



**EFFECTIVE FRAMEWORK OF SMART TOILET IN ADDRESSING THE
EMOTIONAL NEEDS OF NEW ELDERLY**

By

LI QIUYI

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Master of Science**

July 2024

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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July 2024

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With the advent of social transformation and population ageing, a unique group known as the “new elderly” has emerged. Unlike traditional elderly people, this group is significantly influenced by contemporary social structures and technological advancements, reshaping their emotional needs and expectations from products. There is a close connection between the emotions and health of the elderly, so addressing their emotional needs is essential for their overall well-being. As one of the most common daily activities, toilet usage can significantly impact their emotional state, with difficulties in this area often leading to negative emotions. Well-designed smart toilets can greatly alleviate these negative emotions. Despite their importance, the integration of various technologies into smart toilets for the elderly is often overlooked. Currently, there is no clear product design framework specifically tailored to meet the emotional needs of the new elderly regarding smart toilets. This study aims to identify the specific emotional needs of the new elderly by combining Norman’s theory on three levels of emotional design with Maslow’s hierarchy of needs theory. We conducted a survey in China yielding 501 valid responses and performed a detailed

analysis to identify the emotional factors in designing products, especially smart toilets, for this demographic. Based on the comprehensive research findings, we have developed a product design framework that addresses the emotional needs of the new elderly and provided recommendations for designing smart toilets suitable for this group.

Keywords: design framework; emotional design; new elderly; smart product; smart toilet

SDG: GOAL 9: Industry, Innovation and Infrastructure



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**KERANGKA KERJA BERKESAN UNTUK TANDAS PINTAR DALAM
MEMENUHI KEPERLUAN EMOSI WARGA EMAS MODEN**

Oleh

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Seiring dengan perubahan sosial dan penuaan populasi, telah muncul satu kelompok baharu yang dikenali sebagai “warga emas moden”. Berbeza dengan warga emas tradisional, kumpulan ini lebih dipengaruhi oleh struktur sosial moden dan kemajuan teknologi, yang mampu mengubah keperluan dan jangkaan emosi mereka terhadap sesuatu produk. Faktor kesihatan dan emosi warga emas berkait rapat sehingga menjadikan keperluan emosi mereka amat penting untuk kesejahteraan secara keseluruhan. Antara salah satu aktiviti harian mereka adalah penggunaan tandas yang boleh mengakibatkan kesan besar terhadap keadaan emosi mereka yang mendorong kepada emosi negatif. Oleh itu, dengan wujudnya rekaan tandas pintar ini dapat membantu mengurangkan emosi negatif mereka. Walaupun penting, penggunaan teknologi dalam tandas pintar untuk warga emas sering diabaikan. Sehingga saat ini, belum ada rangka kerja reka bentuk produk yang khusus untuk memenuhi keperluan emosi warga emas moden dalam konteks tandas pintar. Tujuan kajian ini dijalankan adalah untuk mengenal pasti keperluan emosi khusus warga emas moden dengan menggabungkan teori Norman mengenai tiga tahap reka bentuk emosi dan teori hirarki

keperluan Maslow. Kami telah menjalankan penyelidikan di negara China dan berhasil mengumpulkan 501 jawapan sah dan melakukan analisis dengan lebih terperinci untuk mengenal pasti faktor emosi dalam merekabentuk sesuatu produk, khususnya tandas pintar, bagi demografi ini. Berdasarkan penemuan penyelidikan yang komprehensif, kami telah membangunkan rangka kerja reka bentuk produk yang mampu memenuhi keperluan emosi warga emas moden dan menyediakan cadangan untuk merekabentuk tandas pintar yang sesuai untuk kumpulan ini.

Kata Kunci: rangka kerja reka bentuk; reka bentuk emosi; warga emas moden; produk pintar; tandas pintar

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LIST OF ABBREVIATIONS

| | |
|-------|--|
| RQ | Research Questions |
| RO | Research Objectives |
| SDT | Self-Determination Theory |
| EEG | Electroencephalogram |
| TMN | Tuberomammillary Nucleus |
| HAR | Human Activity Recognition |
| IoT | Internet of Things |
| ICT | Information and Communication Technology |
| NTTED | Norman's Three Levels Theory of Emotional Design |
| MHNT | Maslow's Hierarchy of Needs Theory |
| EVs | Emotional Variables |
| CDHT | Chengdu High-tech Industrial Development Zone |

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter presents a succinct overview of the study, elucidating the background, problem statement, research questions, and objectives that frame the goals of this research. It also outlines the research methodology and the scope of the study. To facilitate a better understanding, the structure of this thesis is outlined, summarizing the flow of the research execution.

Specifically, this section introduces the aging population, the new elderly group in China, and the importance of considering the emotional aspects when designing products for them. Additionally, it identifies a specific research gap and formulates three research questions aimed at developing a product design framework based on the emotional needs of the new elderly in China. A detailed research framework, including preliminary research, a case study, and the development of the design framework, is outlined to address the research gap.

1.2 Background of Study

Currently, 10% of the global population is 65 years of age or older (Population Reference Bureau, 2023). Projections for 2050 indicate that the elderly will constitute less than 7 percent of the population in just 33 countries—a significant decline from 115 countries in 2015. Conversely, the elderly will represent over 21 percent of the population in 94 countries, with 39 of these countries having at least 28 percent of their population composed of older individuals (He et al., 2016). In China, the aging

trend is evident. Data from China's Seventh National Population Census show that there were approximately 264.02 million people aged 60 and above, accounting for 18.70% of the total population, with about 190.64 million people aged 65 and above, making up 13.50% of the population (National Bureau of Statistics of China, 2021). Furthermore, it is estimated that the number of people in China aged 65 and older will more than double, from 172 million in 2020 to 366 million by 2050 (Lobanov-Rostovsky et al., 2023).

As the population ages, enhancing the quality of life for the elderly becomes crucial. This improvement should begin with health considerations, encompassing both physical and mental wellbeing (Chen et al., 2020). Older adults encounter numerous challenges due to aging that affect them physically and psychologically (Moody & Sasser, 2020). The aging process can impact bodily functions from a physical perspective, while there is also a psychological need to live with dignity. These physical and psychological aspects reciprocally influence each other (Ohrnberger et al., 2017).

Products tailored for the elderly can significantly fulfill their physical and psychological requirements (Fisk et al., 2020). Products that cater to the elderly's emotional needs are particularly advantageous to their health. As the elderly population's proportion increases, so does the focus on elderly-related issues and the design of products for this demographic. A good product should meet the emotional needs of users. Under the condition of ensuring the normal use of its functions, emotional needs should also be considered (Norman, 2007). The integration of technology into products can effectively address these needs. For instance, wearable

smart health devices facilitate sustained health behavior support, enhancing self-awareness, health comprehension, and health literacy (Meyer et al., 2016).

Despite being one of the most common yet least researched activities of daily living disabilities, toileting is a significant issue among the elderly population (Fong & Feng, 2021). Since using the toilet is an important process for detoxification, they spend a lot of time on it. Consequently, a poor experience can significantly affect their physical and mental health, and the difficulty of going to the toilet can result in their negative emotions (Fong & Feng, 2021; Brim et al., 2021; Liu et al., 2020a). Well-designed sanitary products, particularly smart toilets, can greatly alleviate these negative emotions (Han et al., 2020).

Moreover, smart products incorporate various technologies (Raff et al., 2020), and technology is seen as effective tools to help older adults maintain their health (Lee & Coughlin, 2015). Therefore, sanitary products, particularly smart toilets, can be specially designed to meet the specific needs of the elderly. Given the expansive market for smart toilets in China (Gong et al., 2020), it is imperative that these designs prioritize the elderly's requirements.

With societal and scientific advancements, a distinct group known as the “new elderly” is emerging. Unlike the traditional elderly of the past, the new elderly, shaped by influences of contemporary society and technological progress, exhibit unique characteristics. Emotionally, their product demands differ from those of the previous generation of elderly (Teng & Shen, 2018). It is anticipated that an increasing number of elderly individuals will be exposed to new technologies, leading to a rise in the

proportion of the new elderly within the elderly demographic. Consequently, product designs for this group particularly the smart toilets should be thoughtfully developed, with particular attention to their emotional needs.

1.3 Problem Statement

A review of the existing literature reveals a gap in design criteria for smart toilets that consider the emotional needs of the new elderly in China. This deficiency is attributed to the lack of a product design framework that caters to the emotional requirements of this demographic. To address this, there is a need for a product design framework that encapsulates the emotional needs of the new elderly, which would inform the development of a smart toilet design tailored to these needs.

Researchers have emphasized the significance of the elderly's emotional needs and the profound impact of the toileting experience on their physical and mental health. To establish design principles for smart toilets that meet the emotional needs of the new elderly in China, a thorough literature review was conducted.

Problem Statement 1: Currently, there is no well-defined product design framework that addresses the emotional needs of the new elderly, which is essential for guiding the design of relevant products.

In China, research on design for older adults, especially regarding smart products, exhibits a variety of approaches but often lacks depth in emotional considerations. Huang (2019) introduced design methods for smart household appliances using the Product Design-Senior Technology Acceptance Model, focusing on user-centered

design without a comprehensive analysis of emotional factors. Zhang et al. (2023) reviewed literature on intelligent product usability for the elderly, highlighting factors like ease of use and policy impact, yet they did not delve extensively into emotional aspects. Liu et al. (2021) proposed an Emotional Design Process framework for intelligent sleep products, centering on emotion-oriented design but not providing wide-ranging product design frameworks. Zhou et al. (2022a) offered interface design principles for senior care products, emphasizing simplicity and reduced cognitive load, but they also neglected the broader emotional factors. Finally, Li et al. (2020) investigated wearable products, identifying design factors that influence stigma perception among older adults, such as aesthetics and privacy; however, their focus was mainly on the emotional aspect of stigma, not on a thorough emotional analysis. Collectively, these studies contribute to our understanding of design needs for older adults in China but reveal a gap in addressing the emotional needs in product design comprehensively.

Furthermore, research on designing for the new elderly in China stresses psychological needs like aesthetic preferences and independence but lacks all-encompassing guidelines. Teng and Shen (2018), as well as Wang and Liu (2020), underscored the significance of innovative smart product design. (Mao et al., 2022) recommended a balance between functionality and emotional appeal, but their findings are not supported by robust data. Specific studies, such as Wang's (2021) on entertainment products and Jiang's (2021) on empathic design for smart wearables, provide focused insights but are confined to certain product categories and do not thoroughly explore medical context research methods. While Liu et al. (2020b) developed principles for smart homes for the future elderly, they did not elaborate on

the specific emotional factors pertinent to the new elderly. Although these studies recognize the distinctive characteristics of the new elderly, they fall short of offering comprehensive and applicable design strategies.

Therefore, there is a notable gap in product design principles that specifically address the emotional needs of the elderly population. Existing frameworks often concentrate on practical aspects, such as usability and functionality, yet may overlook the significance of creating products that cater to the emotional well-being and satisfaction of older adults.

Problem Statement 2: Currently, there is a lack of design frameworks specifically for smart toilets that address the emotional needs of the new elderly in China, which are essential to inform the design process for this demographic.

The elderly may encounter numerous challenges when using the toilet. As they age, their physical functions decline, particularly in the mobility of muscles and joints, which can make using the toilet challenging. Many elderly individuals may have difficulties standing or sitting, such as discomfort or lack of balance when squatting and rising. Additionally, they may experience issues like frequent urination, incontinence, or difficulty in bowel movements, contributing to the inconvenience and challenge of toilet use (Yang & Sanford, 2012; Liu et al., 2020a). Given these factors, using the toilet can become a complex or even hazardous task for the elderly, necessitating additional support and equipment to perform these fundamental activities of daily living. The challenges that the elderly encounter when using the toilet not only affect their daily life convenience but also significantly impact their

physical and mental health (Han et al., 2020). It has been suggested that alleviating these difficulties can reduce the psychological stress associated with worry or fear in the elderly, aiding in the maintenance of a positive mindset and emotional health.

Therefore, smart toilets are crucial in addressing the challenges faced by the elderly when using the toilet. Moreover, smart toilets provide enhanced convenience and safety features, such as adjustable height for easy sitting and standing, handrails for stability, and intelligent functions like automatic flushing and heated seats, which make the toilet experience more comfortable, convenient, and secure for the elderly. These advanced devices not only offer a better toilet experience for the elderly but also significantly reduce their inconvenience and potential safety hazards, contributing to an improved quality of life and independence.

The new elderly may have higher emotional expectations and needs towards smart toilets. With technological advancements, the new elderly have become more familiar with interacting with smart devices and may have greater expectations for smart toilets, desiring that these devices better fulfill their personalized needs. They might anticipate smart toilets to feature more intelligent functionalities, such as automated adjustments to individual habits and requirements; moreover, the design of smart toilets should be more human-centric, taking into account the emotional needs of the elderly. For the new elderly, smart toilets are not merely tools to alleviate toileting difficulties but also symbols of convenience and attention to care. Intelligent design and emotional consideration in smart toilets can more effectively meet the emotional needs of the new elderly, allowing them to feel more valued and cared for in their daily lives, thereby enhancing their quality of life and sense of well-being. However, in China,

research on smart toilet design that incorporates the emotional needs of the new elderly is lacking; therefore, this study aims to investigate smart toilet designs that cater to their requirements.

1.4 Research Questions

In any research endeavor, it is crucial to identify and refine research questions (Alvesson & Sandberg, 2013). Three research questions (RQs) are constructed in relation to the research gap identified in this study.

RQ1: What are the key principles of product design that are relevant to the emotional needs of the new elderly?

RQ2: How to be integrate the principles of emotional design to identify the emotional factors in product design for the new elderly in China, particularly in the design of smart toilets?

RQ3: How to develop a product design framework based on the emotional needs of the new elderly in China to provide suggestions for designing smart toilets tailored for them?

1.5 Research Objectives

This study aims to identify the design criteria required to design products for the new elderly. To address the research questions, three research objectives have been developed, each corresponding to one of the research questions (ROs):

RO1: To identify the key principles of product design relevant to the emotional needs of the new elderly.

RO2: To integrate the principles of emotional design to identify the emotional factors in product design for the new elderly in China, especially in the design of smart toilets.

RO3: To develop a product design framework based on the emotional needs of the new elderly in China and provide suggestions for designing smart toilets tailored for them.

1.6 Research Scope

This study aims to develop a product design framework and propose design suggestions for smart toilets for the new elderly in China by examining the characteristics of this group, including their physiological and psychological attributes, as well as their emotional experiences with smart products, particularly smart toilets. The research concentrates on understanding how the unique characteristics of the new elderly population influence their emotional needs and preferences regarding smart products. Especially, this study specifically investigates the emotional factors that affect the design and usability of smart products for this demographic. Besides, the research was conducted in Chengdu, Sichuan Province, China, as it provides a representative context for exploring the emotional needs of the new elderly population in a specific region of the country.

The survey for this research involves a cluster sample of elderly individuals aged 60 and above living in Chengdu, Sichuan Province. Importantly, the study does not impose any gender restrictions, ensuring a diverse representation of the new elderly population. The selection of this particular group of elderly individuals is motivated by their designation as the “new elderly”, which refers to the aging population in China that has gone through significant social, economic, and technological transformations. Hence, this study aims to garner insights into their emotional needs and experiences

related to smart products, particularly smart toilets, recognizing that the characteristics and preferences of this group may differ from those of previous generations.

To ensure the study's focus on the new elderly group in China, specific methods are employed to screen and identify participants who meet the criteria. As a result, the findings of this research focus exclusively on the emotional needs of the new elderly in China. The study aims to develop a product design framework based on these emotional needs and provide design suggestions for smart toilets tailored for them. Additionally, the research emphasizes that the topics discussed are centered on designing products, especially smart toilets, and examines how to apply the product design framework to smart toilets. Therefore, the results may not be generalizable or applicable to other fields of study or to other countries and regions.

1.7 Research Framework

As depicted in Figure 1.1, the research process of this study primarily consists of three stages: preliminary research, case study, and developing framework.

STAGE 1: Preliminary research. This stage begins by discussing the research background, summarizing the problem statement, and presenting the research questions and objectives. Researchers cover issues such as population aging, toileting difficulties for the new elderly, the emotional needs of the new elderly, the importance of emotional design in products used by the elderly, and the current state of related design research. They identify a research gap and summarize it as a lack of smart toilet design principles based on the emotional needs of the new elderly due to an absence of a relevant product design guide, thereby defining the research question of this study.

Next, the study examines the characteristics of the new elderly, including psychological and physiological aspects, and their use of smart products, particularly smart toilets. This includes a detailed discussion on the functionalities and emotional impact of smart toilets, followed by a discussion on related design principles and theoretical correlations, ultimately leading to the theoretical framework of this study. This stage aims to answer the first research question.

STAGE 2: Case study. From the theoretical framework, researchers identify the emotional variables of the new elderly and apply them to the design of a questionnaire. Based on the research questions, the questionnaire primarily includes questions about the new elderly's experience with smart products and smart toilets and surveys the characteristics of the new elderly group to corroborate previous literature reviews and summaries. Researchers then collect data and conduct data analysis to identify the emotional need factors for the design guide, thereby answering the second research question.

STAGE 3: Framework development. Researchers perform text analysis on the identified emotional need factors, and in combination with the stylistic and functional features of product design, researchers develop a product design framework based on the emotional needs of China's new elderly. Furthermore, they combine the experiences of the new elderly with smart toilets to provide design recommendations for smart toilets based on their emotional needs.

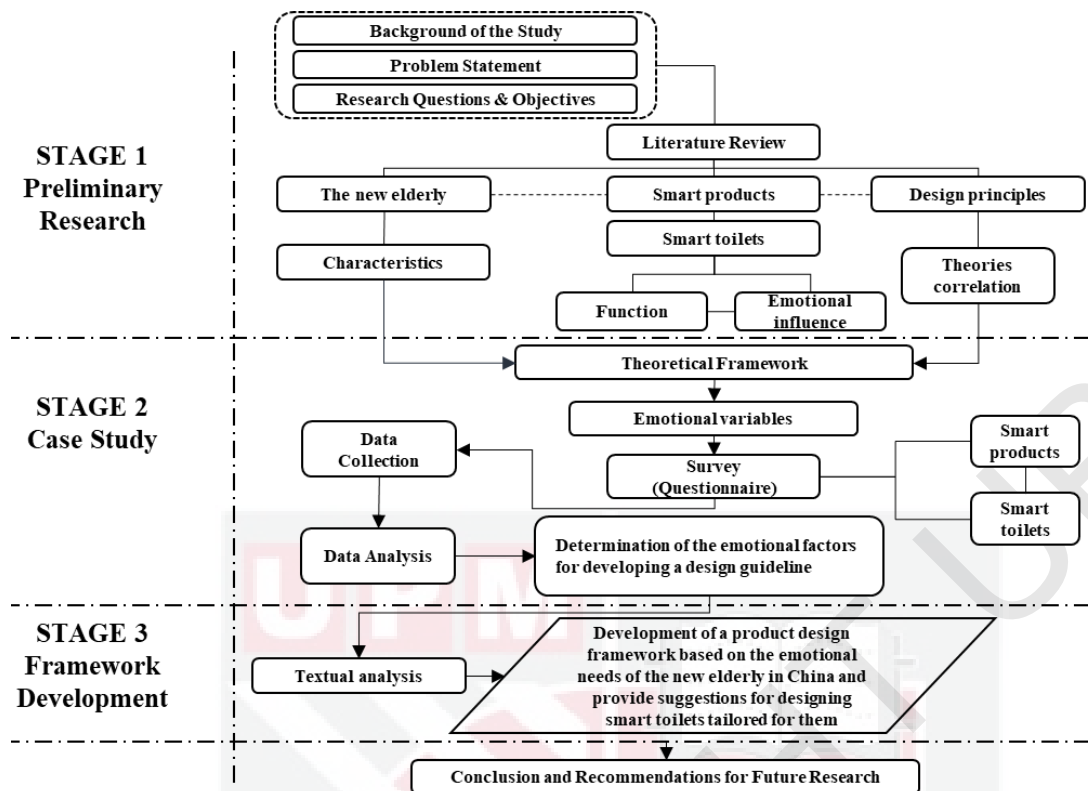


Figure 1.1 : Research Framework

1.8 Thesis Structure

This thesis is organized into five chapters, which systematically present the research flow and findings. The content of each chapter is summarized as follows:

Chapter 1 serves as the introduction, providing the research background and identifying the research gap. It includes a concise explanation of the research questions and objectives, outlines the research flow, and describes the thesis structure.

Chapter 2, through a literature review, examines the definition and characteristics of the new elderly, their emotional needs, smart products (with a focus on smart toilets for the new elderly), related theories, and the establishment of a theoretical framework to identify emotional variables in designing for the new elderly.

Chapter 3 introduces the research design by delineating the research methods utilized in this study. It then elaborates on the Research Methodology Framework by conducting a detailed assessment of the methods applied in preliminary research, case study and framework development. As outlined by the framework, the case study section specifically details the questionnaire design and data analysis techniques.

Chapter 4 begins with an overview of the analysis and discussion process employed in this study followed by separate examinations. It features a comprehensive analysis of the case study data, including the extraction and summarization of emotional factors, as well as the development of a product design framework and its application to smart toilets designed for the new elderly in China.

Chapter 5 discusses the findings of this study, addressing the research questions posed earlier. It also examines the knowledge contributions and limitations of the study in relevant fields and offers recommendations for future research.

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