A Comprehensive Review of Color-Emotion Design Models in Enhancing Usability for the Elderly of Mobile Healthcare Applications

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Abstract. This literature review explores the integration of color psychology and emotional design principles in mobile healthcare applications (MHAs) tailored for elderly users. As global populations age and digital health solutions become increasingly vital, optimizing these applications for older adults is crucial. The review synthesizes recent research on the psychological impacts of color and the role of emotional design in enhancing usability. However, it identifies significant gaps in current design frameworks, particularly in effectively addressing how color and emotional design specifically influence the usability of MHAs for elderly users. The review underscores the need for future research to better integrate these elements, ensuring that MHAs are both accessible and engaging for this demographic.

Keywords: Color Psychology, Emotional Design, Mobile Healthcare Applications, Elderly Users, Usability, Interface Design.

1 Introduction

1.1 Background and Rationale

The global aging population presents unique challenges for the design of mobile healthcare applications (MHAs). These applications are becoming increasingly vital in delivering healthcare services to older adults who may have limited mobility or access to in-person healthcare. However, despite their potential, many MHAs fail to consider the specific cognitive and emotional needs of elderly users, leading to low adoption rates and re uced effectiveness [1].

On the other hand, according to Article 2 of China's Law on the Protection of the Rights and Interests of the Elderly, the official age threshold for being considered

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elderly is 60 years. By the end of 2022, China's elderly population (aged 60 and above) reached 280 million, indicating a significant degree of population aging [2,39]. Driven by the Healthy China strategy, the public, particularly the elderly, has shown increased interest in integrating into the digital society, utilizing online platforms for health knowledge and communication[3]. However, the design of many MHAs does not sufficiently address the emotional needs of elderly users, leading to dissatisfaction with current interfaces [4].

This review aims to synthesize current research on the role of color psychology and emotional design in enhancing the usability of MHAs for elderly users, addressing key gaps, and proposing future research directions.

1.2 Scope of the Review

Color psychology is a well-established field that explores how different colors can evoke specific emotional responses and influence behavior. Studies have shown that colors such as blue and green are associated with calmness and trust, making them ideal for healthcare applications [5–7]. Conversely, colors like red and yellow can evoke urgency and excitement, which might be suitable for alerting users but could also increase anxiety if overused [5]. For elderly users, color selection becomes even more critical due to age-related changes in color perception, such as reduced sensitivity to contrast and brightness [8]. Therefore, using high-contrast color schemes and careful consideration of color combinations is essential to ensure that interfaces remain accessible and engaging for older adults.

1.3 Structure of the Paper

The paper is organized as follows, section 2 discusses the challenges faced by elderly users in adopting technology, focusing on cognitive and sensory declines and psychological barriers. Section 3 examines the role of color psychology in interface design, particularly in MHAs. Section 4 explores emotional design principles and their impact on user engagement. Section 5 identifies gaps in existing frameworks and suggests potential strategies for integrating these elements into MHAs. Section 6 outlines current gaps in the literature and proposes future research directions. Finally, Section 7 concludes with a summary of key findings.

2 The Elderly Population and Technology Adoption

2.1 Cognitive and Sensory Declines in Aging

As an individual age, they experience various cognitive and sensory declines that can significantly impact their ability to interact with technology. Research indicates that working memory, processing speed, and visual acuity decline with age, making it difficult for older adults to navigate complex digital interfaces [9]. For instance, it found that older adults had lower success rates in completing tasks on digital interfaces compared to younger users, largely due to difficulties in processing information quickly and accurately [10–12].

Table 1 presents a summary of studies examining the cognitive and sensory changes associated with aging and their impact on technology use.

Table 1. Cognitive and Sensory Declines and Their Impact on Technology Use

study	Cognitive/Sensory Decline	Impact on Technology Use
Smith & Baltes (2019)	Reduced working memory, slower processing speed	Difficulty navigating complex interfaces
Fisk et al. (2009)	Declining visual acuity, reduced contrast sensitivity	Challenges in reading small text, low-contrast elements
Czaja et al. (2006)	General cognitive decline	Lower task success rates, slower completion times
Witzel & Gegenfurtner (2013)	Reduced color discrimination	Difficulty distinguishing between similar colors
Gatto & De Rosa (2008)	Technophobia, low self-efficacy	Anxiety, reduced willingness to engage with new technologies

These declines necessitate the design of MHAs that accommodate these limitations. Key design considerations include simplifying navigation, increasing text size, and ensuring high contrast between text and background[13, 14]. Recent studies investigate how humans categorize and discriminate between color differences, with a focus on the enhanced sensitivity near category boundaries[15].

2.2 Psychological Barriers to Technology Adoption

In addition to cognitive and sensory declines, psychological factors such as technophobia and low self-efficacy can also hinder the adoption of technology among older adults. It found that many elderly users experience anxiety when using new technologies, which can deter them from engaging with MHAs[16]. Moreover, low self-efficacy—belief in one's ability to use technology effectively—has been identified as a significant barrier to technology adoption among the elderly[17].

To address these barriers, MHAs should incorporate user-friendly interfaces that build confidence and reduce anxiety. Simplified interfaces, combined with clear instructions and supportive features, can enhance self-efficacy and reduce technophobia[18]. Research on elderly users are more likely to adopt MHAs that feature intuitive designs and positive reinforcement [19].

3 The Role of Color Psychology in Interface Design

3.1 Psychological Impacts of Color

Color psychology is a crucial factor in interface design, influencing both user behavior and emotional response. Research has shown that different colors can evoke specific emotions and affect decision-making processes [20]. For instance, blue is commonly associated with calmness and trust, making it a preferred color in healthcare settings, while red can evoke urgency or alertness, suitable for alerts or emergency notifications [21].

Table 2 summarizes the emotional responses associated with various colors and their potential applications in MHA design.

Table 2. Emotional Responses to Colors and Their Applications in MHAs

Color	Associated Emotions	Potential Application in MHAs
Blue	Calm, Trust	Backgrounds, information sections
Red	Urgency, Alertness	Warnings, critical notifications
Green	Relaxation, Safety	Confirmation messages, health indicators
Yellow	Attention, Optimism	Highlights, important reminders
Orange	Warmth, Encouragement	Calls to action, motivational prompts

This table illustrates how color can be strategically used in MHAs to influence user behavior and improve the overall user experience.

3.2 Age-Related Changes in Color Perception

As people age, their perception of color can change, with reduced sensitivity to brightness and contrast being common. This change necessitates careful considera-tion in the selection of color schemes, particularly for elements requiring high visi-bility, such as text and buttons [8, 22, 23]. This research is significant in areas such as environmental psychology and the design of lighting in workspaces and healthcare settings. High-contrast combinations, such as black text on a white background, are often recommended to enhance readability for elderly users [24, 25].

It was found that older adults have a significantly reduced ability to distinguish between similar colors, such as shades of blue and green, compared to younger adults [26]. This finding suggests that using high-contrast color schemes is essential for improving the usability of MHAs for elderly users.

The application of color in MHAs should align with both the functional and emotional needs of the user. For instance, the use of green in health indicators can reinforce the perception of safety and well-being, while red can be reserved for alerts to draw immediate attention [5]. It was demonstrated that interface using color schemes tailored to the emotional needs of elderly users had higher user satisfaction and engagement levels compared to those that did not [27].

4 Emotional Design Principles in MHAs

4.1 Theoretical Foundations of Emotional Design

Emotional design is rooted in the understanding that users form emotional connections with the products they use. This connection is particularly important in the context of MHAs, where user engagement and satisfaction are critical to the success of the application. Norman (2004) identifies three levels of emotional design: visceral, behavioral, and reflective[1]. Each level contributes to how users perceive and interact with a product, making it essential for MHA design, particularly for elderly users who may have heightened emotional responses to technology [28].

4.2 Impact of Emotional Design on User Engagement

Research has shown that emotional design can significantly enhance user engagement, particularly among elderly users who may be hesitant to adopt new technologies. By designing interfaces that evoke positive emotions, such as trust, comfort, and reassurance, developers can increase the likelihood that these applications will be used consistently[29]. For instance, it was found that elderly users were more likely to engage with MHAs that incorporated warm, welcoming colors and user-friendly language[19].

Incorporating emotional design into MHAs involves understanding the user's psychological state and how the interface can support positive emotional experiences. This may include the use of friendly, approachable language, intuitive navigation, and visuals that resonate with the user's cultural and personal background [29–31].

5 Gaps in Existing Frameworks and Proposed Strategies

In the modern healthcare environment, mobile healthcare applications (MHAs) play an increasingly important role in managing health conditions. However, the adoption rate of these applications among elderly users in China remains significantly low[32]. This issue primarily stems from the fact that existing MHAs are designed with younger users in mind, failing to address the unique physical and cognitive needs of the elderly[33].

Firstly, In the process of interaction with application products, users obtain more than 70% of the interaction symbol information through visual color channels, and visual symbols are the main source of information, and have the qualities of fast, fierce, and accurate information transmission, which occupies an important position in the applications interaction interface[34, 35]. But many existing MHAs do not consider the cognitive decline that often accompanies aging. Elderly users may struggle with complex interfaces and small fonts, leading to frustration and a sense of helplessness during use [22]. Additionally, elderly adults may have diminished vision and hearing, which current applications often fail to accommodate, resulting in poor user experiences[6, 35, 36]. Interactive interface design of application products from the perspective of interface color can help elderly users get rid of cognitive dilemma, reduce the difficulty of using applications, and better integrate into the digital era[37, 38].

Secondly, elderly users generally have lower levels of technological acceptance and familiarity [27]. They require more support and guidance to use these applications effectively. However, many MHAs do not provide sufficient user education and support resources, further hindering adoption among elderly users [28, 29].

Moreover, the emotional aspects of design are often overlooked in MHAs. Colors and emotional design can significantly influence users' emotional experiences and willingness to use the application [30,31,32]. Yet, current design models typically ignore these crucial factors, failing to enhance usability for elderly users [33,34].

The color interface model designed by the elderly in many studies is shown in Table 3 However, it does not involve interface design based on emotional models. At the same time, research on the interface design of MHAs for the elderly is scarce.

Table 3. Existing Framework of color design model on the interface design for elderly

NO	Researcher	Description of Models/Frameworks
1	Sha et al., 2017	Principles for designing interface icon for elderly
2	Du, H et al.,2023	The effects of background color and font size on the experience of elderly
3	Zhang, H. 2018	A model of color semantics of the elderly mobile phone interface.
4	Mao, Y. Y. 2014	A model of color design for mobile digital media interfaces
5	Feng, L., & Luo, J. 2022, June.	A chat application model for the elderly based on color cognition and user demand

In addition, Table 4 shows the existing usability framework affecting the use of MHAs by older adults, which focuses mainly on usability and research on MHAs. Relatively little research has been done on color interfaces in the elderly.

Table 4 Existing Framework of usability of MHAs for elderly

NO	Researcher	Description of Models/Frameworks
1	Huang, Z. (2023)	Systematic review of mobile application usability studies, discussing seven usability attributes in the PACMAD model.
2	Islam, M. N., Karim, Md. R., et al. (2021).	Aging barriers influencing mobile health usability for older adults: A framework. Journal of Biomedical Informatics.
3	SpringerLink. (2021).	Usability Evaluation Method for Mobile Applications for the Elderly: A Methodological Proposal.
4	Wang, Q., Liu, J. (2022)	stability evaluation of MHA for the elderly, covering 96 articles from 2010-2020, proposing evaluation methods for elderly users.

Related to this, the emotional design model shown in Table 5 does not include color interface related model behaviors. The studies also did not specifically design models to design elderly MHA.

Table 5. Existing Emotional design models of interface for elderly

NO	Researcher	Description of Models/Frameworks
1	Donald Norman.,1993	Affective three-level design theory model
2	Nagamachi M., et al.,1975	Kansei engineering：emotions and image analysis
3	Zhu, Y. N. 2019	Emotional design model of the elderly population MHAs

4	Zhao, X. Y. 2022	Emotional model in the elderly elimination class game interface design
5	Wang, M., & Zhang, W. F. 2023	Aging Design of "smart TV" based on emotional design model

To summarize, while many scholars have conducted research on the adaptation of medical and MHAs and explored interface design from the perspective of the elderly users, few have approached the design of MHAs from the angle of color-emotion. Therefore, it is essential to study this gap, as it could help to improve the quality of interface design, optimize the user experience for the elderly, and enhance the health literacy of the elderly population. The clearer gap as shown in Figure 1.

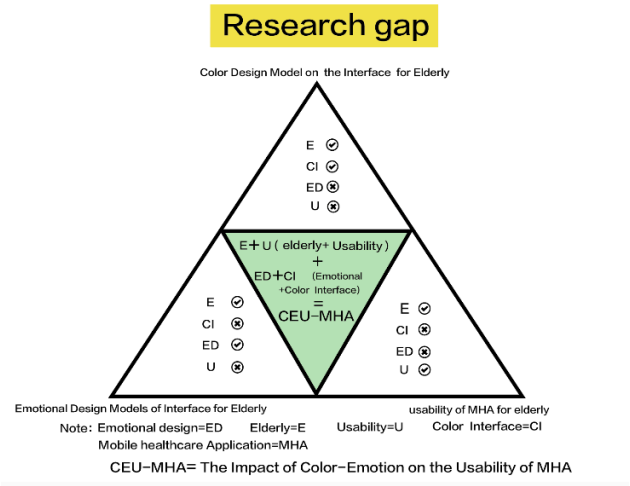

Fig. 1. Clearer Gap for This Study

As can be seen from Figure 1, in the case of the elderly, the interface color model includes color research, but it does not focus on usability and emotion. The affective model includes affective studies, but it does not include color and usability studies. Even though it contains the study of MHAs design and the study of usability, does not include emotion and color. Therefore, the focus of this study is to develop a conceptual design model that is the impact of color and emotion on the usability of MHAs.

6 Conclusion

The integration of color psychology and emotional design into MHAs presents a significant opportunity to enhance the usability of these applications for elderly users. By creating interfaces that are not only functional but also emotionally engaging and visually accessible, developers can improve user satisfaction and increase adoption

rates among older adults. However, further research is needed to fully understand the best practices for implementing these design principles and to develop guidelines that can be broadly adopted in industry.

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