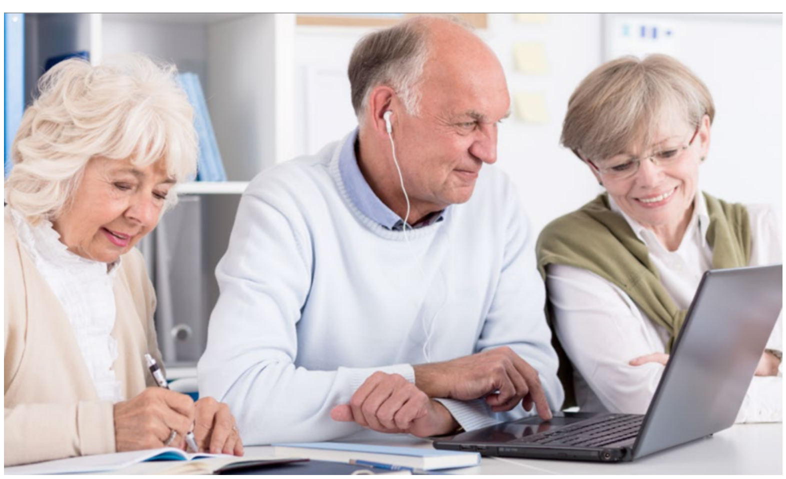


Figure 2.15 Peer Support in Learning Technology

Catalyst is a project to identify ways to improve wearable devices for older adults. (AARP Organization, 2015) In the study, participants found the trackers beneficial, especially with regards to learning activity and sleep patterns, receiving motivation by seeing progress made toward goal, having their current activity levels confirmed, and finding the devices to be easy to use. However, some drawbacks such as lost data and difficult to wear were also summarized. A set of 7 guidelines and 10 specific recommendations have thus been analyzed in this paper.

Turning to the relationship between older adults and wearables, a co-creation model was provided to discuss important factors that impact elderly use with wearable devices (Warraich M. U., 2018) (Figure 2.16): trust, unobstructive, deployment strategies, usability, and personalized thresholds. Designing with these factors in mind can improve the satisfaction of intended older adults.

Trust. The digital intervention should be able to keep users motivated and feeling safe.

Unobstructive. Wearables should be designed as unobstructive as a passive recorder of individual's activities and to notify or interact with user when important.

Deployment strategies. Suggest deployment strategies for wearable trackers like creating tutorials or instructions to facilitate the learning of new/difficult features, especially with elderly people.

Usability. Usability problems like small screen and small characters should be addressed by analyzing user behaviors to know correctly what they need.

Personalized thresholds. It is important that the analysis of the personal data of individuals is done on the activity thresholds suitable for elders since physical threshold values may vary by age. That means such system should adapt to the users' thresholds to set goals and plan properly.

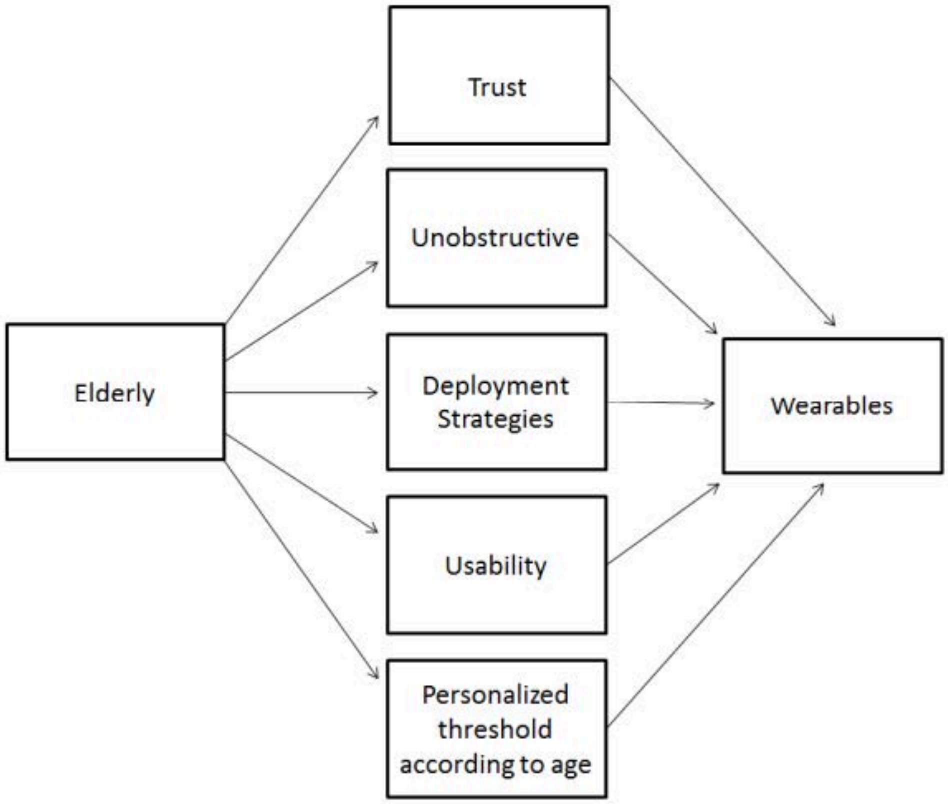


Figure 2.16 Co-creation Model to Design Wearables for Elderly Users

2.4 Inclusive Design

With inclusive design, we can better understand our users' behavior and needs.

2.4.1 Introduction

The definition of inclusive design is "aiming to increase the range of users for a particular product, but in practice unlikely to reach all potential users." (Newell, 2006) Compared to universal design aiming to satisfy the whole population, inclusive design is focused on understanding and learning from the variety of the user groups and avoiding unconscious design exclusion in the process and outcome of a design. The pyramid model of user diversity vividly shows the different ranges of inclusive users based on the capability (Figure 2.17). The higher level the designer can reach, the more people can be accommodated in such design.

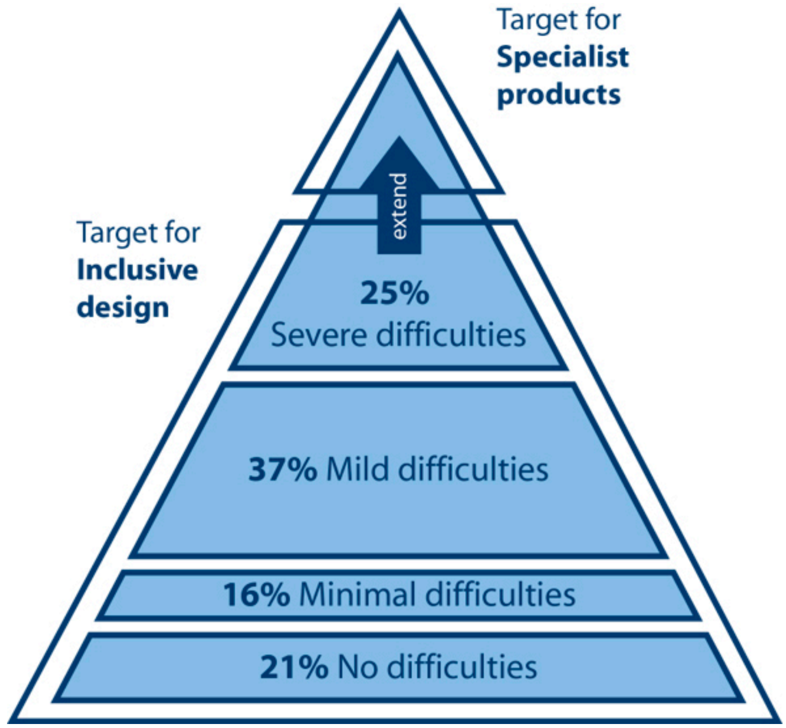


Figure 2.17 Inclusive Design Pyramid of User Variety

To ensure a match between the technology and all potential users, developers can work according to an inclusive design approach, but must be realistic. (Abascal, 2005) Due to great diversity of users' characteristics, it is almost impossible to consider all users in the design phase, but it is possible to avoid unnecessary barriers for accessibility. In the meanwhile, this design philosophy enhances the usability of the product and it is also extremely beneficial for non-disabled people trying to use the system under special conditions. The Persona Spectrum created by Microsoft divides the user ability in three types: permanent, temporary, and situational. (Figure 2.18)

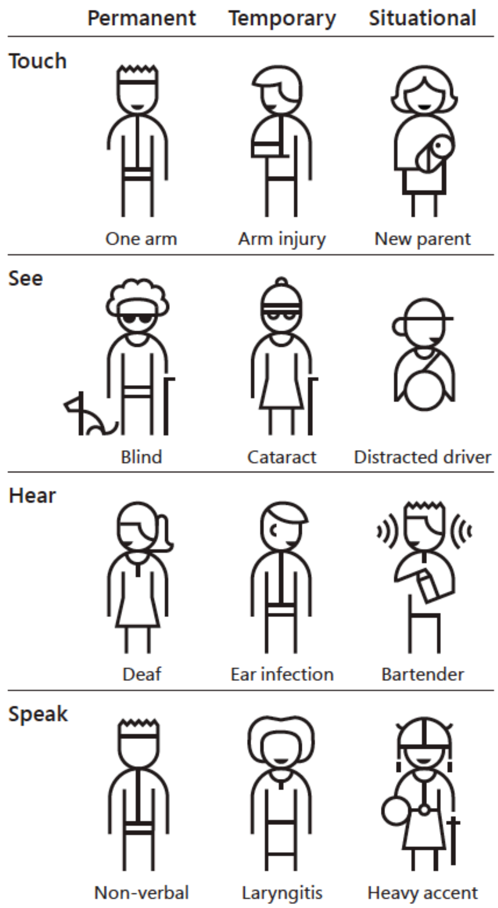


Figure 2.18 Microsoft Persona Spectrum Model

"We use the Persona Spectrum to understand related mismatches and motivations across a spectrum of permanent, temporary, and situational scenarios. It is a quick tool to help foster empathy and to show how a solution scales to broader audience." (Microsoft, 2016) For instance, a person tries to listen from others in a noisy environment has a similar situation with a person with impairment in hearing. Inclusive design can not only accommodate the users with fewer abilities, but also bring convenience to normal users in special situations.

2.4.2 Design principles for Inclusive Design

There are several principles provided by researchers and companies. For example, Microsoft (2016) created an Inclusive Toolkit with three general inclusive design principles:

1. **Recognize exclusion**. Inclusive design is hard to satisfy all the potential users, so recognizing user exclusion is necessary at the early stage. An important thing to keep in mind is exclusion is sometime situational – as people move through different environments, the abilities can also change dramatically. In a loud crowd, they cannot hear well. In a car, their vision will be diminished at different levels. New parents spend much of their day doing tasks one-handed. An overwhelming day can cause sensory load.
2. **Learn from diversity**. To achieve a successful inclusive design, getting real and diverse insights from people is of great significance. Human beings have amazing capabilities to adapt to different situations; thus, understanding those adaptions is a good way to get valuable insights. By showing empathy to users, designers can recognize and learn more than just the barriers that people encounter, like motivations of users' behavior.
3. **Solve for one, extend to many**. For example, closed captioning was initially created for the impaired hearing community. But there are many benefits of captioning such as reading in a crowded airport or teaching children how to read. Similarly, high-contrast screen settings were designed for helping people with vision impairments. But today, many people benefit from high-contrast design when they use a device in bright sunlight.

Based on website and application interfaces, TPG also created several inclusive design principles, including provide comparable experience, consider situation, be consistent, give user control, offer choice, prioritize content, and add value. (Swan, n.d.) Following the general principles of inclusive design is an efficient way to avoid experience pitfalls at early design stage.

2.4.3 Elderly Inclusive Design

"Design for the young and you exclude the old; design for the older and you include the young." This notable slogan created by Bernard Isaacs showed the importance of elderly inclusive design. In terms of inclusive design for the older adults, the main concern lies in their impairments or disability as aging. Farage in his research discussed age-related impairments and accommodations in visual presentation, auditory presentation, and suggestions to accommodate diminished touch sensation, movement restriction and cognition changes. (Farage M.A., 2012)

More guidelines are provided for optimizing human computer interactions to the older adults covering the range of compatibility, consistency, error recovery, feedback, individualization, memory, structure and workload. (Fisk, 2018) And compiled recommendations of touch-based mobile phone interface for elderly users are classified into three dimensions: (Al-Razgan, 2012)

Look and Feel. Expected to of consist three-dimensional appearance button for touch-screen, and clear spacing between buttons. Larger text and labeled icons are welcomed. Also, important features should be available directly via a labeled button rather than menu navigation.

Functionality. Functionality of the same type should be grouped together to avoid clutter. For the navigation, the main navigation and critical functions should never disappear. Also, the older adults expect ways to prevent accidental action, which may be solved by proper placement or a locking button. Lastly, the designer has to carefully consider naming programs and commands, and make sure of not too many or too few features on interfaces for older adults.

Interaction. Easy zoom in and out and pinching features are preferred, and tabbing with audio confirmation is helpful for elderly with reduced vision. Research also showed that the elderly prefers features of voice call, slow motion interface, and tabbing but not drag and drop actions.

They were also tired of repetitive actions and showed their confusion when the screen turned off when being idle, thinking the device is not working.

You are not the user, when designing technology; the computer skills of your users are worse than you think. So, identifying the technical threshold is crucial before actual design. Great insights were concluded by Nielson Norman Group, who conducted a skill research with a total of 215,942 people to quantify the difference of computer skills between the broad population and the tech elite on a world-wide scale, at least 5,000 participants aged 16 to 65 in most countries in 2016. (Jakob, 2016) They analyzed four levels of technology proficiency and indicated if designers want to target a broad consumer audience, it is safe to assume that the users' skills are those specified for Level 1, which is "keep it extremely simple". (Table 2.2) To sum up, a successful elderly inclusive design should be aligned with the "KISS" principle – keep it simple, stupid.

Level 1 Skills
Little or no navigation required to access the information or commands required to solve the problem.
Few steps and a minimal number of operators.
Problem resolution requiring the respondent to apply explicit criteria only.
Few monitoring demands. (e.g. have to check one's progress toward the goal)
Identifying content and operators done through simple match rather than transformation or inferences.
No need to contrast or integrate information.

Table 2.2 Level 1 Skills Defined by Nielson Norman Group

2.4.4 In the Context of Wearables

An inclusive wearable device means it is friendly and accessible. Guidelines were created for stimulating accessible wearable technology design. (Wentzel, 2016) One is using multimodal presentation of information and multimodal interactions to allow users with different preferences and abilities to use information in their preferred way. Adequate feedback is another crucial feature when designing the wearable device. The system or application should provide relevant feedback on the user behavior and the system actions. This can consist of positive confirmation, reinforcement of actions, status or process updates, notifications, and instructions on unexpected or incorrect behavior or actions. Also, it would be pleasing if system settings are adaptable. These adaptions include context-aware feedback intensity based on localization or user preference. With the benefit of a self-learning algorithm, the wearable system should enable optimal automated adaptive settings.

Although universal design is one-size-fits-all while inclusive design, from my understanding, is one-size-fits-more, they share the same characteristic of accessibility. The advantages and principles of universal design (Figure2.19) were discussed within the context of wearable technology and thus can give us some good insights. (Tomberg, 2015)

PRINCIPLE ONE: Equitable Use
The design is useful and marketable to people with diverse abilities.

PRINCIPLE TWO: Flexibility in Use
The design accommodates a wide range of individual preferences and abilities.

PRINCIPLE THREE: Simple and Intuitive Use
Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

PRINCIPLE FOUR: Perceptible Information
The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

PRINCIPLE FIVE: Tolerance for Error
The design minimizes hazards and the adverse consequences of accidental or unintended actions.

PRINCIPLE SIX: Low Physical Effort
The design can be used efficiently and comfortably and with a minimum of fatigue.

PRINCIPLE SEVEN: Size and Space for Approach and Use
Appropriate size and space is provided for approach, reach, manipulation, and use regardless of the user's body size, posture, or mobility.

Figure 2.19 The Principle of Universal Design

Equitable Use. For this purpose, the following recommendations are defined: to provide the same means of use for all users, to avoid segregating or stigmatizing any users, to make provisions for privacy, security, and safety equally available to all users; make the design appealing to all users.

Flexibility in use. In contrast to the Equitable Use principle, the flexibility in use is the process-related principle. The principle can be applied to the design of wearables to provide choice in methods of use, facilitate the user's accuracy and precision, and provide adaptability to the user's pace and using environment.

Simple and intuitive use. It promotes usability and simplicity of use. The distinction of the wearables to other smart things is that the wearables, in many cases, should be imperceptible by the user. In order to accomplish tasks through such a small gadget, the communication system should be seamless and easy to set up.

Perceptible information. When visual displays are impractical due to different forms or specific situations, other modalities should be possible to export the information to a device or system that can present the information in the most accessible way for a person. Perceptible information is also a feature of personalization that would be needed for a wearer's different context.

Tolerance for error. Wearable devices need to be dependable and reliable at all times, even when encountering accidental or unintended actions. For example, putting the device on backwards should not cause the wearable to suffer a catastrophic malfunction. It likely should be able to give some sort of indication about which way is correct, but it might be possible to use it while worn incorrectly.

Low physical effort. If a wearable will be in everyday activities, it should not cause extra strain or be tiring itself. Wearables addressing the theme of health monitoring and management may be worn by people who may have limited physical strength. For instance, synchronization with other devices should not cause great physical effort.

Size and space for approach and use. This concept relates to the spatial dimensions of an appliance that typically should be adapted to the user's characteristics. For example, the size of the buttons on screens should be adjustable for easy recognition, or the space between elements can be properly designed to avoid unnecessary maloperation.

2.5 User Experience Design

With user experience design, we can better enable our users' behavior to finish tasks.

2.5.1 Introduction

Don Norman (2016), inventor of the term "User Experience" (UX), defined UX as encompassing all aspects of the end user's interaction with the company, its services, and its products. He also distinguished the total user experience from the user interface (UI) and usability, which are often used interchangeably – UX is far more than those. (Figure 2.20)

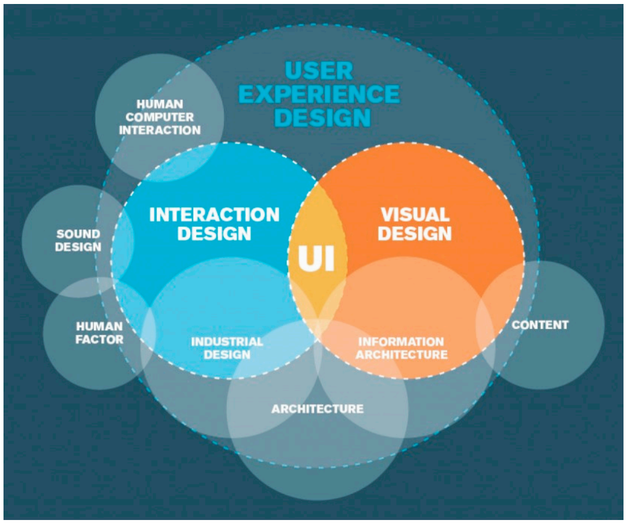


Figure 2.20 Scope and Relationships of User Experience Design

Kuniavsky (2010) held a similar idea and explained the relation between user experience and usability: "usability, is the practice of making things easy to use which is often equated with user experience, but while bad usability can break a good product, good usability is insufficient to create a good user experience." That is, an experience can be usable without being useful or desirable. In his definition of user experience, the user experience of a product or service includes effectiveness (how good is the result?), efficiency (how fast or how cheap it is?), emotional satisfaction (how good does it feel?), and the quality of the relationship with the entity that created the product or service (what expectations does it create for subsequent interactions?)

For product designers, the user experience design is thus the process of creating products that provide meaningful and relevant experience to users. This involves the design of the entire process of acquiring and integrating the product, including aspects of branding, design, usability, and function.

Why is UX so important? Simply, UX design aims to provide positive experiences that keep users loyal to the product or brand. The importance of designing for user experience can also be generated as following reasons:

1. The product will be used by people, not yourself, so understanding your users is important. We also call it user-centered design.
2. Users want a better, more fulfilling, more valuable experience.
3. Users have the expectation that whatever the device they use (mobile, tablet, PC), it behaves the same way across all devices. Good UX design makes the such experience that same.

4. User experience effort aims to improve efficiency, which basically comes in two key forms: helping people work faster and helping them make fewer mistakes.

5. Good UX design make things enjoyable; it has the power to satisfy the emotional need of a user along with the functional need.

Normally, the UX design process follows the steps from understand, research, sketch, design, and implement to evaluate. (Figure 2.21)

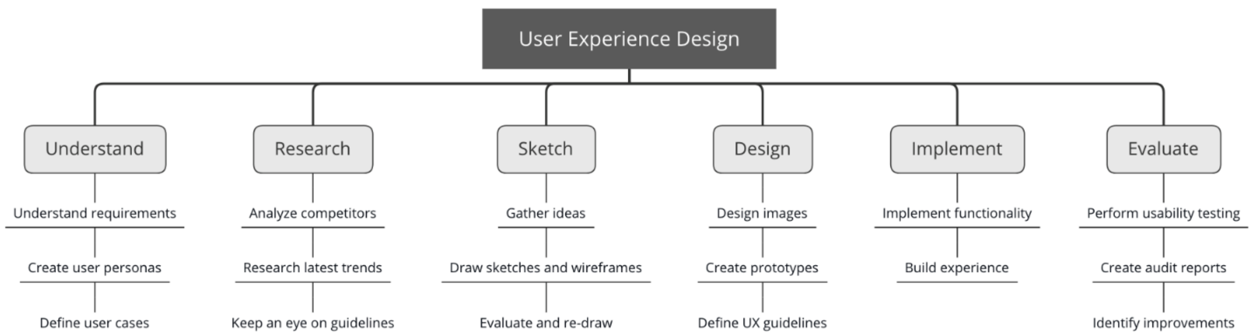


Figure 2.21 A Sample of User Experience Design Process

2.5.2 The Elements of User Experience

Introduction. Garrett (2010) defines the five elements, or planes, of the user experience design process in his book, which have been leveraged by many designers and companies when designing their products or services. The five elements of user experience design are presented as five dependent layers, each level building on the level before it, and they start with the abstract level towards the concrete one (from bottom to top) (Figure 2.22). These five planes provide designers a practical conceptual framework for talking about user experience problems and the tools we use to solve them in an orderly way. As said before, these layers are not completely independent, that is, it is not necessary to finish each plane before work on the next to avoid unsatisfactory results. (Figure 2.23)

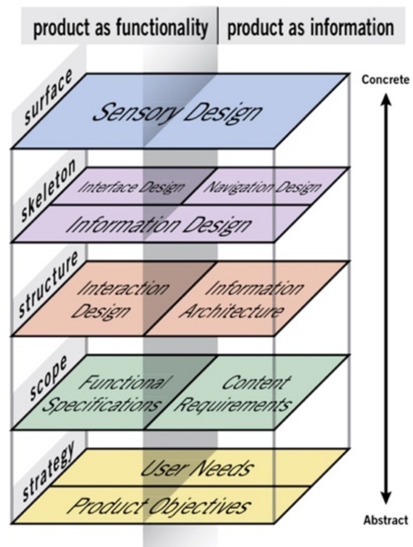


Figure 2.22 Five Planes of User Experience Design

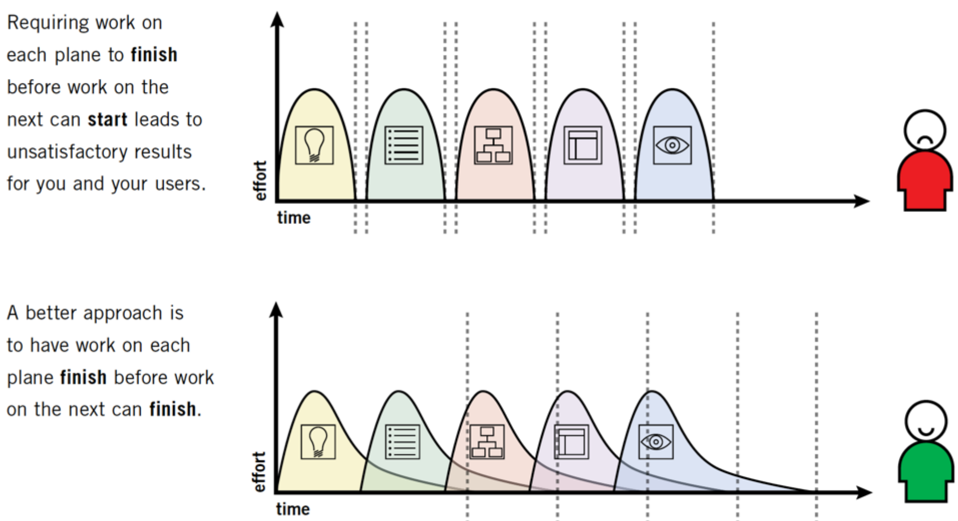


Figure 2.23 Working Process and Relations Between Each Layers

This conceptual tool was initially a web-based approach, but its strong and methodical design approach is aligned with a product design process, as wearable technology is a typical dual-facet area, with hardware design in wearable devices and software considerations in mobile phone application, website, and even the wearable itself. This design approach thus provides a solid foundation to create my new design flows and related guidelines.

Strategy plane. The strategy plane incorporates not only what the stakeholders want to get out of it but what their users want to get out from the product or service as well. Sometimes strategic objectives are pretty obvious like "user want to buy products and we want to sell them", while it can be very different since different stakeholders have different purposes or success metrics. For knowing user needs, we will first clarify our potential users and segment them in groups. Various quantitative and qualitative research tool could be applied in determining their needs. Also, creating personas is always an effective way to define needs and goals of your users and show empathy. After that, a strategy/vision document is always used as an outcome of all the elements defined above.

Scope plane. The scope plane is fundamentally determined by the strategy of the product or service. In this place, we translate user needs and business objectives into specific requirements for what content and functionality the product will offer to users. All design requirements will be generated, negotiated, prioritized, and finally documented. We may collect a pile of requirements at the beginning, but we should very carefully consider the feasibility to decide whether postpone or delete some of them. Factors such as technically impossible, time constraints, or conflicts between features can influence the feasibility of requirements.

Structure plane. The structure plane defines how user interact with the product and how the system behaves when user interact. It also determines the way in which the various features and functions of the product fit together. Based on the functionality-based or information-based of the product, interaction design or information architecture, sometimes both, will be considered in this stage. An architecture diagram is the best documentation tool to present the outcomes of the structure plane, which can deliver a simple and understandable representation of how the application works and contribute to convenience of developing new features, updating existing ones, and for seeing what is possible to consider of the existing product.

Skeleton plane. The skeleton plane is designed to optimize the arrangement of elements for maximum effect and efficiency. On the structure plane, we looked at the large-scale issues of architecture and interaction; on the skeleton plane, our concerns exist almost exclusively at the smaller scale of individual components and their relationships. This plane is split into three components: interface design, navigation design and information design. These three elements are closely bound together, because you can hardly think about interface design without information design (how information is presented clearly) and navigation design (how to present and move around structure and information). At this stage, wireframes are widely used to represent a visual format of the product.

Surface plane. The surface plane is about dealing with the sensory design and presentation of the logical arrangements that make up the skeleton of the product. It is a sum total of all the work and decisions we have made, which determines how the product will look, and choosing the right layout, typography, and colors, etc. If wireframes are skeleton, visual mockups, as the outcomes of the surface plane, are the skin. Besides, depending on the product planning, we may also need a set of style guides to keep other related or future products consistent and save time to develop.

2.5.3 User Experience Honeycomb

User Experience Honeycomb (figure 2.24) was proposed by Peter Morville (2004) to illustrate the facets of user experience - initially to help his clients understand why they must move beyond usability. Along the design process, it could be a great tool for designer to consider how to enhance the user experience from these factors.

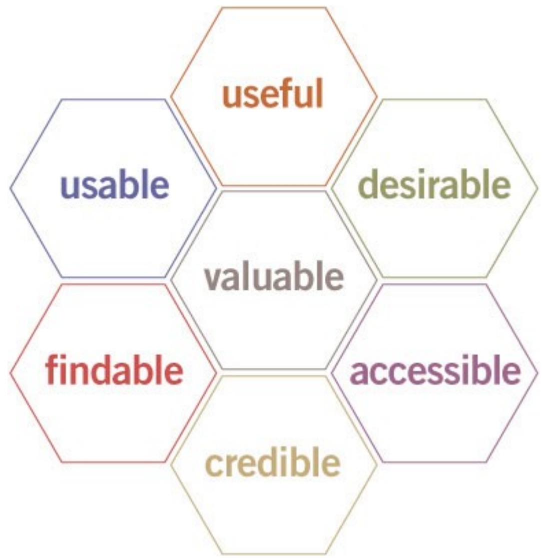


Figure 2.24 User Experience Honeycomb

Valuable. Always ask yourself a question "Does the product deliver value to our users?" There are many usable or useful designs that failed because of the inconsistency between the product's functions and the user's needs. Therefore, our design should fulfill user needs and deliver values.

Useful. A product or service needs to be useful and fill a need. Designers should apply their knowledge to define innovative solutions that are more useful.

Desirable. Image, identity, brand, and other design elements can be used to evoke emotion and appreciation.

Accessible. The product or services should be designed in a way that even users with impairments or disabilities can have the same user experience as others. It is good business and the ethical thing that designer need to do.

Credible. The company and its products or services need to be trustworthy.

Findable. Information needs to be findable and easy to navigate. If the user has a problem, they should be able to quickly find a solution. The navigational structure should also be set up in a way that make sense.

Usable. The system in which the product or service is delivered needs to be simple and easy to use. Systems should be designed in a way that is familiar and easy to understand. The learning curve a user must go through should be as short and painless as possible.

2.5.4 User Experience Design for The Older Adults

Many user experience design problems were discussed in the barriers section above; here I have two supplements. For one, in order to address the capability limitations, Shahaf Bornstein (2016) provides eight principles for enhancing elderly user experience.

Consistency. Unlike younger people, the older adults didn't grow up in a technological world, so they are required to put in effort and time to learn the norms and rules of navigation in an app or software. The encounter with a new interface is often muddled with trepidation. An easy way to relieve these users fear and ease their learning is maintaining visual consistency: menus should be placed in set locations, instructions should be plain and coherent, elements such as fonts, sizes, links, and buttons should be consistent throughout the system.

Age-appropriate contrast relations. The golden years are abundant in eyesight issues. Some users suffer from blurry vision, some darkened, and some have a very light vision. It is highly important that our design support limited vision, with high contrast. It is best to avoid grey tones and subtle color changes. Our elements should be clear enough in order not to merge with the background.

Golden age safe coloring. Due to varying factors, there is a yellowing of the eye lens, which alters the colors and makes us slightly color blind. Therefore, our design should not rely on user's ability to differentiate between similar colors (such as blue and purple, green and yellow), and we should maintain a relatively wide coloring gap between the shades we use.

Relieving cognitive overload. Memory issues are among the most ubiquitous complaints among elderly users. In order to ease their load, we should use more than one form of communication to communicate the same information. In other words – double coding. For example, a home icon with the word "Home" attached to it. When we find it necessary to divide an action into stages, we would be better to bind tasks that relate to each other in one stage and display any required information from previous stages.

Experience-boosting sound. It is beneficial for older adults to use sound to mark and emphasize important stages or changes, especially for those with eyesight difficulties. In addition, sound use is contextual, and there are many social contexts where it is inappropriate, so we should include a clear and easy way to mute and control the sound's level.

Design within the confine of motoric challenges. These days, most older adults suffer from different levels of motoric and agility difficulties, such as arthritis, tremors, Parkinson's, or coordination challenges, that hinders delicate movement and generally turns their motion slow and inconsistent. Generally, designers should avoid relying on small button and movements such as long continuous swipe and double clicks.

Size does matter. Large and readable fonts are needed as the older adult's vision deteriorates. If possible, the designer should consider allowing users to customize the font size to their liking and preference. Also, fonts without decorative elements, like sans serifs, should be used, and designers should use no more than two to three fonts and maintain consistency in their use.

Assisting navigation and scanning. Compared to the average users, elderly users are less apt in using advanced interfaces. It is thus crucial to assist them in finding their way around the applications. A simple, clear and coherent navigation system is optimal, which repeats the same conventions and orders as much as possible. Using experimental and innovate UI elements can confuse users. So, it is important to conform to known patterns and make navigation systems as "flat" as possible instead of a deep structure with too many sublevels.

The other point is getting insights from an expert-based usability evaluation for identifying usability problems of current smartphone interface. (Salman, 2018) With participation of five experts, it was productive to detect around 80% of usability problems during user experience that were classified into four categories: (1) appearance; (2) language; (3) dialogue; and (4) information. These problems with suggested solutions are presented in Appendix 1.

These guidelines and research results are all good references for designing and checking with the design concept. User experience design process is an iterative method that helps designer continuously improve and polish his or her designs and keep his or her users in center of the design process.

2.6 Strategies for Promoting Behavior Changes

With persuasive design, we can influence and ultimately promote healthy behavior changes of our users.

4.4.1 Behavior Change Techniques

A Behavior change technique is a theory-based method for changing one or several psychological determinants of behavior such as person's attitude or self-efficacy. (Wikipedia, n.d.) Such behavior change techniques are widely used in behavior change interventions. The wearable technology will be more valuable to users if it could be more "actionable", that is, can optimize health management function and promote behavior changes of users. The design theories and strategies I apply are aligned with the process of behavior changes. (Figure 2.25)

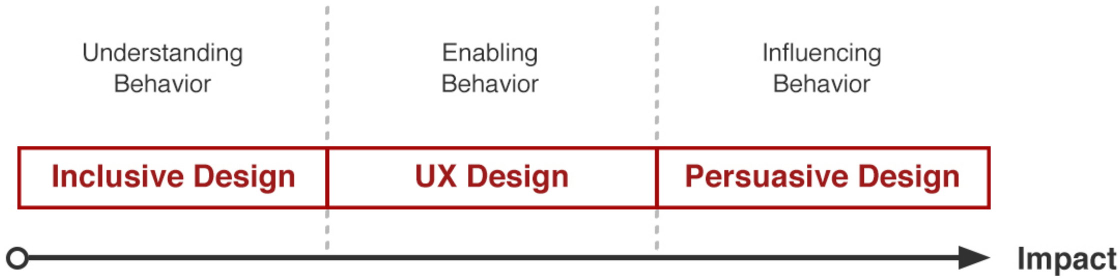


Figure 2.25 Design influence Behavior Change Process

Sullivan (2017) discuss several practical behavior change techniques in increasing physical activity of people.

Goal setting. Small goals and realistic goals are more effective for long-term engagement.

Framing, feedback and rewards. Positively framed messages are more effective than negative ones in increasing activity for older adults (Notthoff, 2014). Feedback and rewards are closely tied to goal setting that can be effective for increasing activity, and many fitness apps and interventions include feedback tool such as reminders, text messages, and real-time alerts when the user has met a goal or has been sedentary for too long. Tracking one's changes in activity levels can motivate steady progress toward goals, while increasing self-efficacy. For rewards, fitness trackers may vibrate, make a noise, or display a congratulatory message when a goal has been reached.

Social factors. Social supports involve having an active friend or family member and is especially helpful for increasing physical activity in older adults.

Coaching. Coaching contains techniques of peer coaching and virtual coaching. Based on social cognitive theory, delivery of physical activity information by a similar peer should facilitate user's attention, retention, and motivation to act on that information, (Ginis, 2013) while the virtual coaching is widely applied on fitness apps such as providing instruction and demonstrations. However, some research showed too frequent messages may become intrusive and cause frustration for elderly people. (Wang, 2015)

Action planning. Many older adults who are inactive do not know how they can increase their activity. Action planning or prompting users to make detailed plans about when and where they will exercise could aid in changing physical activity behaviors and also beliefs about one's own ability. Identifying individual barriers and subsequent problem-solving solutions is rarely included in current wearable devices and smartphone apps. (Conroy, 2014)

Environmental supports. There are ways to incorporate environmental factors into technology, including providing people with maps of safe walking routes within their area by GPS.

There are still challenges of applying these techniques for motivating healthy behavior changes. In a study of using persuasive technology to promote healthy aging, the author put forward six challenges to overcome in the future (Intille, 2004):

1. **Achieving subtlety**. Individual messages, which may be presented hundreds or thousands of time in a year, must balance subtlety (so they do not be easily disturbed) with motivational influence (so they lead to behavior change). Presentation of information may need to adapt over time as the user habituates to particular motivational strategies.

2. **Sporadically interacting in time**. The opportunity to present messages at points of decision and behavior may be fleeting, occurring at brief moments intermixed with everyday life. Just-in-time messages must be conveyed quickly.

3. **Avoiding over-reliance on external justification**. Interfaces that motivate behavior using only external justification (i.e. timely rewards) may lead to behavior change that dissipates over time if the external incentives are removed. Interfaces that encourage behavior change with just-in-time prompting may also need to promote attitude change to ensure long-term results.
4. **Leveraging consumer technologies**. Health messages can be delivered today at a low cost utilizing ubiquitous computing, because consumers purchase the technology for other purposes. Similarly, computer systems that motivate behavior change using just-in-time techniques will be most economical if they can exploit consumer sensor and computer technologies purchased by consumers for reasons other than healthcare.
5. **Motivating the "healthy"**. Motivational applications may need to incorporate elements that are fun, humorous, creative, or inspirational to entice users to keep using them.
6. **Proving efficacy**. The greatest challenge when developing user interfaces that motivate behavior change for healthy living is evaluation. Technology is needed not only to motivate the behavior change but also to monitor if behavior actually does change.

In terms of wearable devices, the new opportunity for applying behavior change techniques is to exploit the sensor's ability to detect the best time to provide feedback and to provide it in a way that is tailored both to the user and the situation. If such feedback could be delivered longitudinally, without aggravating the user, it could lead to slow but steady behavior change that improves quality of life and health for the user.

4.4.2 Motivational Interview

Research demonstrated that increasing control beliefs and self-efficacy for exercise with behavior change techniques will likely facilitate long-term increase in physical activity (Sullivan A. N., 2017). Recently, a method of motivational interviewing is suggested to increase motivation and self-efficacy. Motivational interviewing is a directive and client-centered style process that helps people resolve their ambivalence and move toward healthy behavior change. (Miller, 2012) The researcher provides five principles for conducting it successfully (Table 2.3). For wearable devices to promote health, this method could be potentially utilized in the application at an early stage, for example, when a user is creating an account.

Principles of Motivational Interviewing	
Express empathy through reflective listening	by communicating acceptance of clients as they are, they are freed to change. Seek to compliment not denigrate. More listening, not telling. Gentle persuasion.
Develop discrepancy between clients' goals or values and their current behavior	Promote the client's awareness of consequences of continued behavior. Clarify how present behavior is in conflict with important goals.
Avoid argument and direct confrontation	Counterproductive. Make clients defensive. Resistance may indicate a need to change strategies.
Adjust to client resistance rather than opposing it directly	Use resistance to help build motivation. Reframe statements. Acknowledge ambivalence as natural.
Support self-efficacy and optimism	Explore past success in other problem areas and apply to present situation. Client is responsible for choosing and carrying out personal change.

Table 2.3 Principles of Motivational Interviewing

4.4.3 Persuasive Design

As the design-behavior process shows above, the persuasive design, one of the most important methods of behavior change techniques, is the last step to influence the user's behavior change. Persuasive design is an area of design practice that focuses on influencing human behavior through a product's or service's characteristics. The use of persuasive techniques, aimed at bringing about desirable change by shaping and reinforcing behavior and/or attitude, is growing in virtually all areas of health and wellness, which is good for long-term change.

While having such advantages, the applications of persuasive techniques in the elderly market are still deficient. According to the analysis of prevalent motivational affordance and persuasion outcome, tracking and monitoring is the most frequently employed strategy, followed by audio, visual, and textual feedback. However, in targeted age demographic distribution diagram, only 13% are targeted specifically at older adults. (Orji, 2016) Similarly, monitoring technologies, reasoning algorithms, and coaching strategies are vital building blocks of persuasive technologies but must in the end be embedded in valuable tools and applications that support individuals in their active and healthy aging. However, most of the technology-based devices or applications for older adults focus on monitoring and detection of behavior (e.g. recognition of activities and fall detection) and are not persuasive systems for prevention and promotion of health and wellbeing. (Cabrita, 2018)

The most famous theory in this field is the Fogg Behavior Model (Figure 2.26) created by Dr. BJ Fogg (2009). This model suggests that a new behavior must result from a combination of three elements: motivation, ability, and a prompt. This is means that an individual must be motivated and have the skills or ability to perform a new behavior. The prompt given by the behavior change system must meet the motivation and ability of the individual at any given moment. To be specific, there are three core motivators highlighted in the behavior model: sensation, anticipation, and belonging, and each of these has two sides: pleasure/pain, hope/fear, and acceptance/rejection. For ability, there are three paths to increasing user's ability to perform a task. The hard one is to train people, giving them more skills or ability to perform the target behavior. Another option is to give someone a tool or resource that make the behavior easier to do. For example, a tutorial can make elderly users to learn technology easier. Another relatively easier option is to scale back the target behavior. The elements of ability and motivation have a trade-off relationship when it comes to performing behaviors – when motivation is high, you can get people to do hard thing. But once it drops, then people will only do easy things. Without a prompt, the target behavior will not happen. There are three types of prompts according to this model: facilitator, signal, and spark. How to use these prompts should match their target user's context, which combines motivation and ability (Figure 2.27). Each design consideration is small, while combining them can be a powerful design tool for promoting behavior change.

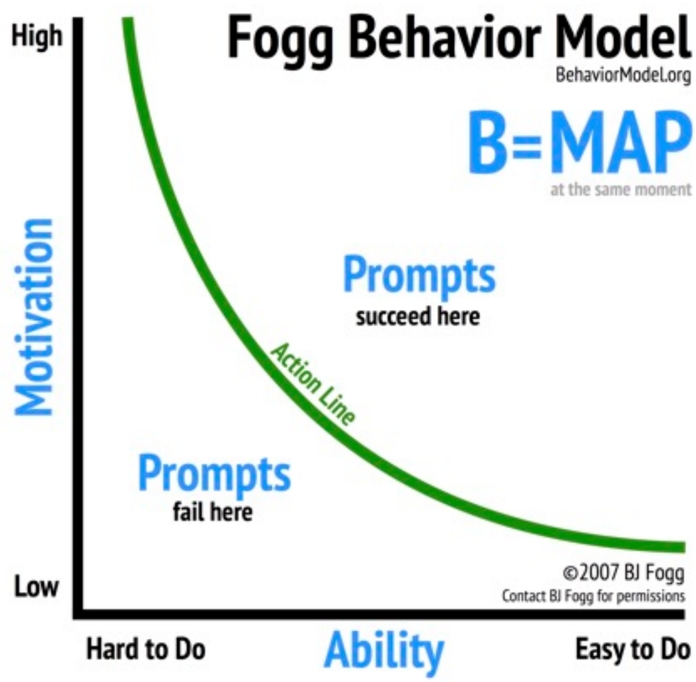


Figure 2.26 Fogg Behavior Model

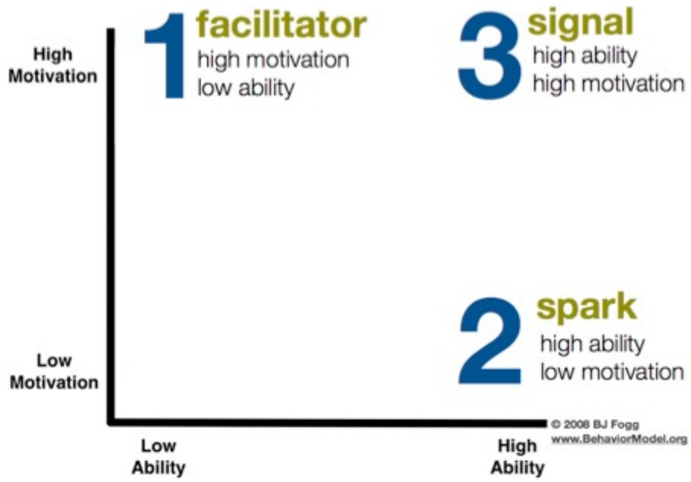


Figure 2.27 Three Types of Prompts

In his later publication, Fogg (2009) also provides a step-by-step process for adopting persuasive technology design (Figure 2.28). The eight-step process drawn from demonstrated success in industry practice, begins with defining the persuasion goal to match a target audience with an appropriate technology channel. Subsequent steps include imitating successful examples of persuasive design, performing rapid trials, measuring behavioral outcomes, and building on small successes.

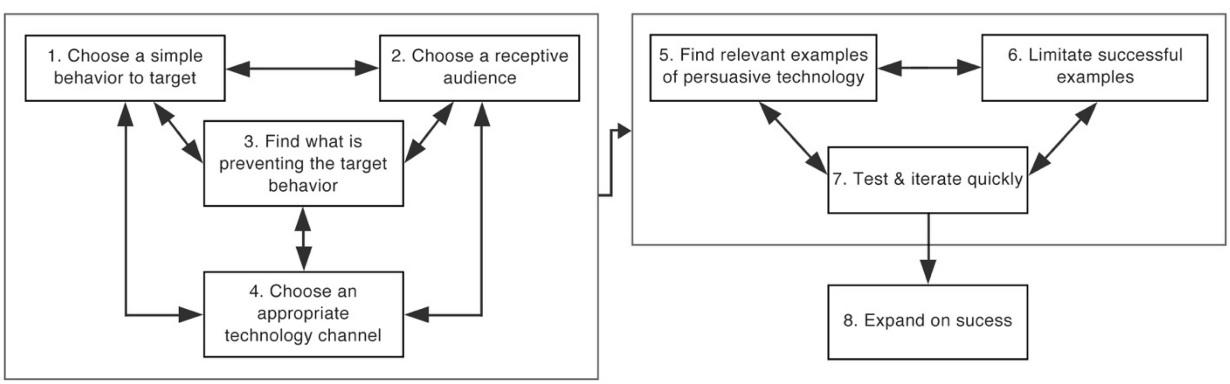


Figure 2.28 8-Step Design Process for Persuasive Technology

A related method is the Fogg Behavior Grid, which was also defined by BJ Fogg (2010) to describe the ways behavior can change in a 3x5 matrix (Figure 2.29). The first dimension concerns the duration of the intended behaviors, and the other dimension concerns what the author calls "flavor". A combination tool of motivation, ability, and prompt in the behavior model and this systematic approach can empower designer to think more clearly about behavior change and create persuasive technology more efficiently.

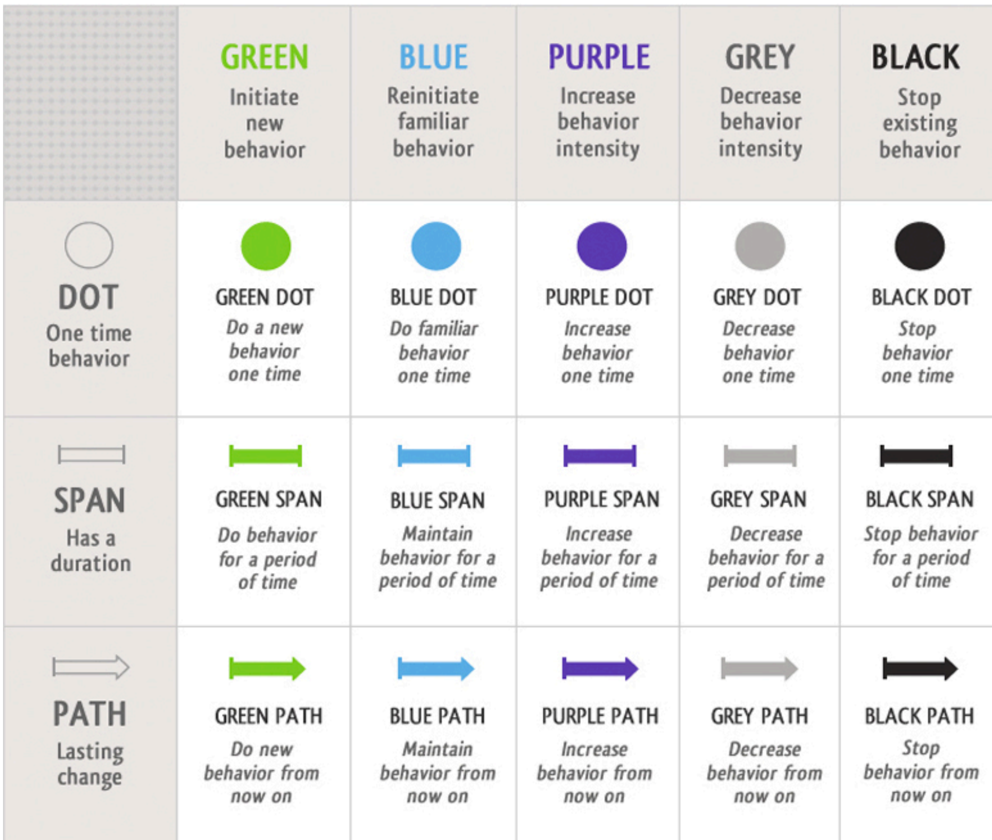


Figure 2.29 Fogg Behavior Grid

Adaption is in fact a key of persuasive technology. (Oinas-Kukkonen, 2018) Adaption over time is particularly relevant when the user is an older adult as the needs of this population are more likely to change than in their counterparts. (Cabrita, 2018) Also, since each individual is different, and even each step needs to be adjusted, it is widely believed that tailoring or personalization helps increases the adherence and effectiveness of technology promoting behavior change. The wearable device system thus should include adaptable settings to accommodate user's needs. For instance, a framework that provides tailored communication to individuals is given in (op den Akker, 2015), and identifies four properties that can be tailored to each particular instance of communication: timing (when is the communication provided?), intention (what is the goal of the communication?), content (what is stated in the communication?), and representation (how is the communication presented to the user?) (Figure 2.30).

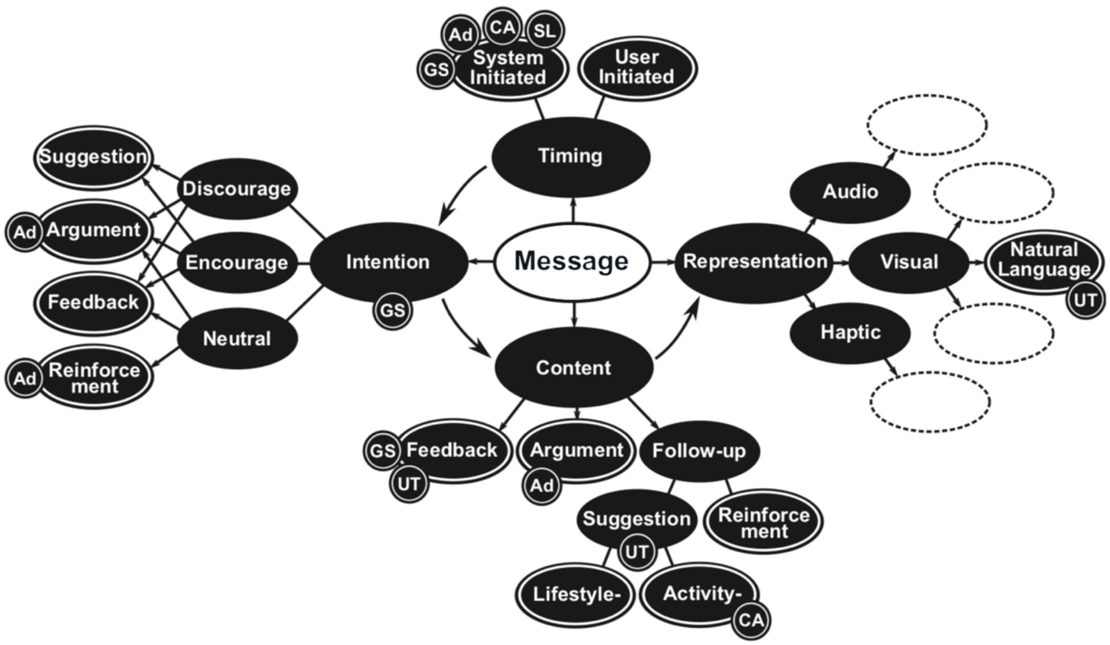


Figure 2.30 Motivational Message Model.

Abbreviations: goal setting (**GS**), adaption (**Ad**), context awareness (**CA**), self-learning (**SL**), and user targeting (**UT**)

4.4.4 The Hook Model

Today, many companies or designers strive for users' limited attention; however, a lot of wearable devices are abandoned after few weeks or few months. So, how to create a product or service compelling enough not only catch consumers' attention, but also help them form a healthy behavior and keep them returning for more? Nir Eyal (2014) answered this question in his book with creating a Hook Model (Figure 2.31), which suggests designers to build products that create habit-forming behavior in users via a looping cycle that consist of trigger, an action, a variable reward, and continued investment.

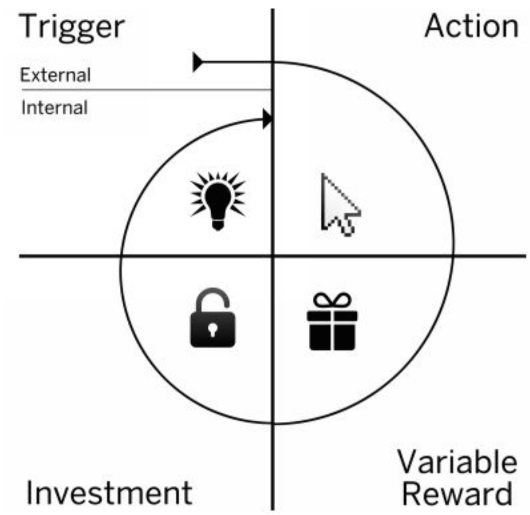


Figure 2.31 The Hook Model

It could be a useful tool to apply on intended wearable devices design for promoting healthy habits, as these products need to be used habitually by users. Along the design process, we should consider these four categories:

Trigger. Triggers can be defined as initiators of action. The Hook Model divides these into internal and external triggers. We use the external triggers first to create repetitive action patterns in our users; these could be listed as e-mails, notifications, ads, and basically every channel that gets us in contact with the user. Internal triggers, on the other hand, are the motivations that occur within the users themselves, with no outer factor in play. Examples include checking Facebook or Instagram when you feel lonely or bored. In this case, loneliness or boredom are your internal triggers.

Action. After users are motivated by triggers, they will take their first action. Designers need to make sure the users' actions in this section are smooth and as easy as possible. The designer needs to keep thinking "what is the simplest behavior in anticipation of reward". For example, too many choices or irrelevant options can cause hesitation, confusion, or worse, abandonment because more choices require the user to evaluate multiple options. Therefore, reducing the thinking to take the next action increases the likelihood of the desired behavior occurring unconsciously.

Reward. In order to form a habit in our users, we need to have rewards that pertain to the main value the product is offering. Pinterest, as an example, is a platform where we are able to find new visual content depending on individuals' area of interest and each time we check the site. Designer needs to be certain that the rewards to put forward are satisfactory and interesting.

Investment. The final phase in the Hook Model, is the time for the users to contribute with the investment phase. For example, when users choose to engage with content on Facebook by reposting, replying, or favoriting, they have made an investment. Also, these contributions users make to the product during the investment phase turn into triggers or rewards for other users.

4.4.5 In the Context of Wearables

Many wearable devices do include multiple behavior change techniques for goal setting, self-regulation, and social support. However, techniques related to self-efficacy, such as planning, consequences, and knowledge, were identified to be present in less than half of the wearable devices. (Mercer, 2016)

A systematic review by French et al (2014) showed that the three behavior change techniques with greatest effect on physical activity in older adults are problem-solving, rewards for successful behavior, and modeling or demonstrating the behavior. Inventions like activity trackers had the greatest effect on older adults when they provided a combination of normative information about others' behavior and information on where and when to perform behavior and helped participants plan support or social change.

In recent years, self-efficacy has emerged as a priority for improving physical activity in older adults. (Lightsey, 1999) Self-efficacy is "the belief in one's capabilities to organize and execute the courses of action required to produce given attainments" (van Stralen, 2009). It is one of the most intensely studied and constant predictors of physical activity maintenance for elderly people.

To conclude, using wearable devices to effectively promote health behavior change is a complex, multistep process. First, a person must be motivated enough to want a device and be able to afford it. Second, once a device is acquired, a person needs to remember to wear it and occasionally recharge it. Third, the device must be able to accurately track its targeted behavior. Fourth, assuming information is collected with a satisfying accuracy, it must be presented back to the user in a manner that can be understood and motivate action, and that sustains that motivation toward improving health.

Chapter 3 Design Guidelines

3.1 Overview

The purpose of this thesis is using multiple methods of inclusive design, user experience design, and behavior change techniques to improve creation of wearable device design, especially to accommodate the needs of older adults. The user experience design model of five planes is initially web-based, but it gives a clear and systematic design flow, which can be adjusted and applied to wearable device design.

The design guidelines are created based on the user experience design model, and I include the product design process in the flow. Because the inclusive problems mainly occur in interactions with the software sides, the emphasis is still put on the user interacting with the user interfaces. Also, wearable device design here refers to the whole wearable systems, which may include the mobile phone applications and/or the related websites. Moreover, an evaluation process is added as the last plane of my design flow for testing and final production.

On each design plane, I create a set of guidelines for designers to follow and to leverage them as criteria to evaluation and iteration. These design guidelines will be discussed separately in the following sections.

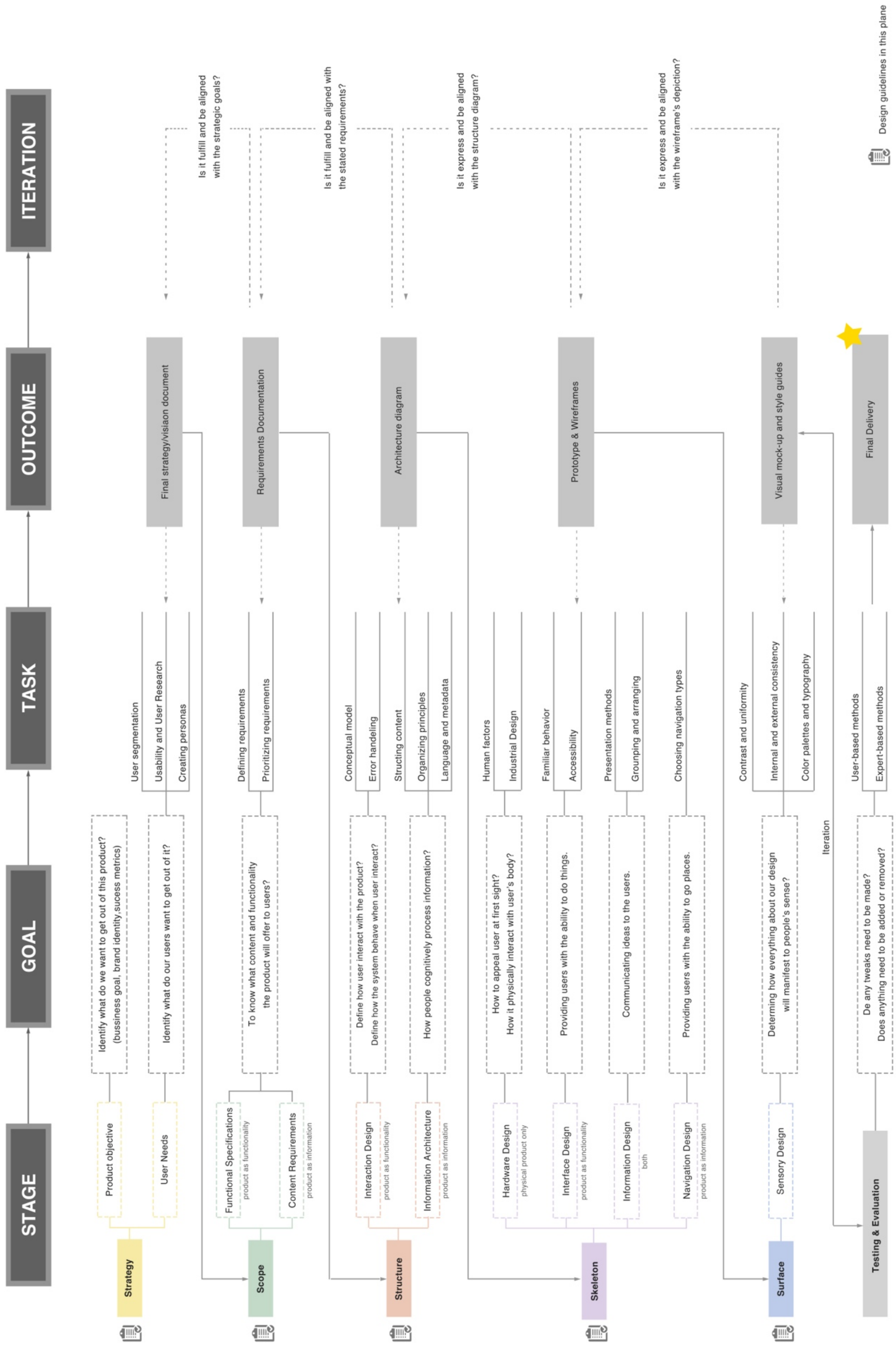
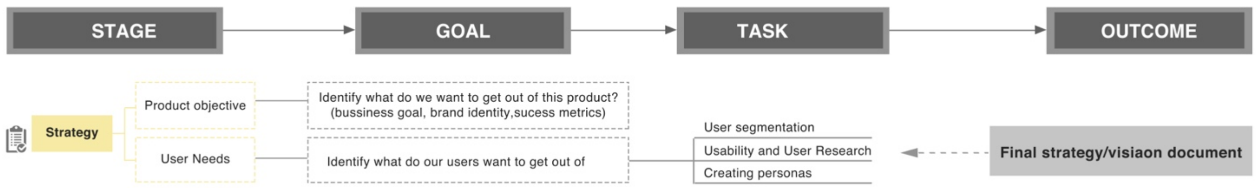
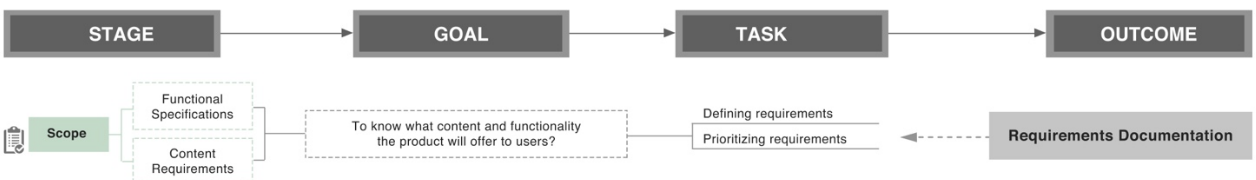


Figure 3.1 Flow Chart of the Design Process



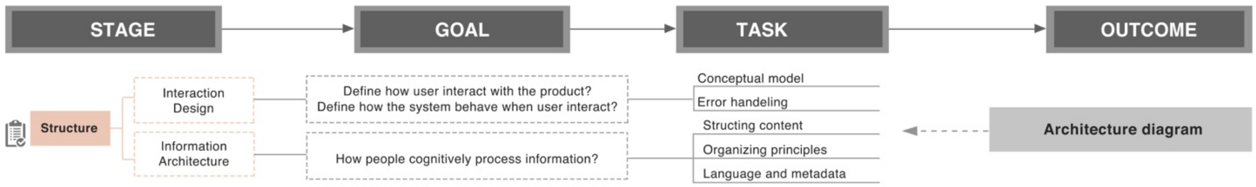
Design Guidelines of Strategy Plane	
What do we want to get out of this product? What do our users want to get out of it?	
Product Objective User Needs	**Collaborative.** Employ a shared vision to define your strategy.
	Think big. Make your product vision broad and ambitious.
	Inclusive. Recognize exclusion, learn from diversity, and solve for one, extend to many.
	Achievable. Vision should be broad and engaging, but not unrealistic.
	Explicit. Keep your strategy/vision document concise and to the point.

Table 3.1 Design Guidelines of Strategy Plane



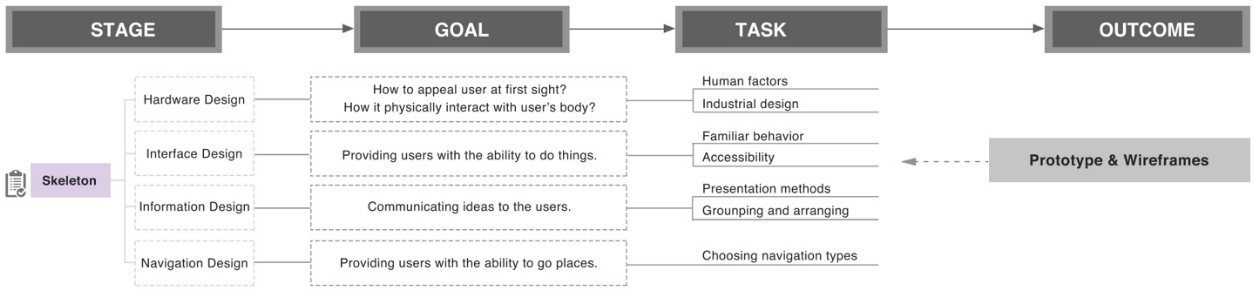
Design Guidelines of Scope Plane	
What content and functionally the product will offer to users.	
Functional Specifications Content Requirements	**Dual character.** Both hardware and software requirements included.
	Be positive. Instead of describing a bad thing the system shouldn't do, describe what it will do to prevent that bad thing.
	Be specific. Leaving as little as possible open to interpretation is the only way we can determine whether a requirement has been fulfilled.
	Don't be subjective. Requirements shouldn't be based on personal opinions or preferences.

Table 3.2 Design Guidelines of Scope Plane



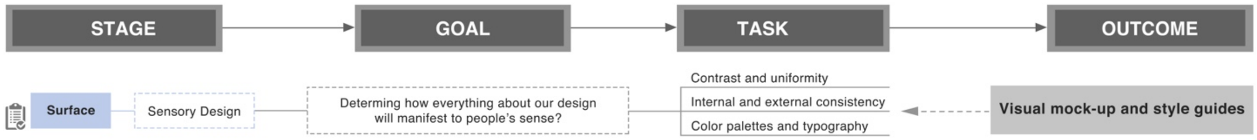
Design Guidelines of Structure Plane	
How user interact with the product? How the system behave? How people cognitively process information?	
Interface Design Information Architecture	**Visibility.** The opportunities for interactions should be visible
	Learnability. Interactions should be easy to learn, and easy to remember.
	Usability & Accessibility. Design should be able to help users of different abilities and in various circumstance finish tasks and fulfill their needs.
	Familiarity & Consistency. Interactions should use user's language and be applied consistently throughout the system.
	Adaption & control. Design should be flexible to accommodate growth and adapt to change, and give user control.
	Feedback. Feedback should be provided to users properly to inform useful information.
	Tolerance. Design should help users easy to recognize, diagnose, and recover from errors.
	Memory. Design should minimize demands on working memory.
	Motivation. Use various tools to increase user's motivation and promoting behavior changes.

Table 3.3 Design Guidelines of Structure Plane



Design Guidelines of Skeleton Plane	
How to appeal user at first sight? How it physically interact with user's body? Providing users with the ability to do things. Communicating ideas to users. Providing users with the ability to go places.	
Hardware Design **Interface Design** **Information Design** **Navigation Design**	**Visibility.** The design should make all needed options and materials for a given task visible.
	Clarity & Simplicity. The design should communicate effectively through clear and simple structure.
	Consistency. Create repetitions to enhance design and clarity.
	Easy to manipulate. Allow user to interact and navigate the system easily.
	Gestalt. Apply gestalt theory to facilitate content organization and visual pleasing.
	Priority. Make your important information obvious cause user attention.
	Familiarity. Match between system and the real world.
	Memory. Design should relieve user's cognitive overload to finish tasks.
	Comfort. Wearables should be aesthetic pleasing and be worn in a comfortable manner.

Table 3.4 Design Guidelines of Skeleton Plane



Design Guidelines of Surface Plane	
How everything about the design will manifest to people's sense?	
Sensory Design	**Visibility and readability.** Present all visual elements in more visible way.
	Clear & Consistency. Elements should be ambiguous, and create repetition to add visual interest and unify.
	Hierarchy & Dominance. Focus on having one element as the focal point and others being subordinate.
	Balance. Creates the perception that there is "equal" distribution.
	Alignment. Unify and organize elements on a page.
	Proximity. Group related items together, Separate unrelated elements.
	Familiarity and unambiguity. Use plain and familiar language to avoid confusion.
	Auditory presentation. Audio should be provided in an appropriate and adjustable way.
	Haptic presentation. Haptic feedback should be an add value, not an interference.

Table 3.5 Design Guidelines of Surface Plane

3.2 Strategy Plane

In the strategy plane, designers should determine the reason for the product, why we create it, who are we doing this for, why people are willing to use it, and why they need it. The goal here is to define the product objectives and user needs.

3.2.1 Product Objective

For product objective, the consideration includes identifying the business goal, brand identity, and success metrics. While it is fundamentally important from the company's perspective, it is usually not the focus for a designer.

3.2.2 User Needs

The most critical factor of this plane is defining the user needs. It can be easy to fall into the trap of thinking that we are designing our product or service for one idealized user – someone exactly like us. To get to the bottom of those needs, we have to define who our users are and can conduct research with people by asking questions and observing their behavior. To learn user needs, there are normally three steps to take: user segmentation, user research and creating personas.

User segmentation. The diversity of customers should be considered adequately, especially in inclusive design to define the exclusion. Dividing the entire audience into smaller groups with shared needs can help designers understand user needs (Figure 3.2).

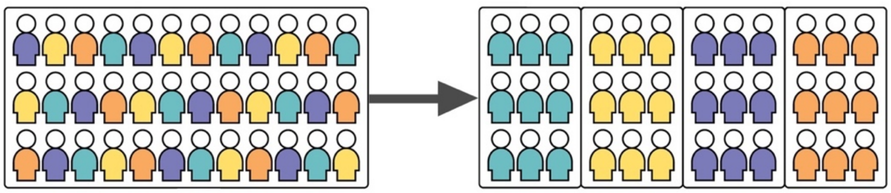


Figure 3.2 User Segmentation

User research. There is no set requirement about which user research tool designers have to use; different research methods have different characteristics. A three-dimensional framework of common user research methods was provided by Christian Rohrer (2014), which organizes these tools in three distinctions: attitude vs behavioral, qualitative vs quantitative, and context of use. (Figure 3.3)

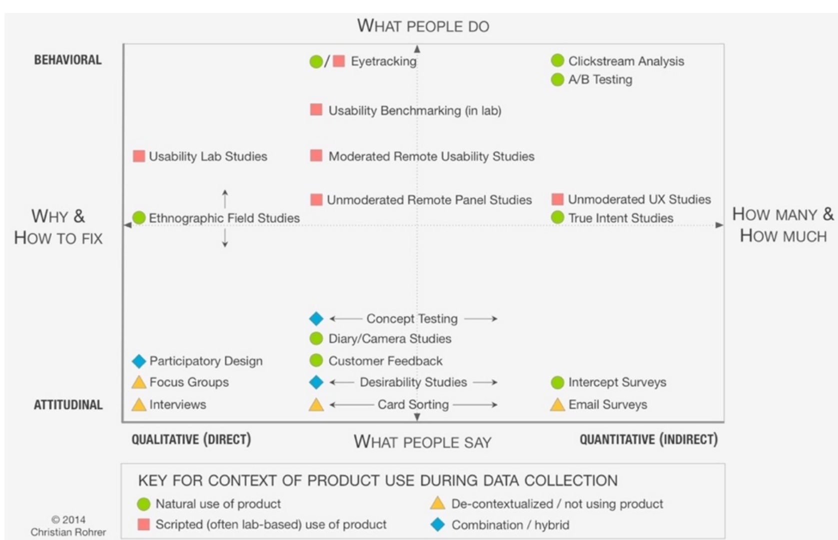


Figure 3.3 A Landscape of User Research Methods

Creating personas. A persona is a fictional character constructed to represent the needs of the whole range of real users (Figure 3.4). By putting a face and a name on the disconnected bits of data from user research and segmentation work, personas can help ensure designer perceive more empathy and keep users in mind during the design process.

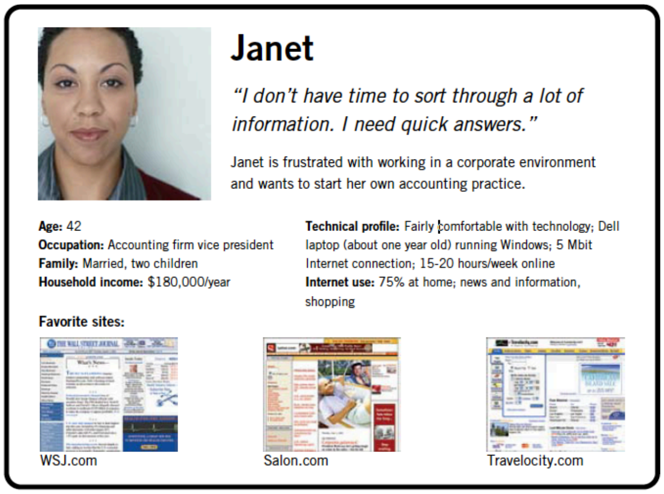


Figure 3.4 A Sample of Persona

We may gain a great amount of user needs after these processes; however, there is still a risk of misunderstanding users' real needs or it being too tough to fulfill all needs. The Kano Model is thus a simple and versatile technique for evaluating and deciding which features of a product or service should have (Figure 3.5). The Kano model of product development and customer satisfaction was published in 1984 by Dr. Noriaki Kano, which classifies customer satisfactions into five categories: delighted, satisfied, neutral, dissatisfied, and frustrated; and implements into five types: none, some, basic, good, and best. These two dimensions put together are the basis of the Kano Model and determine how customers feel about the product's features, so that the designer can define the basic needs, performance needs, attractive needs, indifferent needs, and reverse needs.

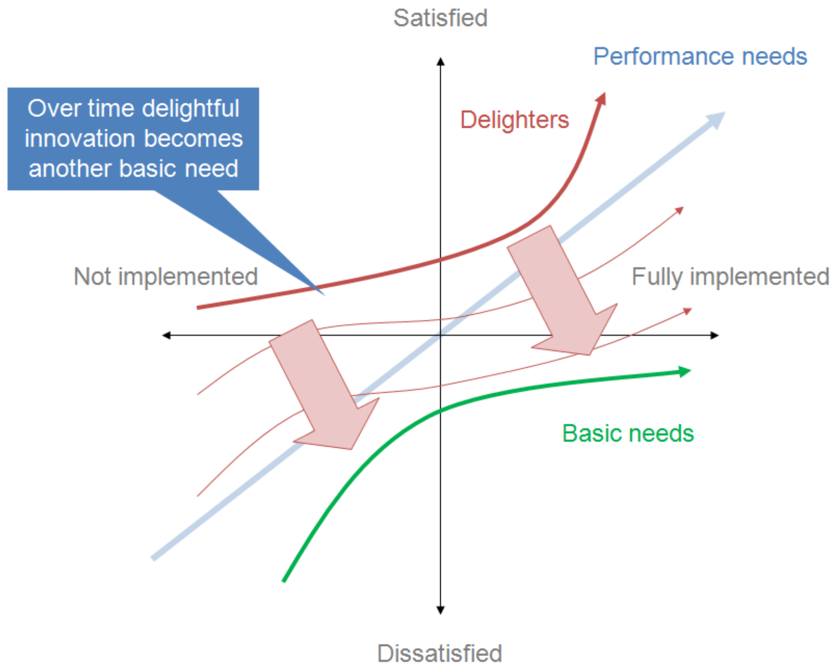


Figure 3.5 The Kano Model of Product Development and Customer Satisfaction

3.2.3 Outcome: Vision Board

A strategy or vision document is needed for an outcome of this plane to help designer or company clarify and maintain focus on their strategic goal during design process. This document also acts as an overarching goal guiding everyone involved in the development effort. A representative example is the Product Vision Board which was created by Roman Pichler (Figure 3.6). This vision board help designers describe, visualize, and validate the product strategy by capturing the target group, the user needs, the key product features, and the business goals. In the extended version, it also describes key elements of business model including competitors, revenue sources, cost factors, and channels. According to the specific situation, designer can flexibly choose blanks to fill in.

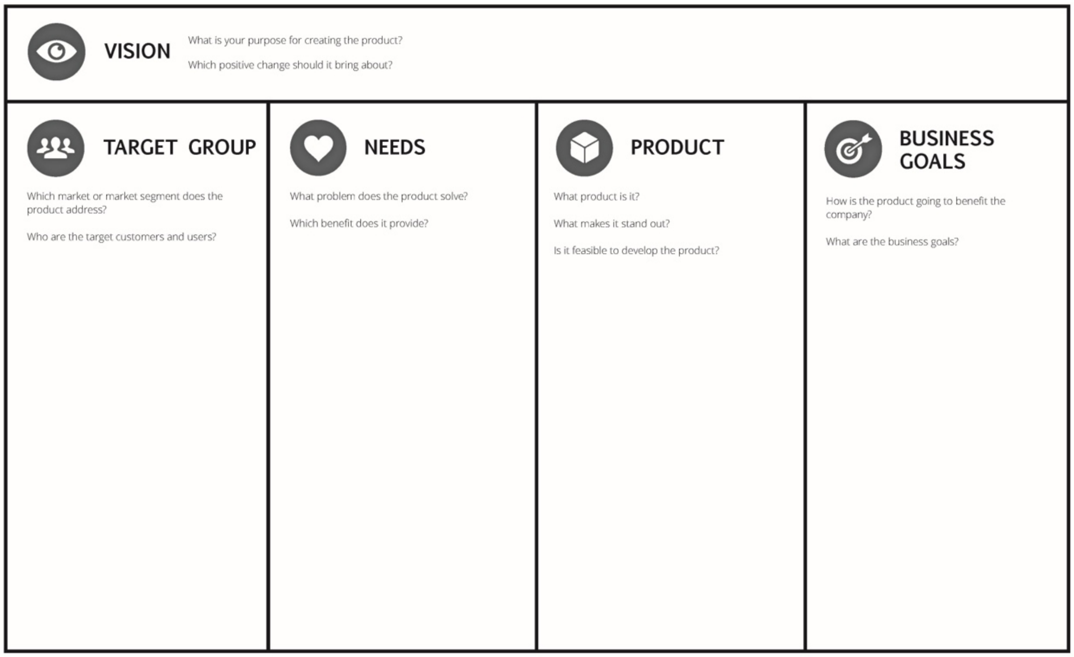
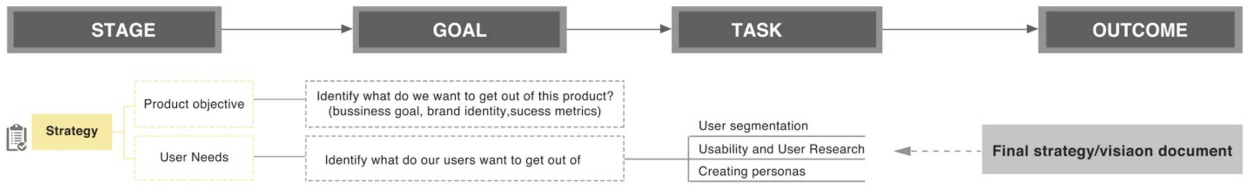


Figure 3.6 The Product Vison board

The Product Vision Board can capture the initial ideas and assumptions for a new product. In this step, designer does not want to describe users, products and business model comprehensively or in great detail. In the “Target Group”, it states who should use and purchase the product or who should benefit from it. The “Needs” is looking for the main problem the product should solve or the primary benefit it should provide. In terms of “Product”, designer should list three to five features that help the product stand out. The “Business Goal” will consider the product’s value or answer why the organization should invest money in the product.

3.2.4 Guidelines of Strategy Plane

Five general guidelines are provided in this plane for designers to follow and document in an effective way (Table 3.6).



Design Guidelines of Strategy Plane	
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	Achievable. Vision should be broad and engaging, but not unrealistic.
	Explicit. Keep your strategy/vision document concise and to the point.

Table 3.6 Design Guidelines of Strategy Plane

Collaborative. Employ a shared vision to define the strategy. For example, designers should invite teammates or other stakeholders who can contribute to the bigger picture by providing professional knowledge, passion or visionary skills. Developers, designers, researchers, business or marketing people could all fit here.

Think big. The product vision should be broad and ambitious so that it can facilitate a change in the strategy and give the design more options and possibilities. For example, "Help older adults enjoy technology" is a broad and ambitious vision.

Inclusive. Trying to appeal wider range of users could be a success for a business and user's satisfaction as well. But designers should keep in mind that there is not one-fit-all solution so recognizing exclusion is needed. Also, wearable device should not be tagged like elderly design to avoid stigma.

Achievable. The strategy should be broad and engaging, but not unrealistic. Although a vision should be a futuristic idea of what the product might become, a goal that can be actually met is important.

Explicit. Keep the strategy/vision document concise and to the point. Rather than volume, it should be easy to communicate and to understand.

Strategy has the most impact on the success or failure on the project. If done well, designers can know the why and who, and then the product is going to be valuable to users. But if mistakes are made, designer will be at a disadvantage during the whole project.

3.3 Scope Plane

Moving to the scope plane, designers need to define specific requirements of the product or service. Depending on the character of functionality-oriented or information-oriented, designer will focus on functional specifications or/and content requirements in this phase.

3.3.1 Functional Specifications

Functional specifications are the requirements about the functions, or features in the product, and also how features work and how they interrelate with each other. It is not about volume or detail, but about clarity and accuracy. So, designers don’t have to embody every aspect of the product now – just the ones that need definition to avoid confusion in the development process. Also, some idealized future state for the product is unnecessary – just the decisions that have been made are needed.

3.3.2 Content Requirements

Content requirements is the information in order to provide the value to intended users. Mostly, information referring to texts, images, audios, and videos will need to be considered. A rough estimation of each of the content features has a huge impact on the user experience decisions that designer will have to make, so knowing in advance could be very helpful.

3.3.3 Outcome: Requirements Documentation

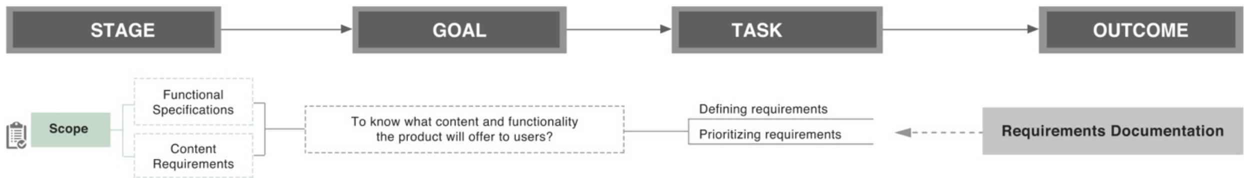
Having a defined set of requirements allows designer to parcel out responsibility for the work more efficiently. Seeing the entire scope mapped out enables designers to see connections between individual requirements that might not otherwise be apparent. Documentation provides a framework for evaluating those ideas and helps designers to know what they are and are not building, so that they can manage the entire process in a more deliberate way. Requirements documentation can be created in a very personalized way but should be organized in a simple and clear way. Here I provide a basic form of requirement documentation for reference (Table 3.7).

No.	Name	Description	Priority	Notes
1				
2				
3				
4				
5				
......				

Table 3.7 A Sample Form of Requirements Documentation

3.3.4 Guidelines of Scope Plane

During the process of requirements definition, several guidelines need to be followed to can create a more reliable and effective documentation. (Table 3.8)



Design Guidelines of Scope Plane	
What content and functionally the product will offer to users.	
Functional Specifications **Content Requirements**	**Dual character.** Both hardware and software requirements included.
	Be positive. Instead of describing a bad thing the system shouldn't do, describe what it will do to prevent that bad thing.
	Be specific. Leaving as little as possible open to interpretation is the only way we can determine whether a requirement has been fulfilled.
	Don't be subjective. Requirements shouldn't be based on personal opinions or preferences.

Table 3.8 Design Guidelines of Scope Plane

Dual character. As wearable devices have a double character of hardware and software, considerations such as both ergonomics and user interfaces are required.

Be positive. Define the requirements in a positive expressive manner. For example, instead of "The system will not allow the user to purchase a kite without kite string", "The system will direct the user to the kite string page if the users try to buy a kite without string" would be better.

Be specific. Leaving as little as possible open to interpretation is the only way we can determine whether a requirement has been fulfilled. For example, instead of "The most popular function will be highlighted", "Function with the most uses in the past will appear at the top of the list" would be better.

Don't be subjective. Requirements shouldn't be based on personal opinions or preferences to avoid abstract feelings. For example, instead of "This interface will have a fashionable style", "This interface will meet the fashion expectation of David" would be better.

3.4 Structure Plane

The work in the structure plane would be defining ways users can interact with the products and how systems respond to users. Structure is split into two components: interaction design and information architecture.

3.4.1 Interaction Design

Given the functional requirements, interaction design is the creation of the dialogue between a person and a product, system, or service. This dialogue is both physical and emotional in nature and is manifested in the interplay between form, function, and technology as experienced over time. (Kolko, 2010) There are several questions designers need to think about for obtaining a better human-computer-interaction: (1) How can users interact with the interface? (2) How can it give users clues about behavior before actions are taken? (3) How to anticipate and mitigate errors? (4) How to simplify the learnability?

Conceptual models. Users' impressions of how the interactive components will behave are known as conceptual models. For example, does the system treat a particular feature as a thing the user consumes as familiar? (i.e. shopping cart in online shop). Knowing the conceptual models that users have will allow designers to make consistent design decisions and improve the learnability. Ideally, the users will not have to be told what conceptual model it is, while they still can pick it up intuitively as they interact with the product.

Error handling. A system will upset users if errors keep popping up on the screen. There are generally three ways for a better error handling (Figure 3.7). To be specific, designers can design the system so the errors are simply impossible; or can make errors merely difficult; ideally, they can provide a way for users to recover from the error (i.e. undo function)

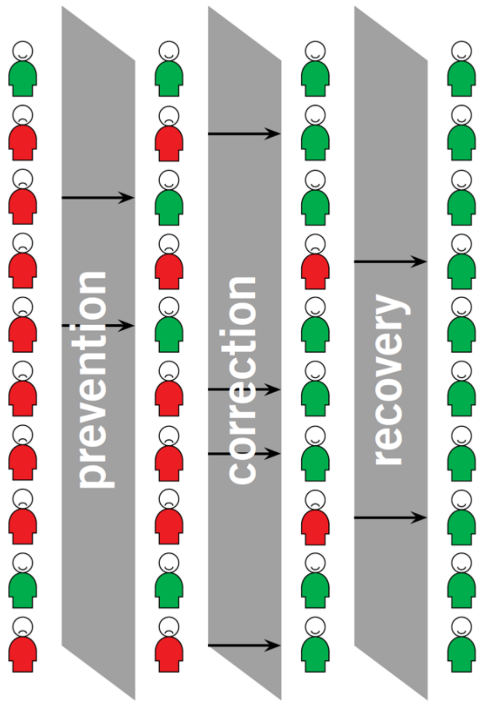


Figure 3.7 Ways of Error Handling

3.4.2 Information Architecture

Based on content requirements, information architecture defines the arrangement of content elements – how they are organized to facilitate user's understanding.

Structuring content. Well-structured content can avoid information clutter and visually please users. There are different structure patterns, such as hierarchical structure (a), matrix structure (b), organic structure (c), and sequential structure (d), which all have their pros and cons. Selecting the right relationships of each contents can greatly enhance the usability.

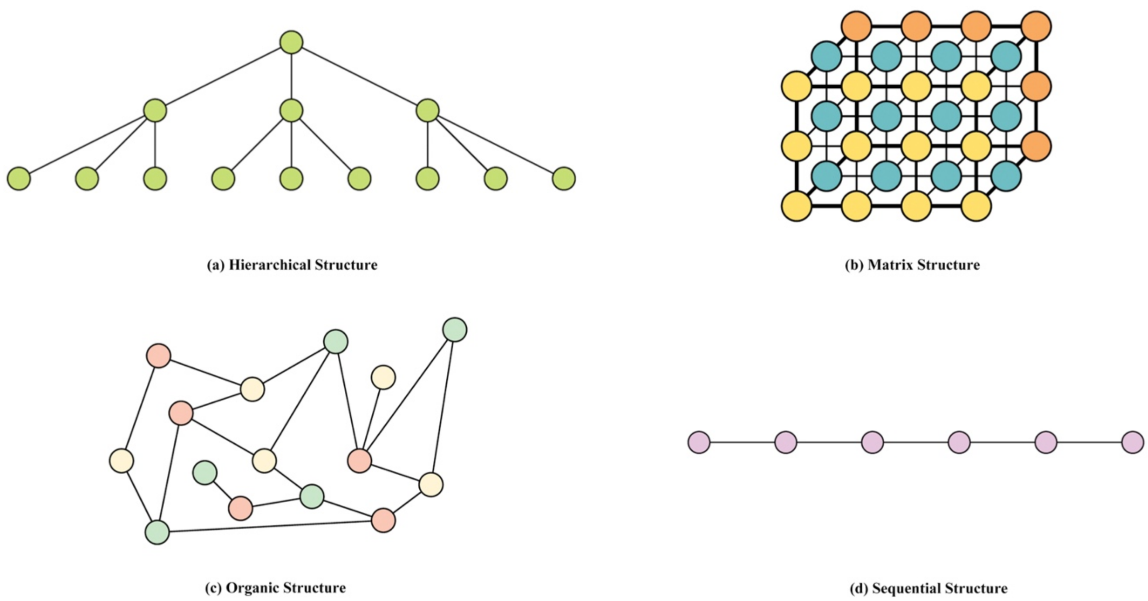


Figure 3.8 Main Structure Patterns for Information Contents

The number of contents does matter. The "magic number seven, plus or minus two" provides evidence for the capacity of short-term memory. Most adults can store between five to nine items in their short-term memory. This result can be applied when designers decide the number of navigation menus or tabs.

Besides, in terms of menu system, the depth versus breadth was discussed. (Fisk, 2018) For a visual menu, a broad structure reduces the demands on memory but also increases the need for visual scanning or scrolling through screens. Menus with deeper structure, however, may improve the organization of the information but also increase the likelihood that users will get lost in the system (Figure 3.9). Designer should keep an eye on the balance of depth and breadth when designing the menu structure for a better exploration.

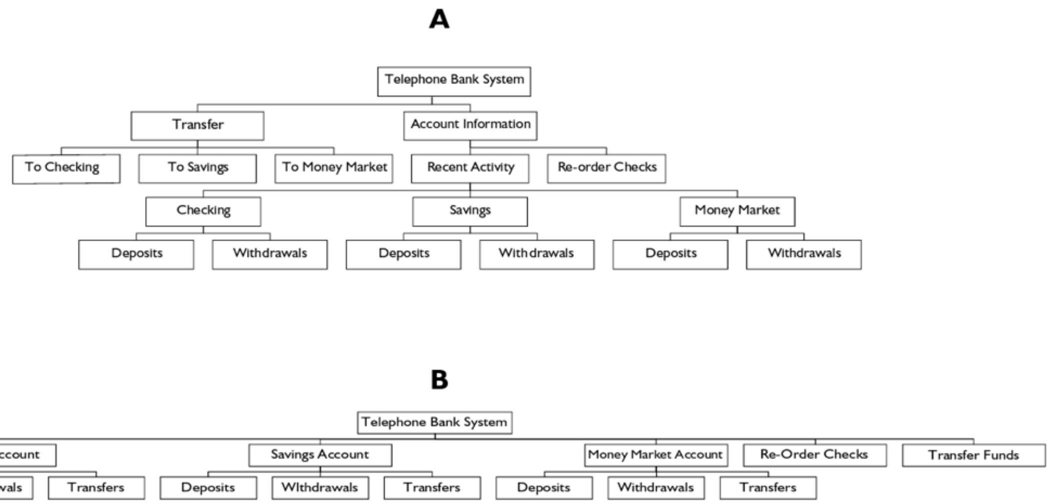


Figure 3.9 Comparison Between (A) Deep Menu and (B) Broad Menu

Also, Hick's Law (Figure 3.10) was first introduced in 1952 to investigate the relationship between the number of choices presented in the interface and the user's reaction time required to make a decision from these choices. (Schneider, 2010) The factor that is affecting the user response time is the number of stimuli (choices) because each stimulus has its own response. So, the more choices, the more time user needs to spend to make a decision. Designing for mobile devices, which already have very limited space, has to consider the priority of the contents to avoid overloading choices to users. The Hick's Law formula defines this principle as follow: T=a+b log2(n). "RT" is the reaction time, "(n)"is the number of choices, "a" and "b" are constants, depending on the tasks and condition.

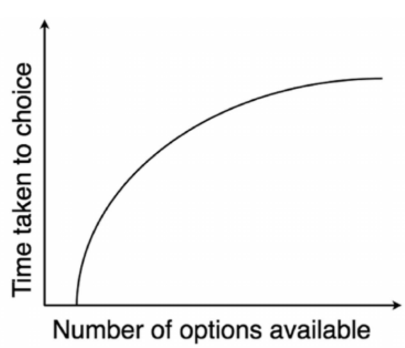


Figure 3.10 The Hick's Law

Organizing principles. Organizing principle is the criterion by which we determine which nodes are grouped together and which are kept separate. We should create the right structure for our objective and the needs of our users. For instance, news and events will often have chronology as its most prominent organizing principle because timeliness is the most important factor for users in these cases.

Language and metadata. It is always better to use users' language. Even if the structure is a perfectly accurate representation of the way people think about the subject matter, users will not be able to find their way around the architecture if they cannot understand the nomenclature such as the descriptions, labels, and other terminology the system uses. For this reason, it is essential to use the language of the users and to do so in a consistent way.

3.4.3 Outcome: Architecture Diagram

The of the major documentation tool for interaction design and information architecture is using the Visual Vocabulary to create diagrams, a system which was created by Jesse James Garrett in 2000. A Visual Vocabulary is a set of symbols used to describe the structure and the flow of a process. (Figure 3.11) Having a single document that delivers a simple and understandable representation of how the product or application work is vital for developing new features, updating existing ones, and for seeing what is possible considering in the current product.

There are two major requirements for actually constructing an architecture diagram - organizing it through a visual hierarchy (i.e. features, functions, and behavior) and creating a legend for displaying different types of features, interactions, and flows. With a standard flowchart, the shapes follow specific requirements, like rectangles are process, diamonds are decision point, etc.

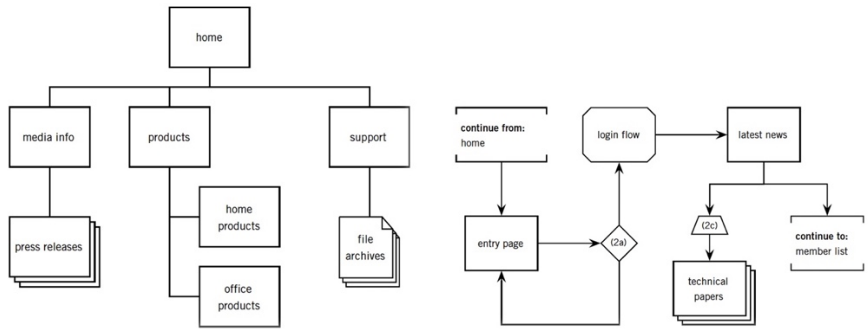
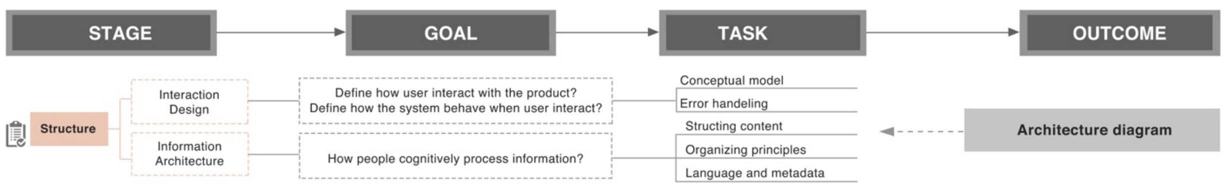


Figure 3.11 A Sample of Architecture Diagram

3.4.4 Guidelines of Structure Plane

A set of ten guidelines are created for building a better structure (Table 3.9).



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	Memory. Design should minimize demands on working memory.
	Motivation. Use various tools to increase user's motivation and promoting behavior changes.

Table 3.9 Design Guidelines of Structure Plane

Visibility. The opportunities for interactions should be visible. Instead of depending on luck or random discovery, users should be able to see what interactions are, since hidden interactions decrease usability and efficiency. Users at any screen or page should know where they are, how did they arrive here, what they can do here, and where they can go from here, so that users can accurately predict the outcome of interactions.

Learnability. Interactions should be easy to learn, and easy to remember. To achieve this goal, designer can leverage what users already know, and ensure the help is available and easy to access. Providing educational tools such as online help, video tutorials, or memory cards can be helpful. Also, the design of the system should prepare users by covering the basics and introduce complexity later on.

Usability & Accessibility. Design should be able to help users of different abilities and in various circumstance finish tasks and fulfill their needs. Firstly, the product should be flexible to use which can accommodate a wide range of individual preference and abilities, for example, to accommodate right-or-left handed users to access and use. Secondly, the product should offer choices where a single design solution cannot accommodate all users. Using multimodal presentation of information can be a good way to enhance experience. (e.g. audio-tabbing with audio confirmation to help elderly with reduced vision, and haptic assistance). Also, due to most elderly users suffering from motoric and digit agility difficulties, design should avoid relying on small buttons and avoid interacting with long movements (such as a long continuous or circular swipe) and double clicks. The designers should adopt “tap” as the main gesture to interact with the UI instead of the use of tricky gestures: “drag and drop”, and “tap and hold”. If used, an alternative way should be provided for the elderly to perform the task corresponding with these gestures.

Familiarity & Consistency. Interactions should use user’s language and be applied consistently throughout the system. To shorten the time for learning, system design should be compatible with user expectations (e.g. a knob turned clockwise results in an increase in something). Designer should be cautious of applying novel interactions or new motor sequences and capitalize the existing behavior for elderly as they do not easily learn, handle and adapt to new interactions that conflict with previously well-established ones compared to younger users. To keep a consistent design, similar functions should act the same across screens (e.g. cancel button should always result in the action).

Adaption & Control. Design should be flexible to accommodate growth and adapt to change and give user control. An adaptable system with preferred settings (e.g. input/output modalities and feedback intensity) should be contextual, based on localization, task or user preference. It could be realized by self-learning to enable optimal automated adaptive settings. The wearables should be able to personalize thresholds (e.g. analysis of the personal data id done on thresholds suitable for the elderly since physical threshold may vary by age). The system should be able to offer choices and allow individualization. For example, a flexible display size of icons enables users to tailor the system into their preferred way. Providing good shortcuts that are meaningfully related to longer procedures is welcomed by experienced users who are annoyed by tedious using sequences. Also, the system should recognize the needs of diverse users and design for plasticity. For example, the target size and timing of actions should be adaptable according to older adults' abilities. It is possible to detect the speed and certainty of the users' movement and adapt the setting accordingly.

Feedback. Feedback should be provided to users properly to provide useful information. These messages may include locations, status, future, and results, should be meaningful and clear and inform through a simple, noticeable and unobstructive way. Such feedback should also handle error messages.

Tolerance. Design should help users easily recognize, diagnose, and recover from errors. Systems should allow easy error recovery so that user should not have to retype entire information if they just enter an invalid number but rather should be guided to repair only the faulty part. Another way is preventing errors wherever possible by proper design. For example, the system gray out items that are not appropriate or provide a descriptive confirmation message for each destructive action indicating the action consequence.

Memory. Design should minimize demands on working memory. Situations like overwhelming learners with too much information and requiring users to make complex inferences to fill in gaps of missing information should be avoided. If possible, memory aids such as cues and labels should be provided. Though system should engage users by giving controls, some functions are better to be automated to save users' time and energy, like synchronization. Designer could also find ways to simplify procedural memory, such as simple intuitive steps, place in context, minimize the number of steps, and frequent repetition for reinforcement.

Motivation. Designer should use various tools to increase user's motivation and promoting behavior changes. By leveraging behavior change techniques such as motivational interviewing, goal setting, positive feedbacks and rewards, peer coaching and action planning, designers can encourage users to finish their goals with wearable devices. On the other side, minimizing repetitive and high, sustained physical effort actions could help achieve the same result.

3.5 Skeleton Plane

The skeleton plane determines the hardware design and visual form on the screen, presentation, and arrangement of all elements that makes people interact with the functionality of the system that exist on the interface. Also, the plane determines how user moves through the information, and how information is presented to make it effective, clear, and obvious. Skeleton is divided into four components: hardware design, interface design, navigation design, and information design.

3.5.1 Hardware Design

Hardware design here refers to a physical model of wearable device. A traditional design process from ideation sketching, to a CAD model, and to finally a prototype can be applied here to determine a physical appearance of the device. The device can be used without defining details like material or color for now, but the shape, dimensions, and especially the screen have to be confirmed in the e skeleton plan for applying user interface design.

4.4.6 Interface Design

Interface design presents and arranges interface elements to enable users to interact with the system. A successful interface is that in which user can immediately notice the important stuff. There are some standard interface elements, which include: (a) checkboxes, (b) radio button, (c) text field, (d) dropdown list, (e) list box, and (f) action button, etc. (Figure 3.12).

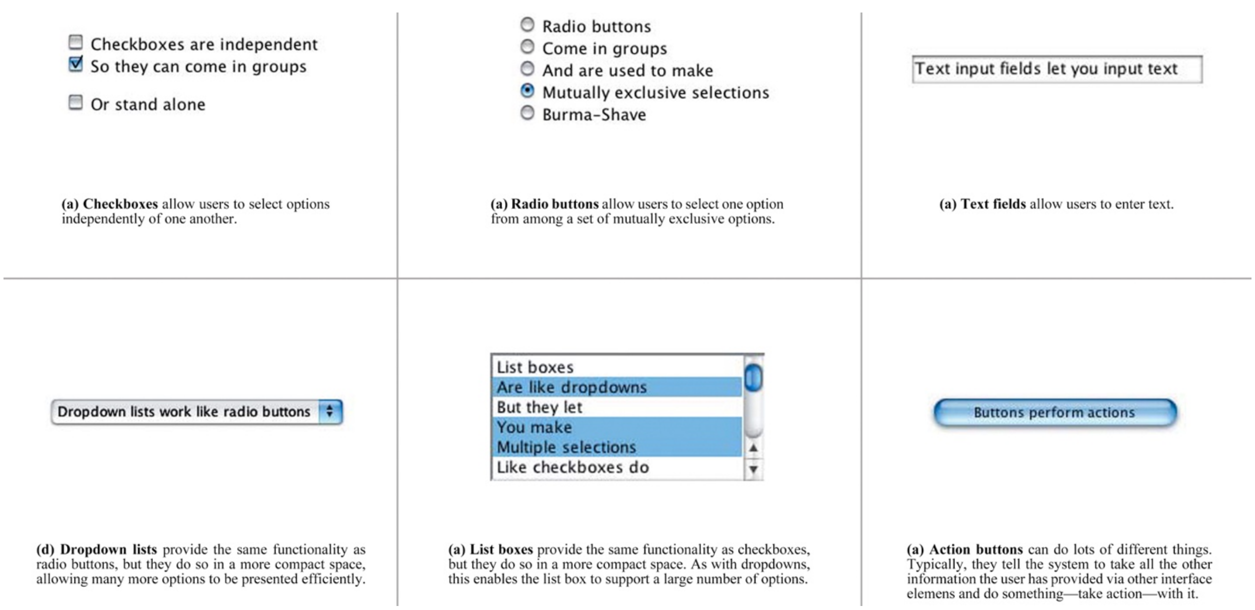


Figure 3.12 Standard Interface Elements

4.4.7 Navigation Design

Navigation design is how to navigate through the information using the interface. There are several typical navigation systems to choose (Figure 3.13).

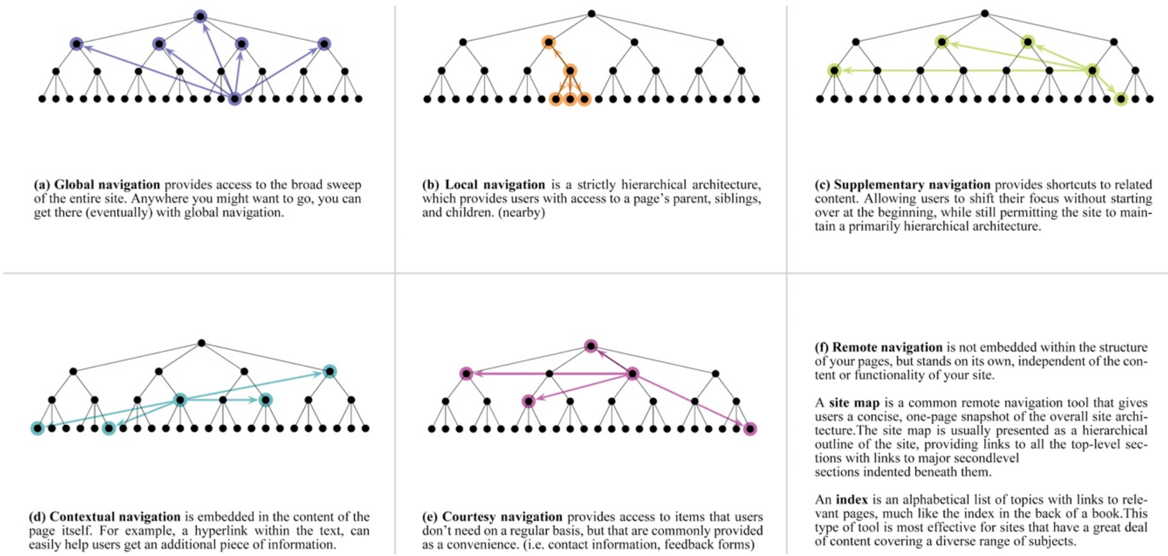


Figure 3.13 Different Types of Navigation Systems

To evaluate the navigation design, a set of 15 checklists created by Nielsen Norman Group on their websites can be a practical tool. (Kathryn, 2015)

4.4.8 Information Design

Information design defines the presentation of information in a way that facilitates understanding. Good information design should have appropriate organization and form. By doing that, designer should group and arrange information in a way that information is related and matches how users think and what they expect to support user tasks and goals. And for better representing the information, Edwin Stanton's Inverted Pyramid is an approach to present the information from the most to least important (Figure 3.14). It starts with the most critical information, which is the conclusion about who, what, where, when and how. In this way, no matter how much users want to get deeper into the information, the most important information has been already delivered.

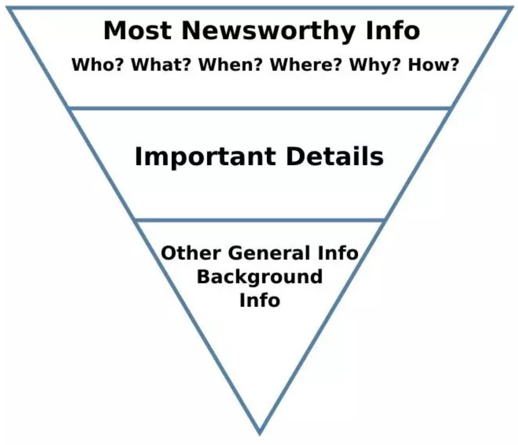


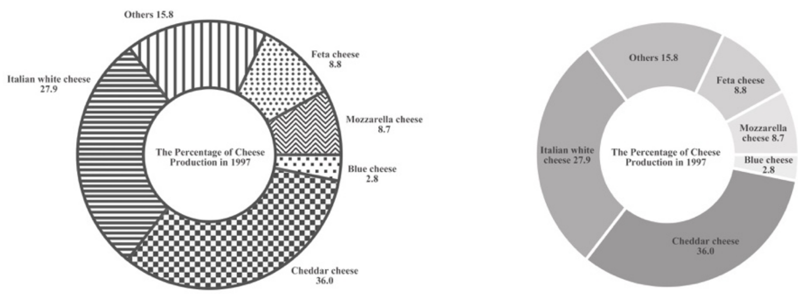
Figure 3.14 Inverted Pyramid by Edwin Stanton

The idea of wayfinding, which comes from the design of public spaces in the physical world (Figure 3.15), can also help users understand where they are and where they can go in cluttered information. Good wayfinding enables users to quickly get a mental picture of which choices will get them closer to their objectives.

Figure 3.15 Wayfinding in the Physical World

(Parking garage sometimes use color-coding to give people cues to help them remember where left their cars.)

A high signal-to-noise ratio is a key outcome for any information presentation work. Relevant information is “signal”, while irrelevant information is “noise”; either by maximizing the content (i.e. simple and prioritize) or minimizing the noise can have a better visual result (Figure 3.16).



Soybean		
	Production	Harvest
1997	2.69	68.1
1998	2.74	71.3
1999	2.65	72.5
2000	2.76	72.5
2001	2.89	73.2

Soybean		
	Production	Harvest
1997	2.69	68.1
1998	2.74	71.3
1999	2.65	72.5
2000	2.76	72.5
2001	2.89	73.2

Figure 3.16 Signal-to-Noise Ratio Demonstration

The serial position effect, a term coined by Herman Ebbinghaus, describes how the position of an item in a sequence affects recall accuracy. The factor that items presented at the beginning and at the end of the sequence are recalled with greater accuracy than items in the middle can be applied to determine the positions of the most frequent features (Figure 3.17).

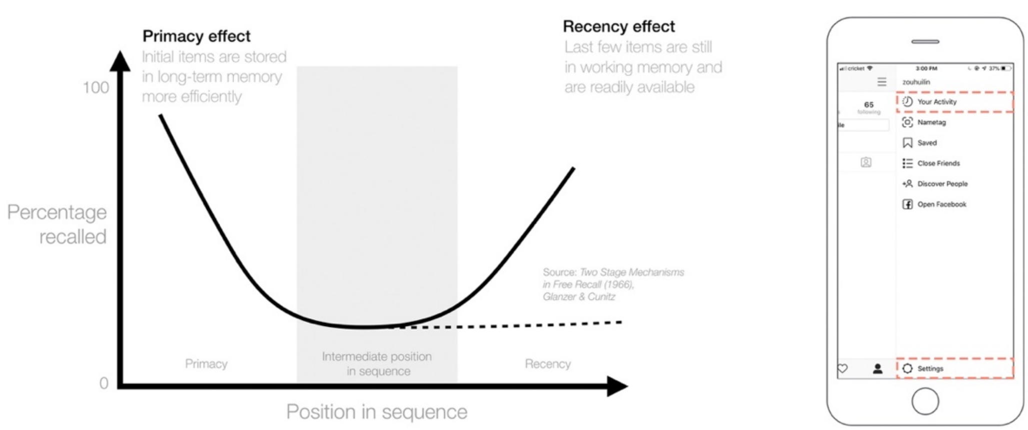


Figure 3.17 Serial Position Effect and Its Application

It is also worth mentioning that Jakob Nielsen discovered an F-shaped pattern of reading in the web (even on mobile), which provides some tips for arranging the information. For example, the system needs to include the most important points at the beginning and use headings and subheadings smartly to make sure they look important and more visible. Also, designers should consider cutting unnecessary content and bolding important words and phrases to add visual weight. Visually group related contents can also catch user's attention.

4.4.9 Outcome: Prototype & Wireframes

Preliminary models or porotypes will be created for testing and adjustment. The dimensions, placement and function of buttons will be defined for further development on user interfaces. Wireframes are widely used to create a visual format, which is a static diagram that represents a visual format of the product, including content, navigation, and ways for interactions (Figure 3.18). With previous work, it is a lot to balance at once.

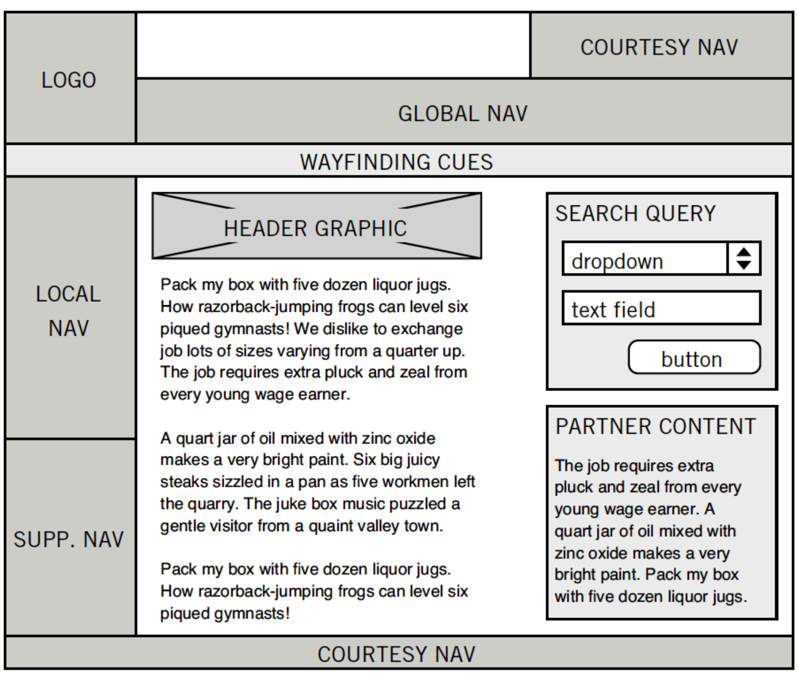
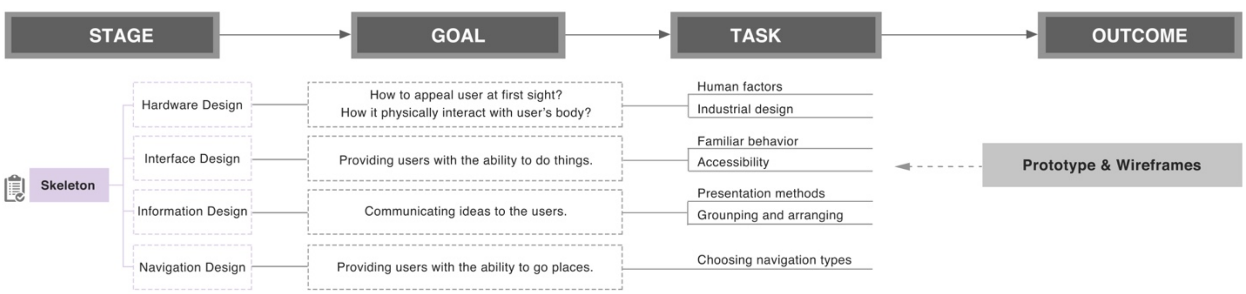


Figure 3.18 A Sample of Wireframes

The architecture diagram we saw in the structure plane is the grand vision for the design, while here, the wireframes is the detailed document that shows how that vision will be fulfilled. The value of wireframes is they integrate all three elements of the structure plane: In interface design, through the arrangement and selection of interface elements; In navigation design, through the identification and definition of core navigational system; In information design, through the placement and prioritization of informational components. By bringing all three together into a single document, the wireframes can define a skeleton that builds on conceptual structure while pointing the way toward the surface design.

4.4.10 Guidelines of Skeleton Plane

A set of eight guidelines are provided in the skeleton plane (Table 3.10).



Design Guidelines of Skeleton Plane	
How to appeal user at first sight? How it physically interact with user's body? Providing users with the ability to do things. Communicating ideas to users. Providing users with the ability to go places.	
Hardware Design **Interface Design** **Information Design** **Navigation Design**	**Visibility.** The design should make all needed options and materials for a given task visible.
	Clarity & Simplicity. The design should communicate effectively through clear and simple structure.
	Consistency. Create repetitions to enhance design and clarity.
	Easy to manipulate. Allow user to interact and navigate the system easily.
	Gestalt. Apply gestalt theory to facilitate content organization and visual pleasing.
	Priority. Make your important information obvious cause user attention.
	Familiarity. Match between system and the real world.
	Memory. Design should relieve user's cognitive overload to finish tasks.
	Comfort. Wearables should be aesthetic pleasing and be worn in a comfortable manner.

Table 3.10 Design Guidelines of Skeleton Plane

Visibility. The design should make all needed options and materials for a given task visible. By doing that, designer should put menus in familiar locations and ensure the menus have enough visual weight, for example, placing bigger elements on the left rail or top of the screen. The navigation system should be as "flat" as possible and avoid hiding important content in the depths of the system. Moreover, menu links should look interactive and avoid overwhelming users with alternatives that confuse with unneeded information.

Clarity & Simplicity. The design should communicate effectively through clear and simple structure. Designer should avoid overloading the screen with much unwanted or less frequent information. A way to solve that is placing most important information in front and grouping less important ones.

Consistency. Designer should create repetitions to enhance design and clarity. The design should reuse internal and external components and behaviors, maintaining consistency with purpose, thus reducing the need for users to rethink and remember. Location of important items should stay the same through screens (e.g. save or home button should be in the same location on every screen). Also, because elderly users are always less apt in using advanced interfaces, designers should aim for a simple navigation system that is clear and coherent. Repeating the same conventions and orders as much as possible could be helpful for this purpose.

Easy to manipulate. The design should allow users to interact and navigate the system easily. Making menu links big enough and spaced enough to be easily tapped or clicked can satisfy, especially the older adults. It is also recommended to place the essential UI elements in a visible area, preferably reachable by the user's thumb. Also, designers should be cautious of long menu design and optimize for easy physical access to frequently used commands, for example, putting the most common items close to the top so that fingers will not have to travel too far. The idea of sticky menus that remain visible at the top could also reduce tedious work for scrolling back, which is especially welcome on smaller screen.

Gestalt. Apply Gestalt Theory to facilitate content organization and visual pleasing. Properly applying methods of proximity, similarity, and common region to group and separate contents can facilitate user understanding in a short time. Besides, applying common fate to indicate actions such as swiping and scrolling is a natural and intuitive way for user to interact. The use of continuation and symmetry could help improve content display and balance. The details of Gestalt Theory will be further discussed in the surface plane.

Priority. Making your important information obvious causes user attention. A combination tools of wayfinding (color-coding), high signal-to-noise ratio, serial position effect (items presented at the beginning and the end), and F-shaped reading pattern can help users focus on core tasks, features, and information by prioritizing them within the content and layout, which has been discussed already.

Familiarity. There should be a match between system and the real world. The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Designer should follow real-world conventions, making information appear in a natural and logical order.

Memory. Design should relieve users' cognitive overload to finish tasks. Users prefer recognition rather than recall as it will not challenge their memory. Designer can minimize users' memory load by making important objects, actions, and options visible, for instance, centering on the user's current task and visually indicating the necessary steps to follow. Splitting one action into many different screens and stages can also upset the older adults while attempting to finish a task. Also, in order to ease their load, designer should use multimodal forms of communication to inform the same message.

Comfort. Wearables should have a good appearance and be worn in a comfortable manner. Firstly, wearable device should have a nice-looking design to feel comfortable instead of segregating or stigmatizing any users. Secondly, the wearable device should be physically comfortable, for example, featuring a softer band with proper material to avoid skin redness or sweating. Also, fine motor skills must be considered when designing a locking mechanism. For older adults, a clasp or magnet is more appropriate than putting pins in the holds for wristband.

3.6 Surface Plane

This is the last step to deliver an experience to users: determining how everything about our design will manifest to people's senses. There generally are five senses: vision, hearing, touch, smell, and taste, which we can employ depending on the type of product we are designing for.

3.6.1 Sensory Design

Visual design plays a role in virtually every kind of product. It is concerned about the visual appearance of content and control, which gives a clue of what users can do, and how to interact with them. A good visual design should make things easier to understand and increase cognitive ability to absorb what users see on the screen.

Contrast and Uniformity. In visual design the primary tool we use to draw user's attention is contrast (Figure 3.19). Contrast is vital to help user understand and distinguish the relationships between the elements on the interfaces and is the primary means of communicating conceptual groups in information design. On the other hand, maintaining uniformity in the design is an important part of ensuring the design can communicate effectively without confusing or overwhelming users. Grid-based layout is one technique from print design that can carry over effectively to web design (Figure 3.20). This approach ensures uniformity of design through a master layout that is used as a template for creating layout variations.

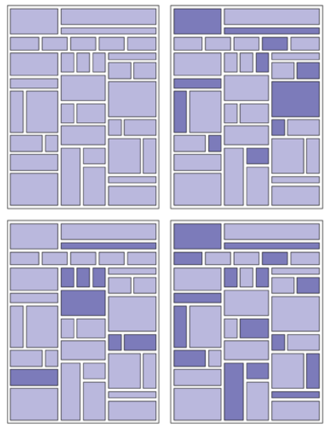


Figure 3.19 Demonstration of Different Contrast Effects

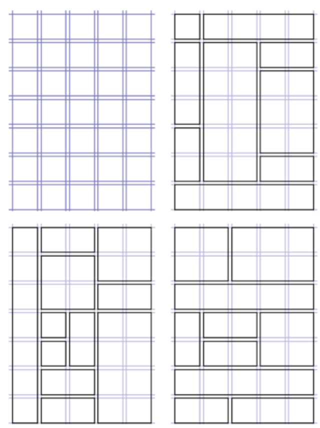


Figure 3.20 Demonstration of Grid-Based Layouts

Internal and External Consistency. There exist problems of internal consistency, in which different parts of the product reflect different design approaches, like the same figures having different performance on wearable device, mobile phone and website. Then there are also problems of external consistency that occur, in which the product doesn’t reflect the same design approach in other products from the same brand or product line.

Color palettes and Typography. Color can be one of the most effective ways to communicate a brand identity (Figure 3.21). For a brand, a color palette should incorporate colors that enable themselves to a wide range of uses. For some company, typography is so important to their brand identity that they have commissioned special typefaces to be produced, like Apple. For designers, even if they choose not to take this extraordinary step, typography can still serve as an effective part of communicating information through visual design (Figure 3.22).

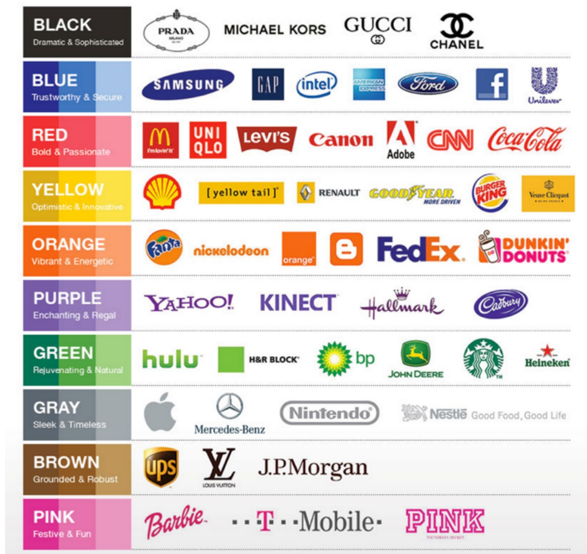


Figure 3.21 Color Palettes: A Rainbow of Brand

Good:	This text is a good size for seniors (12pt Times)
Bad:	This text is a bad size for seniors (8pt Times)
Good:	Arial is a good font to use for seniors
Bad:	*A script font is a poor choice for seniors*
Good:	Black text on a white background is easy to read, as is white on a black background
Bad:	Black text on a gray background is difficult to read

Figure 3.22 Examples of Good and Bad Text Display

Gestalt theory. Gestalt theory was founded by Max Wertheimer (1938) at early 20th century. This psychological philosophy attempts to describe how people perceive visual elements when certain conditions apply. This theory was built on the principle that "An organized whole is perceived as greater than the sum of its parts". Gestalt theory provides some useful principles which can inform today's visual perception design (Figure 3.23).

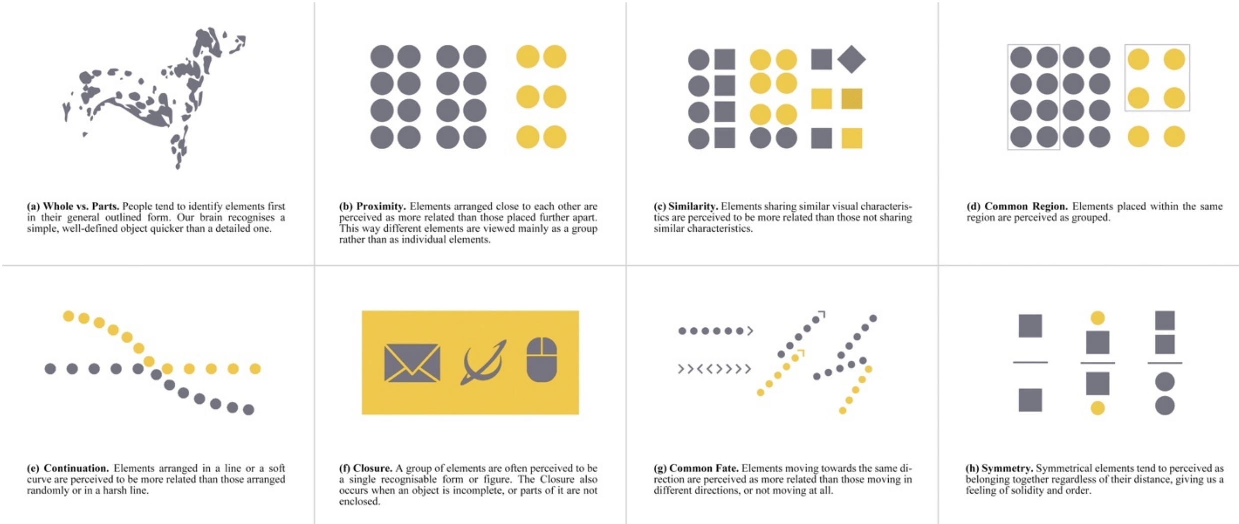


Figure 3.23 Main Principles of Gestalt Theory

3.6.2 Outcome: Visual Mock-ups and Style Guides

In both hardware and software, a designer comes up with one or several visual mock-ups as the outcomes of the surface plane. Typically mid to high fidelity, mockups reflect the design choices of color schemes, layouts, typography, iconography, the visuals of navigation, and the overall atmosphere of the product (Figure 3.24). The mock-up doesn't have to match the wireframes precisely – just account for the relative importance and grouping elements presented in the wireframes.

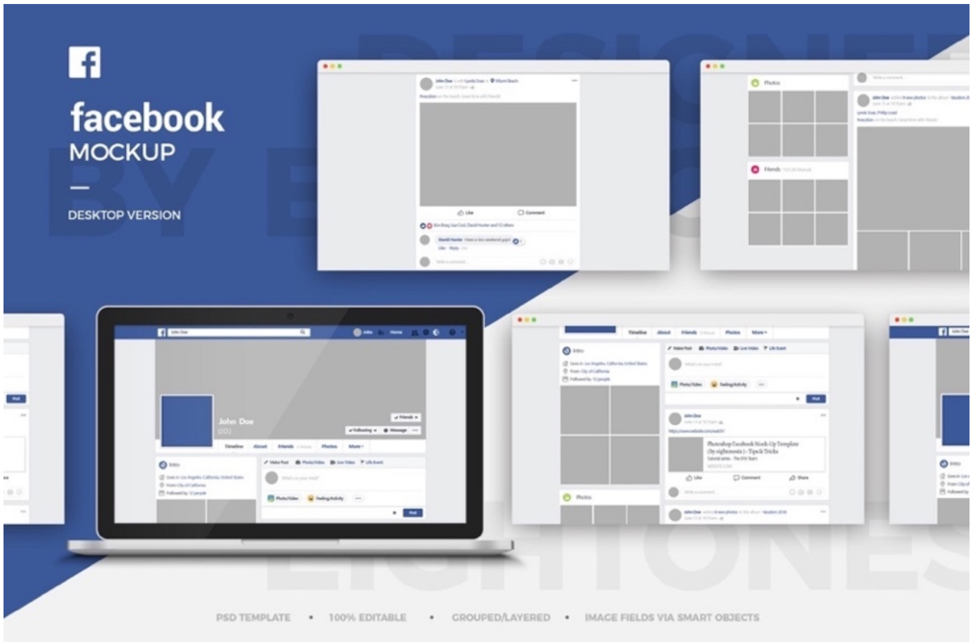


Figure 3.24 Facebook Mockup

The definitive documentation of the design decisions we have made is the style guide (Figure 3.25). This compendium defines every aspect of the visual design, from the largest scale to the smallest. Global standards affecting every part of the product – such as design grids, color palettes, typography standards, and logo treatment guidelines – are usually the first things to go into this documentation.

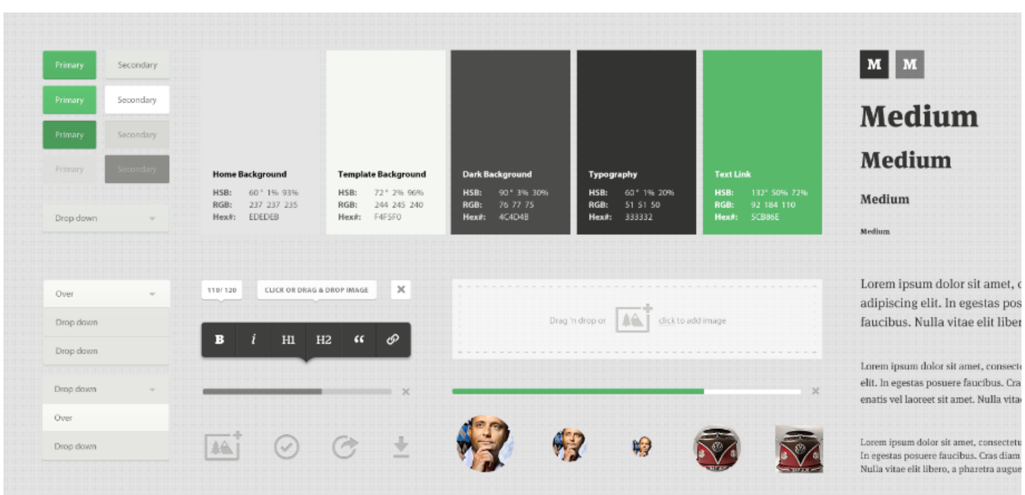
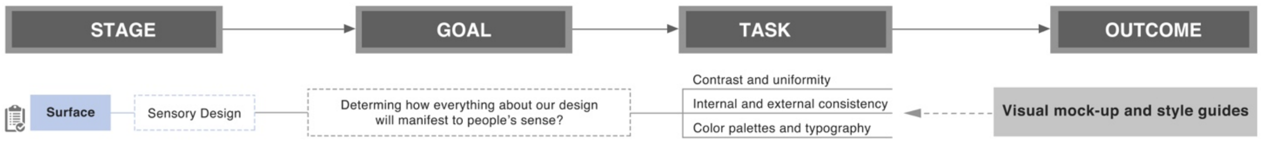


Figure 3.25 A Sample of Style Guide

3.6.3 Guidelines of Surface Plane

Following these nine general guidelines (Table 3.11), designer can be more considerate in delivering information to users in a more pleasing way.



Design Guidelines of Surface Plane	
How everything about the design will manifest to people's sense?	
Sensory Design	**Visibility and readability.** Present all visual elements in more visible way.
	Clear & Consistency. Elements should be unambiguous, and create repetition to add visual interest and unify.
	Hierarchy & Dominance. Focus on having one element as the focal point and others being subordinate.
	Balance. Creates the perception that there is "equal" distribution.
	Alignment. Unify and organize elements on a page.
	Proximity. Group related items together, Separate unrelated elements.
	Familiarity and unambiguity. Use plain and familiar language to avoid confusion.
	Auditory presentation. Audio should be provided in an appropriate and adjustable way.
	Haptic presentation. Haptic feedback should be an add value, not an interference.

Table 3.11 Design Guidelines of Surface Plane

Visibility and readability. Present all visual elements in more visible way (Table 3.12).

Attention	Simple displays and short, discrete signals
	Avoid visual clutter or background noise
	Information should be concentrated mainly in the center
	Clear and detectable changes
	Make the tappable elements obvious
Leverage visual communication	Add Images, graphics, or colors to aid comprehension
	Icon should be simple and meaningful
Lighting	Raise illumination on reading surfaces to 100 Cd/M2 reflected light
	Use several small, low-intensity light sources instead of a single large one, diffuse light
	avoid rapid changes in brightness
Glare	Use matte surfaces
Composition	Stimuli needing inspection should be large, simple, uncrowded, and centered
	Make things conspicuous through size, color, and/or contrast
Text	Font type: Sans Serif, stick to moderate stroke with wide letterforms, avoid script and decorative fonts
	Font size: Minimum 12 pt font
	Font case: Uppercase draws attention but should not be used for long blocks of text
Contrast	Provide adequate contrast between UI elements and the background. (try to achieve 50:1 contrast)
	making items stand out by emphasizing differences in size, color, direction, and other characteristics.
Color	Use warm color, avoid signaling information with Violet-Blue-Green.
	Avoid using similar color such as blues and purples and greens and yellows
	maintain a relatively wide coloring gap between the shades we use.
	Highly saturated colors and bright hues are considered best,
Motion / 3D	Avoid rapidly changing, flickering or moving stimuli, cautious of virtual reality

Table 3.12 Tips to Enhance Visibility and readability

Clarity & Consistency. Elements should be unambiguous and create repetition to add visual interest and unify. Designer should ensure icons are distinguishable and consistent across screens. They should also keep consistency by repeating font style elements or shape and spatial relationships.

Hierarchy & Dominance. Designer should focus on having one element as the focal point and others being subordinate, creating hierarchies through different font sizes, colors, and placement on the page. Dominance is often done through scaling and contrasting based on size, color, position, shape, etc. For example, designer should present UI elements in a more visible color and noticeable size.

Balance. This creates the perception that there is “equal” distribution. Visual design must strike a balance between unity and variety to avoid a dull or overwhelming design. This can also be achieved by using symmetry flexibly.

Alignment. Designer should unify and organize elements on a page. Every element should have some visual connection with another element, but do not always stick with centering headings. To create a better aligned interface, designer can draw invisible lines one the document.

Proximity. Designer should group related items together, and separate unrelated elements. Squint and count the number of visual elements on a page, which should be three to five.

Familiarity and unambiguity. Designer should use plain and familiar language to avoid confusion. They should apply designs that take advantage of previous user’s experience in daily life, specifically, in using tech-products, and avoid using uncommon and drastically new designs, rather, changing gradually. Also, avoiding jargon technical terms such as “PIN” and ambiguous terms helps users clarify the UI element’s function.

Auditory presentation. Audio should be provided in an appropriate and adjustable way (Table 3.13).

Sound intensity	Sound signals should be at least 60 dB at the ear of the listener, conversational speech is 50 dB
	Allow for volume adjustment, use simple instructions and controls with simple movement
Sound frequency	Lowering frequency sounds for older users within frequency range of 500 to 2000 Hz
	If must signal sound at high frequency, use longer duration (>0.5s)
	Male voices are better than female for announcements, and avoid artificial (synthesized) speech
Audio attention	Provide redundant cueing through cross-sensory channels (e.g. sound signal with vibration or with light)
	Provide headphone sets for focused work or other specific environment
Speech recognition	Reasonable pace, predictable linguistic structure, pauses at grammatical boundaries
	Recorded voice should make use of speakers with low pitched voices
	Computer generated speech as output for older people may be a problem

Table 3.13 Tips to Enhance Auditory Presentation

Haptic presentation. Haptic feedback should be an added value, not an interference. It could be applied for a diminished touch sensation with other supplemental sensory cues. If needed, it can consist of three-dimensional appearance button for touch-screen with good spacing between buttons. Also, vibration should be mild but obvious for elderly users.

3.7 Evaluation Plane

To evaluate the visual mockups, designer should perform usability testing, creating audit reports, and identify improvements before the final delivery set. Generally, usability testing can be classified into two categories: user-based and expert-based. (Salman, 2018)

User-based methods, also known as testing methods, is to find and identify usability problems through observing people who are representing users while using the product or service. The goal of such tests is to assess the degree to which the product or system supports the intended users in their workflow.

Expert-based methods, on the other hand, are referred as the inspection process, in which experts inspect the product or service and predict problems users would have while interacting with the interface. (Majumder, 2017) The outcome of such studies can be a formal report that highlights problems identified or recommendations for changes. Among the various expert-based usability methods, heuristic evaluation and cognitive walkthrough are the two most widely used in the field of human-computer interaction.

3.8 Conclusion

To summarize how these planes work together, we start by strategy, which is the foundation of any product design. Strategy becomes scope when user and business needs are translated to requirements for content and functionality. Scope is given structure when we define the ways of interaction with the physical product, system functionality, the system response, and how information is organized. Sketching each screen of the system to present the areas of interactions and structure defined in the structure plane, and how information will be presented clearly, is what we do in the skeleton. Coming to the surface, we take all work and decisions we have made into the final visual presentation. Eventually, the final delivery is proposed after conducting user testing and usability evaluation.

Chapter 4 Design Application

In this chapter, the design flow with guidelines described in the last chapter will be demonstrated with a design application. This design application will cover a completed design flow except for the evaluation process.

4.1 Introduction

The selected brand of my design application is Amazon, which is a multinational technology company which focuses on e-commerce, cloud computing and artificial intelligence. The main reason I choose Amazon is because it already has an integrated product line of smart home (Figure 4.1), for which wearable technology will be a promising direction to extend their existing market. According to research in Chapter 2, physical inactivity is one of the leading causes of mortality and sedentary behavior is prevalent among all age groups. Therefore, a wearable device can be a great intervention to help people increase exercise and develop healthier behavior.

Figure 4.1 Amazon Alexa Smart Home Group

4.2 Strategy Plane

4.2.1 User Segmentation

The first step in the strategy plane is to define the target users. As an inclusive technology device, the user groups are divided by age and ability. There are generally three user groups (Figure 4.2), which are younger adults with higher ability, middle-aged adults with medium to high ability, and older adults prone that have lower ability toward technology. To achieve the inclusive goal, the wearable device should fulfill different needs of such a wide age range of people.

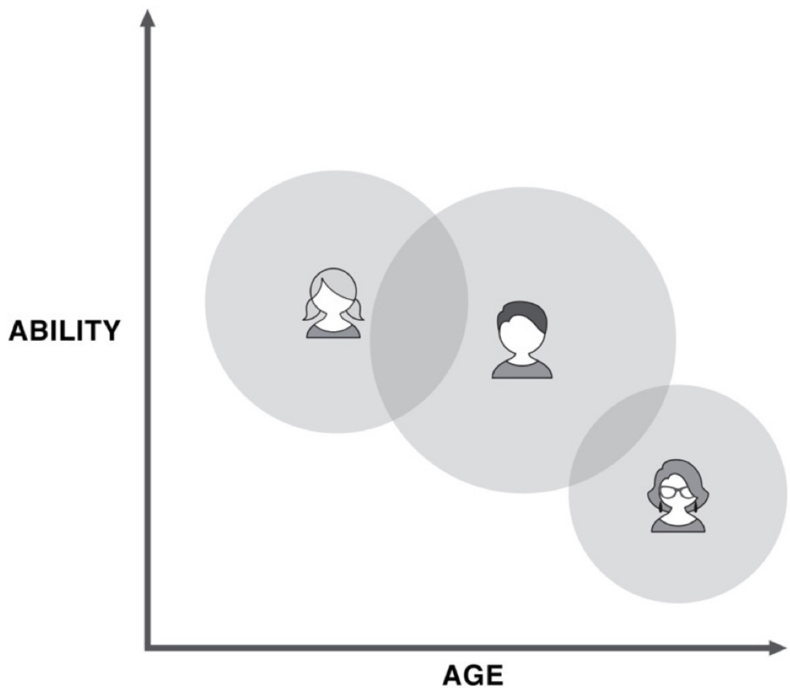


Figure 4.2 User Segmentation

4.4.11 Personas

Three personas (Figure 4.3) are created to represent the needs of the user groups defined in the user segmentation. They have many prospections in common; for example, they all want to know more about their body and form an active and healthier behavior, and they also desire a proper guidance to perform exercise. However, they do have different frustrations and reasons due to age difference and skill discrepancy.

BACKGROUND

Jane is a college student who just decided to loose weight through exercise. She wants to change the habit of staying at home for long.

FRUSTRATIONS

· Don't know how much exerice is needed to achieve goal
· Always give up half way for exercising
· Be dazzled by too many exercise advices shared online

GOALS

· To track and know her body better like energy expendiditure
· Adapt to a new healthy habit of exercise regularly
· To exercise in a scientific and encouraging way
· A nice-looking and functional product

Jane, 24

Student

"I want to control over my body and form a habit of exercising regularly"

BACKGROUND

David is an IT worker who usually spends more than 11 hours working at the computer everyday. He doesn't have habit of exercising.

FRUSTRATIONS

· Has to spend much time working on his job, always forget time
· Don't have the time to exercise in gym
· Has a pain in his back due to sedentary behavior

GOALS

· Remind him to rest without interfering current work
· To evaluate and show his activity and progress.
· Provide activity plan that can be done in short time interval with proper exercise intensity.

David, 40

Office Worker

"I want a product to remind me to active timely in an unobstructive manner."

BACKGROUND

Lisa is retired at home for 3 years, she has much free time to do exercise but she don't know the ability and limitation of her body and age.

FRUSTRATIONS

· Don't know what activity level is suitable as aging
· Don't have enough motivation for exerciseing
· Lacks knowledge of exercising and using technology

GOALS

· Provide clear and understandable information of her body
· Provide rich feedback of her action or progress
· Provide customized plan to do exercise
· To be connective with family members
· The system is easy to learn and intuitive to manipulate

Lisa, 63

Retiree

"I want the product easy to use and understand, also help me be active properly"

Figure 4.3 Personas

4.4.12 Vision Board

Following the guidelines, a clear and proactive vision board is generalized as the outcome of the strategy plane. The vision board is functioning as a general guide to direct the design instead of providing specific solution. For example, it states to help people know, remind and advise of their body condition, but doesn't determine how to present the data or the way to remind and guide.

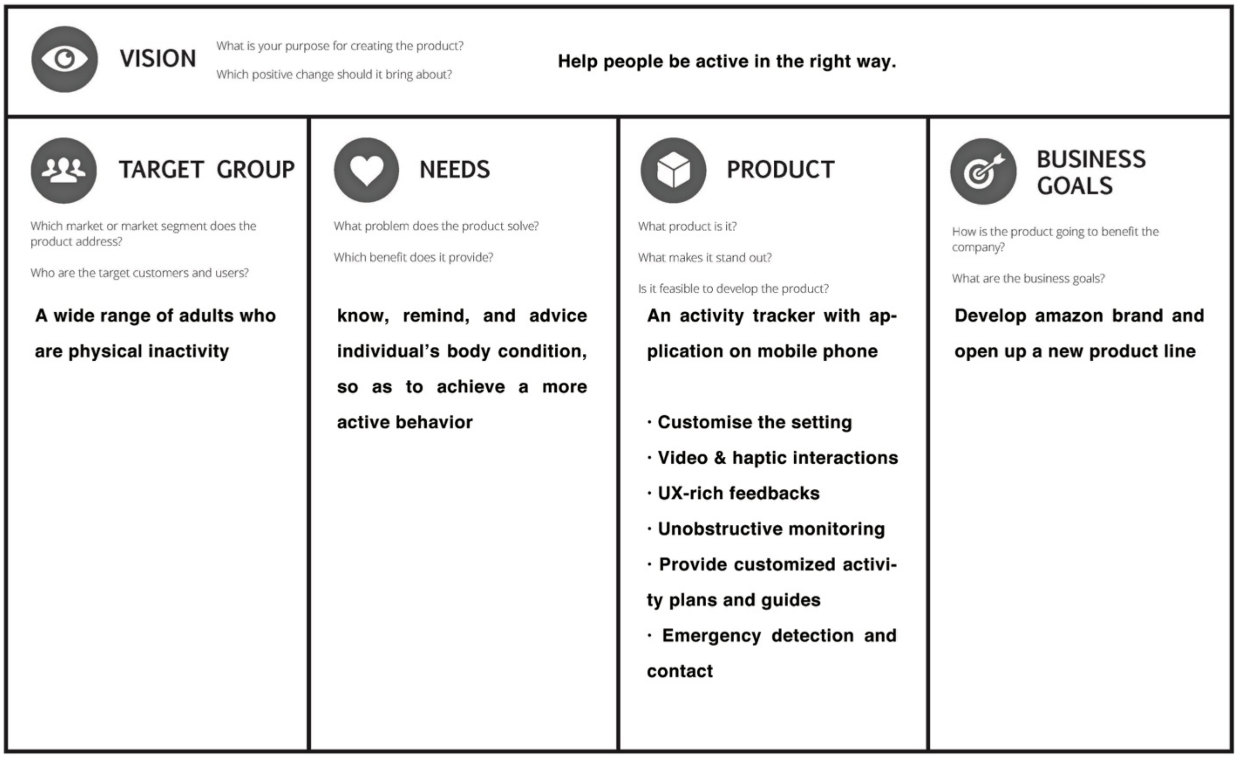


Figure 4.4 Product Vision Board

4.3 Scope Plane

4.3.1 Requirements Documentation

Directed by Product Vision Board, the work in the scope plane is to define and prioritize specific ways to fulfill users' needs. The requirements documentation (Table 4.1) with 25 categories is created and organized by priority levels. For instance, to remind people of their body condition with proper feedback, requirements of "haptic interaction" and "customization" is listed on the form. The "haptic interaction" is of the first priority because it is the necessary function to remind the user, while the "customization" which refers to adjusting the intensity or frequency of the haptic feedback is less important because it tends to be a delighter instead of a basic function. In design practice, designers should set the priority to meet the basic and essential requirements.

NO.	Name	Description	Priority
1	Material	Wristband will use soft, safe and breathable material.	🔴
2	Appearance	Have a modern and compact design following the Amazon echo series.	🔴
3	Haptic interaction	Vibration should be adjustable in intensity and frequency to remind to move.	🔴
4	Wireless synchronization	Data should be automatically synchronized and record with mobile phone.	🔴
5	All-Day Tracking	Use 24/7 heart rate to better track activity and give guidance to act on fitness goals.	🔴
6		Calculate calorie burn to manage weight and stay on track toward the goals.	
7		Recognize and track steps and various exercise modes like run, swim, bike, yoga to show how every parts impacts the daily goals.	
8	Reminder to Move	Know how long you've been active or inactive throughout the day and get personalized reminders to move if users have been sitting a bit too long.	🔴
9	Dashboard	Use the daily on-screen dashboard to check users' health and activity status and get the nudge they need to reach their goals.	🔴
10	Goal Setting	Help users set daily goals and adapt to their progress to increase level automatically.	🔴
11	Feedback & Rewards	Provide feedbacks when important actions be taken or goals have been achieved.	🔴
12	Font size	Can easily adjust font size without changing the whole layout.	🔴
13	Customization	User can zooming elements on the screen in their preferred way.	🟡
14	Audio interaction	Sound volume and mode should be adjustable with visual feedback.	🟡
15	Affordability/Cost	The device should cost less than 100 dollar.	🟡
16	Smart Touchscreen	A durable touchscreen to interact and can automatically adjust to lighting conditions.	🟡
17	Waterproof	With water resistant to 50 meters which can be worn in the pool or shower.	🟡
18	Coaching	Application should provide and recommend personalized training guides.	🟡
19	Instruction	Have a clear step-to-step tutorial to show functions, with physical memory card set.	🟡
20	Customization	User can customize the functions display on the main panel.	🟢
21	GPS	Allow GPS to track and record activity data (path, distance, speed).	🟢
22	ADSL	Share location to the emergency contacts when an emergency occurs.	🟢
23	Fall detection	Device can do fall detection and enable panic button for help.	🟢
24	Battery	Up to 15 days battery life.	🟢
25	Reminder to wear	Device can remind user to put it on if it hasn't monitored for a while.	🟢

Table 4.1 Requirements Documentation

4.4 Structure Plane

4.4.1 Conceptual tool

A conceptual model (Figure 4.5) of wearable device, application, user, and cloud shows their relationships and how the overall system works.

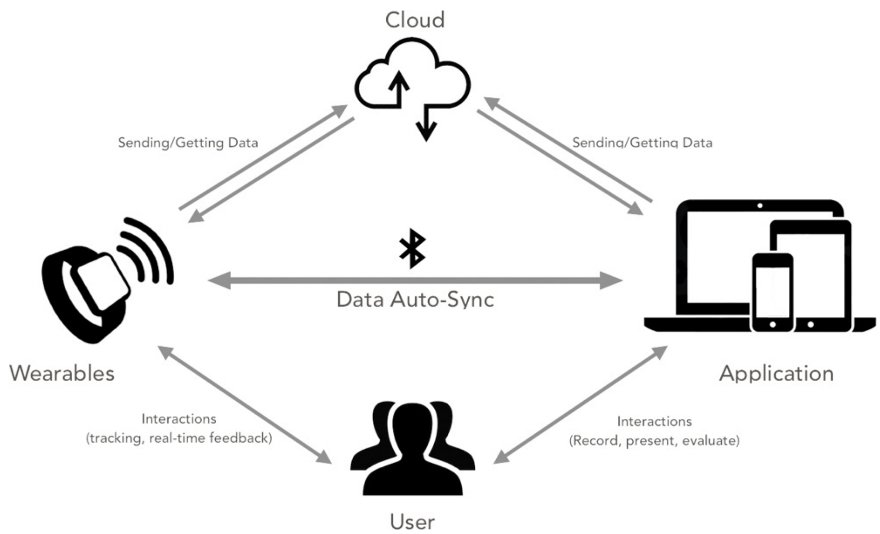


Figure 4.5 Conceptual Model

4.4.2 Architecture Diagram

A hierarchical structure is one of the most popular and coherent ways to structure contents, and it allows designers to flexibly expand or make adjustments on existing system. Using a broad structure can reduce the demands on memory, which helps the user access their needed information quickly and easily.

The goal for the structure plane is to transfer the functions determined in the scope plane to in a systematic structure. Architecture diagrams for a wearable device (Figure 4.6) and the mobile application (Figure 4.7) are created and in accord with the guidelines: Using a broad and "flat" structure (Visibility and Learnability); providing haptic interaction to remind to move (Feedback); Rewards for achieving goals and exercise plan (Motivation); Auto-setting and manual-adjusting of daily goals (Adaption and Control), etc.

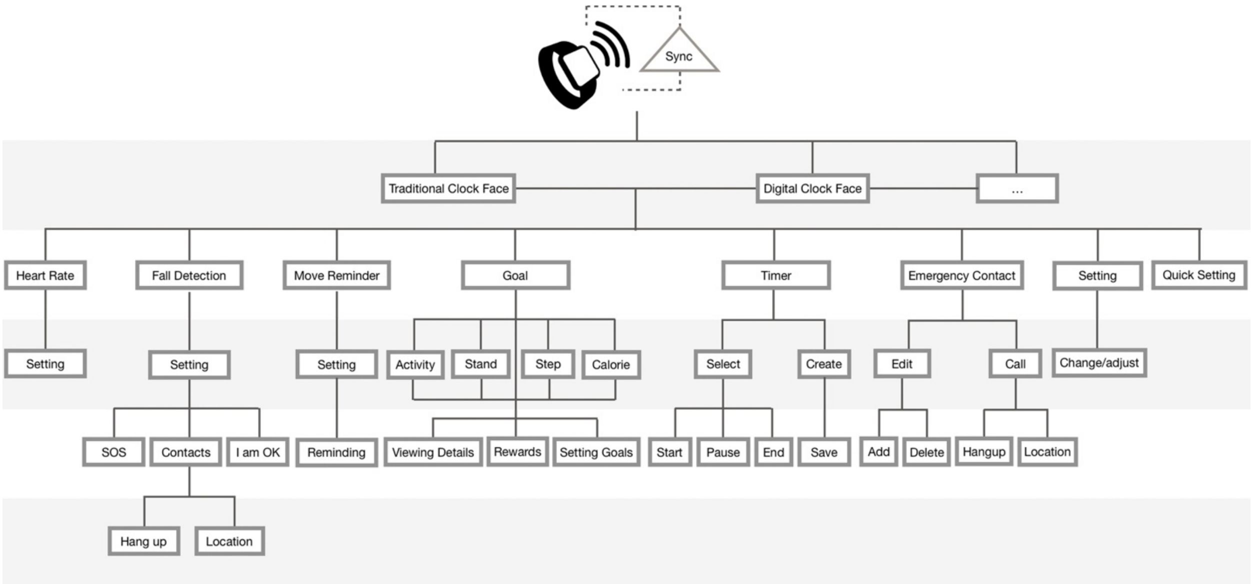


Figure 4.6 Architecture Diagram of Wearable Device

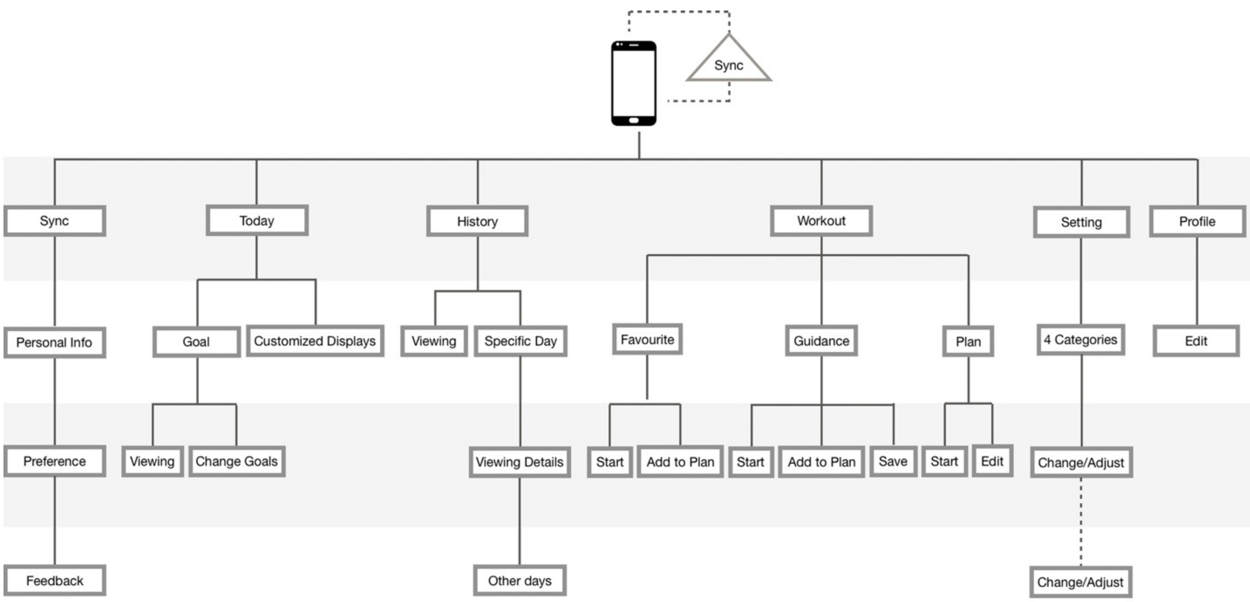


Figure 4.7 Architecture Diagram of Mobile Application

4.5 Skeleton Plane

4.5.1 CAD Model

A CAD model of hardware design (Figure 4.8) is determined with careful consideration of the design guidelines of the skeleton plane. For example, an obvious physical side button and roller with texture is a good way to indicate to the user the way to interact (Visibility).Rounded rectangle shape is the best trade-off of high-tech and friendly feelings, and rectangular is the most popular digital screen shape (Familiarity and Consistency). Appropriate button placement and size could facilitate user intuitive interaction. For this device, the digital button on the screen is of first priority because people need to focus on the current task. Then the roller beneath is the second important because a lot of scroll up/down motion will be needed during interactions. The least priority one is the side button due to the lower using frequency (Priority).

Figure 4.8 CAD Model of Wearable Device

4.4.3 Wireframes

Wireframes for a wearable device (Figure 4.9) and the mobile application (Figure 4.10) are showing the arrangement and prioritization of each interface element in a visual form. Similarly, guidelines will be applied to the interface design decisions. For example, the buttons for turning functions on/off should keep the same, while the button for adding/minus should be differentiated (Consistency and Clarity). The important information or buttons should be obvious on the screen by making them larger or place in the center (Visibility). In the workout category in mobile application, user can choose to start, add to plan, or save for later to an exercise training, which matches between system and people's behavior in the real world (Familiarity).

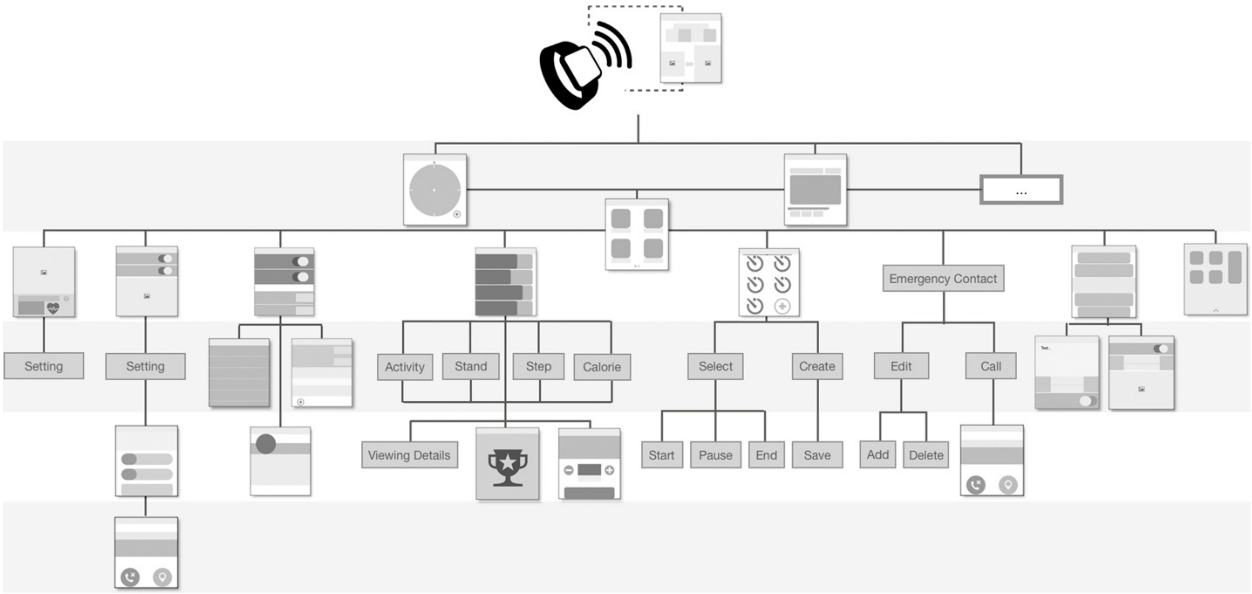


Figure 4.9 Wireframes of Wearable Device

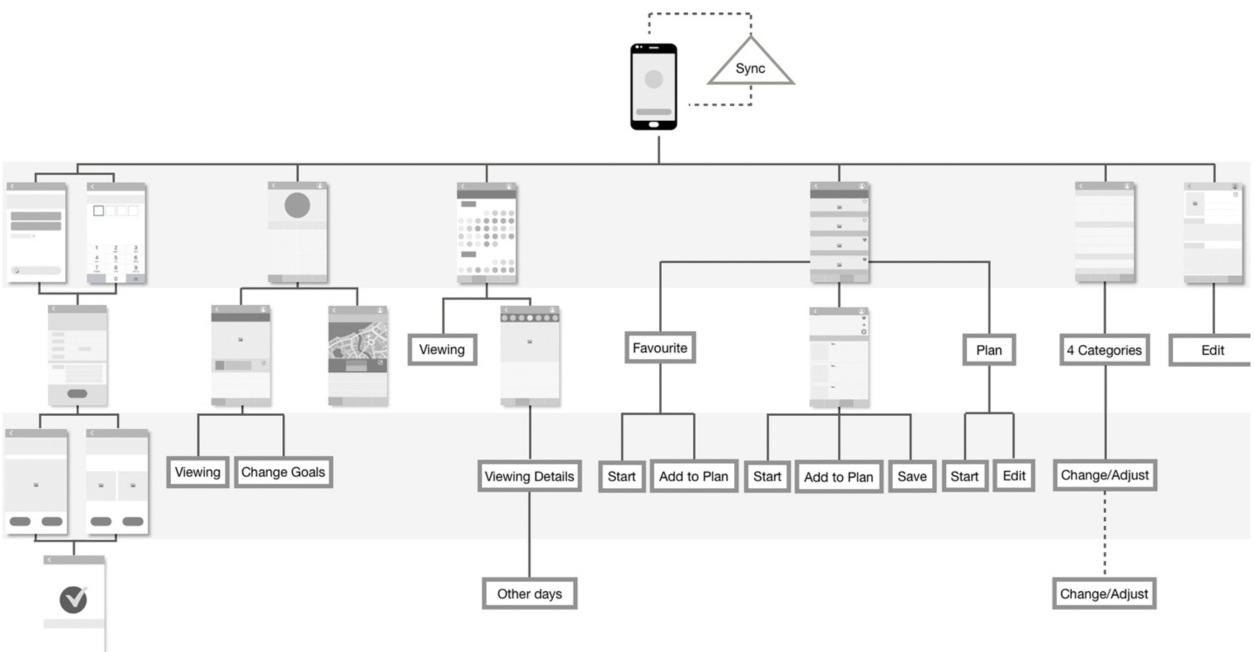


Figure 4.10 Wireframes of Mobile Application

4.6 Surface Plane

4.6.1 Visual Mock-up

A set of visual mock-ups (Figure 4.11, 4.12, and 4.13) is created to make the final design decision according to materials, color schemes, layouts, typography, iconography, the visuals of navigation, and the overall atmosphere of the product. The guidelines are followed during the design and evaluation process. For instance, using a dark background and important elements with bright color to increase visibility and readability, and avoid applying similar color to ensure the elements are unambiguous. Also, use symmetry layouts flexibly to attain balance. Proximity is also applied for grouping the related items together and separating the unrelated ones (e.g. history activity by month), etc.

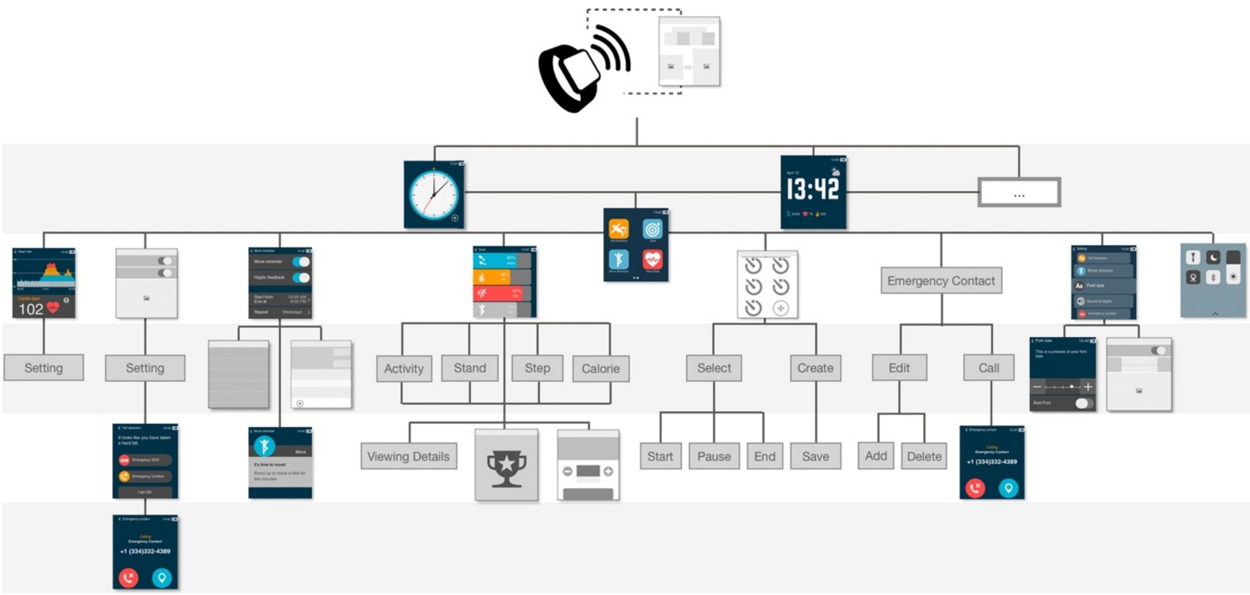


Figure 4.11 Visual Mock-up of Wearable Device

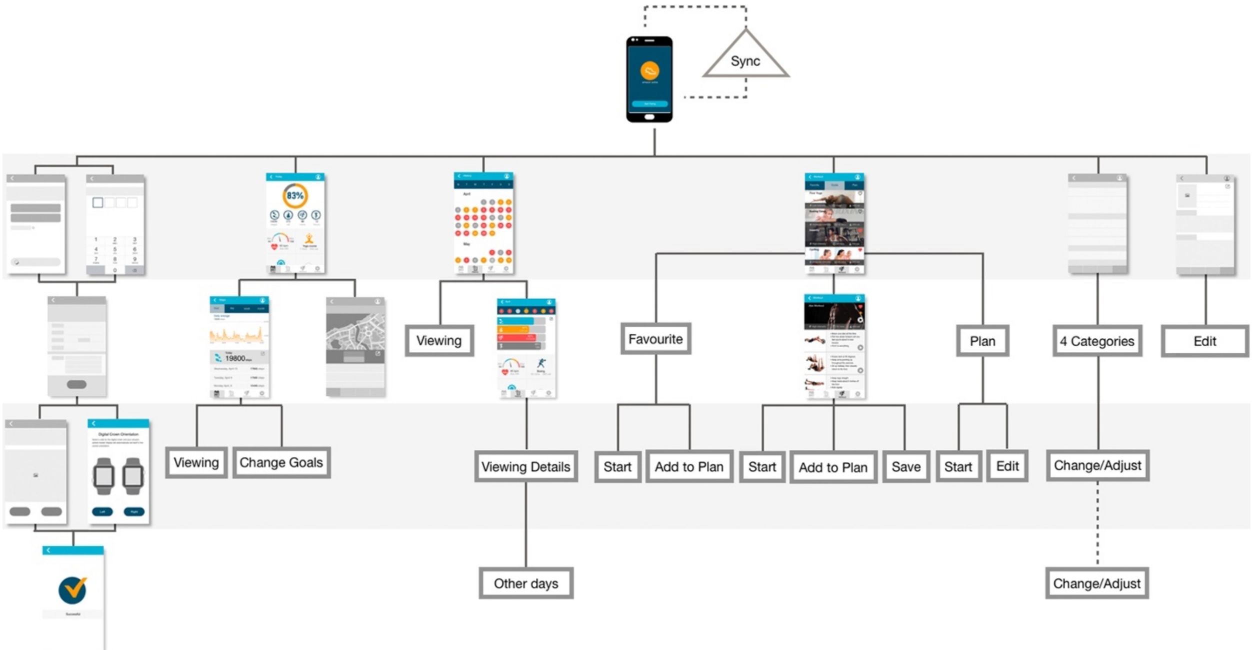


Figure 4.12 Visual Mock-up of Mobile Application

Figure 4.13 Final Delivery of Amazon Active Wearable Devices

Chapter 5 Conclusion

5.1 Conclusion

The intention of this thesis was to develop a completed design flow with guidelines to help designers design wearable devices in health and wellness application with inclusive considerations, especially for older adults. Through the study, the current development and wearable device and the older adults' attitude toward it are discovered, and the barriers and frustrations during their user experience are understood. With theories of inclusive design, user experience design, and behavior change techniques, designers can design the wearable device to accommodate a wider range of user groups from understanding user behavior, enabling user behavior and finally to influence user behavior. The design flow is a step-to-step process from abstract to concrete, which guides designers to develop their concepts in a more rational way. Design guidelines and evaluation process run through each plane can avoid irreparable design mistakes.

5.2 Further Development

Wearables technology is developing rapidly and can be applied in different fields and in various forms. This research is focused on wearable accessory in health and wellness field, while there are still more applications out of this topic. There are already many innovations in wearable technology, but currently no systematic approach to conduct designs of wearables. It will be promising to develop design approach for wearables in other fields.

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Appendix 1

Usability Problems Categories and Associated Design Solutions

Category	Sub-Category	Example	Design Solutions
Appearance	Inappropriate UI element's layout (color, size, label, etc.)	Narrow width of search bar border and pale color of placeholder are not visible in the background	- UI elements in more visible color and size - Make tappable elements obvious and supplement with a text label - Provide adequate contrast between elements and the background
	Using similar icons for labeling UI elements playing distinct roles	Message icon design is similar to the email icon design	- Keep icons distinguishable and consistent across screens
	UI element design is not familiar	Search function design as a button is not as familiar as magnifying glass icon to elderly users	- Apply designs that take advantage of previous elderly experience - Avoid using uncommon and drastically new designs
Language	Language is vague and not meaningful	The elderly is more familiar with the term “enter” or “log in” rather than OK	- Avoid ambiguous terms and employ familiar vocabulary for elderly - Supplement text with icons, when applicable
	Using jargon technical terms	E.g. “PIN”	- If mandatory, support UI with instructions to help user understand system-oriented concepts and respond appropriately
Dialogue	Functions that require user to perform unfamiliar and challenging actions	“Drag and drop” requires the elderly to keep a continuous contact with touchscreen and navigate through screens until pacing the icon on the intended location	- Adopt “tap” as the main gesture to interact - Avoid, or minimize the use of tricky gestures “drag and drop”, “tap and hold”. If used, provide an alternative way to perform the task corresponding with these gesture.
	Lack of confirmation message for some destructive actions	Tapping the cross sign “X” deletes alarm immediately	- Provide a descriptive confirmation message for each destructive action indicating the action consequence.
	No clearly observed feedback provided when the action is taken	No visual and audio feedback provided when the ringtone is changed	- Make it obvious for the elderly when an action has been taken by providing immediate feedback - Provide a mixed mode of feedback
	Automatic OS response that is uncontrolled by elderly	Auto connects to a known Wi-Fi limits the ability to manage the selection	- Allow elderly users to manage resources in use and run applications through short and simple steps
Information	The system shows a different response to the same user action	The system shows a different screen when taps on the “phone” button depending in the last accessed tab	- Provide same system response to the same user action consistently
	Overloading screen with much unwanted information	Too many options under language and input (different keyboards)	- Place most important information in front and group less one - Avoid unwanted information on the screen
	Alerts and notifications are scattered between various sections of the UI	Message notification is scattered between home screen, notification panel, and application drawer	- Provide a control widget that assembles and organized the received alerts and notification and aid user to manage them
	Absence (wholly or partially) of instructions to provide useful user guidance.	Unlock screen lock instruction has disappeared during charging process and replaced by charging percentage	- Provide noticeable instructions centered on the current task page - Supplement visual cues to help users be aware of hidden content - Supplement tooltips, e.g. when specific gesture is required