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Research on the Design of Intelligent Pillows for the Elderly based on Emotional Design

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Abstract: With the progress of society, the problem of sleep difficulties in the elderly has become the focus of attention in the market. This study explores the application of emotional design theory in the development of smart pillows for the elderly, aiming to enhance the user emotional experience of existing products. A comprehensive analysis of the current design of smart pillows is carried out to find out the shortcomings of products based on the principle of emotional design. From the emotional theory to the instinct layer, behavior layer and reflection layer, the function optimization and product prototype design of smart pillows for the elderly are carried out. Based on the research results, a smart pillow for the elderly is designed and the future development direction of smart pillow technology is proposed. Emphasizing the importance of enhancing the emotional experience of older users, this study contributes to advances in smart technology and improvements in the design of sleep products for the elderly.

Keywords: The Elderly; Smart Pillow; Emotional Design; Product Design.

1. Introduction

Improving sleep in older adults has become one of the most pressing issues as the global population ages rapidly. The elderly population is growing rapidly, from the current 205 million people aged 60 years or older to an estimated 2 billion by 2050 (Patel et al., 2018). This not only affects the health and well-being of individuals, but also has a profound impact on the burden on families and society. Studies have shown that many older adults suffer from sleep disorders, primarily insomnia, sleep apnea, and circadian rhythm disorders. These sleep disorders not only reduce the quality of sleep in older people, but also significantly increase the risk of chronic diseases such as hypertension, diabetes, and cardiovascular disease (Figure 1). At the same time, psychological problems such as anxiety and depression have increased in older adults. Therefore, how to effectively improve the sleep of older adults has become an important and worthy topic for in-depth research.

2. Status of Research

Studies have shown that about 25% to 40% of older adults have persistent insomnia symptoms, which seriously affect their quality of life and overall health (Tom et al., 2016). There are many factors that contribute to insomnia in older adults. For example, aging is an important factor, which is often accompanied by physiological changes and an increase in comorbidities, leading to an increase in the rate of insomnia in the elderly. Scholars have proposed that certain factors such as gender, socioeconomic status, and psychological conditions such as depression and anxiety are also associated with insomnia in the elderly (El-Gilany et al., 2017; Kim et al., 2017). In addition, psychological stressors can also lead to sleep disturbances, although they are generally not considered to be the direct cause. This suggests a complex interaction between mental health and sleep quality (Wijayanti & Husain, 2023). The combined results of different studies show the multifaceted nature of insomnia in the elderly, and a comprehensive treatment and management approach is needed (Bangun et al., 2020) to alleviate the worsening of insomnia.

In terms of the development of sleep aid products, firstly, according to market statistics, the sleep aid market is expected to reach $13.135 billion from 2022 to 2032 (Figure 2), which shows that there is a huge market demand and considerable room for development. Second, the treatment of insomnia in the elderly can be divided into pharmacological and non-pharmacological interventions. Typically, pharmacists will prescribe pharmacological treatments, including benzodiazepines and non-benzodiazepine sedative hypnotics. However, medications can carry significant risks. The likelihood of falls and cognitive impairment increases after older people take the drugs (Samara et al., 2020). Clearly, this is not a method suitable for long-term use. However, another systematic review showed that older people are also susceptible to age-related changes in drug metabolism and the development of comorbidities. Therefore, there has been an increased focus on non-pharmacological interventions for insomnia. Nonpharmacological therapies include behavioral modification, relaxation techniques, and complementary therapies; cognitive behavioral therapy for insomnia (CBT-I); sleep hygiene education; relaxation techniques and environmental modifications; the use of sleep aids such as sleep masks, white noise machines, and special mattresses; or the use of aromatherapy and warm foot baths (Mahyuvi et al., 2021; Triningsih & Darmi, 2023). Many of these interventions improve sleep quality and address the underlying psychological and physiological factors that contribute to insomnia. They also confirm that nonpharmacological interventions are safer than medications. Therefore, although various types of sleep products are available for use by older adults, deficiencies in their use and effectiveness remain, and continued research is important to improve these methods and improve the quality of life of older adults with insomnia.

Figure 1. Insomnia State in Elderly People

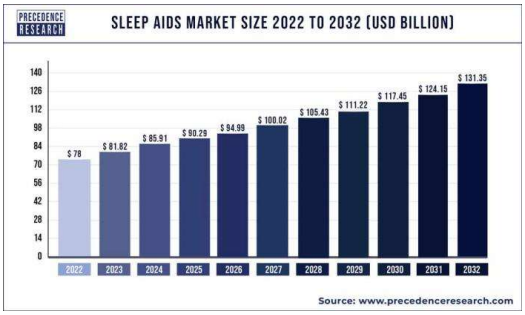

Figure 2. Sleep aids market size 2022 to 2032.

3. Application of Emotional Design Theory to Products for the Elderly

3.1. Overview of Emotional Design Theory

In his 2004 book Emotional Design: Getting Users to Love Your Product, American cognitive scientist Donald Norman introduced the concept of emotional design theory. The main idea is that by designing products to evoke emotional responses in users, it is possible to significantly influence their experience of and behaviour towards the product. This further reflects the fact that good design not only focuses on whether the product is functionally perfect and easy to use, but also needs to appeal to users on an emotional level, so that they become attracted to the product and even develop a sense of dependency. According to emotional reasoning, people can be divided into the following three levels when using emotionally designed products: Visceral Level, Behavioral Level and Reflective Level (Norman, 2004). In fact, these three levels are based on the user's sensory experience, the operation process, and the deeper meaning conveyed by the product, and together they form the user's overall impression of the product, which has a positive impact on product design. The sensory level refers to the direct impact of the product on the user's senses, such as sight and touch, and can be used in aspects such as the appearance design and the feel of the material. The behavioral level focuses on the user's operational experience during use, with an emphasis on the sense of use and the need to meet functional requirements. The reflective level is the most advanced level of design, which focuses on the product's impact on the user's psychology and the meaning it meaning conveyed, and the value recognition felt by the user, etc. They are continuously enhanced from sensory stimulation to deeper meaning, in order to shape the user's overall positive feelings towards the product. At the same time, emotional design also provides an important reference framework for product design, allowing designers to optimize the user experience from multiple perspectives and achieve the goal of making the user truly fall in love with using the product, which is very meaningful.

3.2. Emotional Design Theory in the Design of Smart Pillows

3.2.1. Inadequate Smart Pillow Design for the Elderly

Smart pillows are an innovative product that combines modern technology with everyday life and has the potential to improve the quality of sleep for users. However, many existing products on the market have many design deficiencies, especially in terms of not fully considering the actual needs of elderly users (Table 1). This study analyzed some of the smart pillows already on the market and found the following deficiencies: First, there are usability barriers in the hardware design. Usually, smart pillows need to be recharged regularly, which is a barrier to use for elderly users. In addition, the elderly have poor eyesight or reduced dexterity, and the binding and enhancement of smart functions with smartphone apps complicate product use, causing frustration during the process of connecting devices or setting up. In addition, the design of some pillows with built-in speakers may have ignored the impact of the increased weight on the comfort of use, and while technologies like bone conduction are novel, they are unnecessary, especially for the elderly. Second, there is a lack of personalized scientific guidance, and the data monitoring function is biased towards simple recording. Most smart pillows currently on the market sell data recording functions such as recording heart rate, respiratory rate, number of turns, and duration of deep sleep. However, it is worth noting that this data is often only for display purposes, and lacks in-depth analysis and personalized intervention recommendations. In particular, For older people suffering from sleep apnea or insomnia, the smart pillows on the market do not provide effective solutions, which highlights that the generalized functions of smart pillows are unable to cope when you face specific health problems. In addition, the elderly also rarely receive feedback on healthy behaviors. The lack of interactive design makes it difficult for users to intuitively feel the long-term health effects of the product, which gradually weakens the motivation to continue using it and trust in smart products. Third, the user interface design is not suitable for elderly users. Many smart pillows rely on mobile application interfaces that are too complicated to use, with small fonts and cluttered information. Elderly users find them difficult to use. However, the associated setting processes are complex, which undoubtedly increases the threshold for use for elderly people with low technology acceptance. This directly affects the user experience of elderly users and makes them more inclined to give up using it. Fourth, the lack of emotional support functions. Older users, especially those living alone, have a strong need for emotional and social support. However, most of the current products in the smart pillow market focus on technical functions and neglect the important factor of meeting the emotional needs of the elderly. The design of this part of the game and the need to establish contact between the elderly and others by strengthening human interaction, etc., in addition, smart pillows lack a linkage mechanism for family or community health support, and lack positive incentives from the outside world, which ultimately limits the actual use of the product. Therefore, starting from the actual needs of elderly users, there is still much room for improvement in terms of operational convenience, functional pertinence, user-friendliness of the interface, and emotional support functions. Future product designs should pay more attention to the special needs of the elderly and incorporate a humanized and

emotional design concept in order to truly achieve a balance between technology and user needs, thereby enhancing the practicality of the product and its market acceptance.

Table 1. Design Analysis for Smart Pillows Based on Emotional Design Theory

Product Name and Brand	Visceral Analysis	Behavioral Analysis	Reflective Analysis	Product Shortcomings
Xiaomi 8H Smart Pillow	Uncomplicated design utilizing high-resilience memory form for comfortable support, offering an approachable aesthetic.	Built-in sensors monitor heart rate and breathing, delivering sleep improvement suggestions through an app.	Users appreciate the pillow's comfort and accurate sleep monitoring, noting fair value for money.	Requires regular charging, potentially inconvenient for elderly users; certain functions are app-dependent, adding complexity.
Lefan Smart Music Pillow	Stylish appearance with an integrated speaker system for music-assisted sleep, promoting relaxation.	Plays soothing music to aid sleep, with app-based controls for volume and track selection.	Users find the music feature effective for relaxation, enhancing sleep experience.	The speaker system adds weight, affecting comfort; smartphone connectivity may be challenging for elderly users.
Pilo Smart Music Pillow	Streamlined design with built-in speakers, offering technological and soft-touch experience.	Utilizes bone conduction technology to play music without disturbing others, and monitors sleep data.	Users appreciate the privacy of bone conduction and the utility of sleep monitoring features.	Higher price point: bone conduction may be uncomfortable for some; app integration adds complexity.
REM-Fit Zeeq Smart Pillow	Minimalist design with high-quality materials, providing ergonomic support and a comfortable feel.	Embedded sensors track sleep stages and heart rate, integrating with Fitbit devices for comprehensive health analysis.	Users report accurate sleep data, with enhanced benefits when used alongside other Fitbit products.	Premium pricing: optimal use requires additional Fitbit devices, increasing overall cost; limited appeal for non-Fitbit users.
Hua wei Smart Pillow	Clean and elegant design with high-resilience materials for good support, offering a friendly appearance.	Built-in sensors monitor sleep data, providing improvement suggestions via the Hua wei Health app.	Users note enhanced comfort and accurate sleep monitoring, leading to better sleep quality.	Best utilized with Hua wei devices, which may not be user-friendly for non- Huawei users; some functions are app-dependent, adding complexity.

3.2.2. Emotional Theory in the Design of Smart Pillows

Through the analysis of the current design flaws of smart pillows, combined with emotional theory, the design is improved in three aspects: function optimization, user experience and emotional care. This study incorporates the emotional needs of users into the design of smart pillows for the elderly. It addresses the practical difficulties and psychological needs of this special group, supplements the deficiencies of existing products, and designs a smart pillow that truly meets the sleep improvement needs of elderly users.

Instinctive layer. sensory experience and first impression.In the design of the smart pillow for the elderly, the goal of the instinctive layer is to make the user feel comfortable, intimate and secure the first time they come into contact with the product through sensory experiences such as sight, touch and sound. This study will use a soft beige and light blue Coolmax® polyester fabric developed by Invista for the visual design. The surface's stimulating design allows sweat to quickly transfer from the surface of the skin to the outer layer of the fabric, helping to speed up evaporation and keep you dry. The fabric is also treated with an antibacterial agent to reduce the growth of bacteria and odors. It is lightweight, soft and comfortable, easy to clean and durable. These features make Coolmax® fabric ideal for use in the elderly smart pillow application, which can improve the cleaning performance and product comfort of the pillow. In addition, the pillow has a light and shadow projection function added to the smart chip. At night, it can project images of the starry sky or other styles to help users relax and fall asleep quickly. It also adds dynamic lighting, which adjusts the brightness of the warm light according to the user's sleep stage. By simulating the process of sunset light gradually weakening, it alleviates the interference of ambient light on the elderly's sleep. In terms of tactile design, the surface of the pillow is made of Coolmax® high-tech material to prevent the growth of bacteria and improve the comfort of the pillow for the elderly. A miniature airbag system is embedded to simulate the feeling of a massaging touch, effectively relieving the stiffness of the neck caused by prolonged immobility. In terms of hearing, the smart pillow uses a miniature speaker from KLT Technology Co., Ltd., which is embedded inside the pillow while maintaining its comfort. The speaker features high sensitivity, high power and low distortion, ensuring clear sound quality and providing users with an excellent audio experience, especially suitable for the hearing needs of the elderly. It can play natural sound effects (such as the sound of wind or birdsong) or low-frequency soothing sound waves to create a sleep-inducing environment. It can also upload greetings from family members or grandchildren to provide a personalized sound companion (Figure 3).

Figure 3. Smart Pillow for the elderly

Figure 4. Appearance and Smart Pillow

Behavior layer. Convenient operation and function optimization.In the interactive design of smart pillow products, a built-in intelligent voice assistant is used to easily complete function settings through voice commands, and to complete, adjust the height or play sleep-promoting music, and other operations that are difficult to perform. At the same time, considering that most older people cannot speak Mandarin, and so that older people in different regions can use it without barriers, the voice technology covers and supports the recognition of dialects. A touch control area is set up on the surface of the pillow, allowing simple touch adjustments to be made to the functions without the need for a complicated learning process. There is also vibration feedback to assist the elderly in completing the operation. In terms of functions, the interface of the mobile app has been designed to achieve the most simplified modules. Simple modules have clear graphics and enlarged display fonts, so that the elderly can easily personalize the operation of the smart pillow (Figure 4). In addition, the pillow is equipped with a built-in high-precision sensor that can monitor the user's breathing rate, heart rate and sleep depth in real time, generate a daily health report, and combine it with AI algorithms to dynamically adjust the pillow's hardness and height based on the user's health data, providing personalized sleep support. In particular, when apnea, abnormal heart rate or frequent turning is detected, the pillow will alert the user with a gentle vibration or light, to fully ensure the safety of the elderly. In the event of an emergency, it is directly connected to the family app to form an early warning message to notify family members or caregivers, ensuring the safety of the elderly. It is also set up to link this product with smart home devices, which will automatically adjust the temperature, humidity and lighting in the room based on the monitored sleep stages, thereby create a more comfortable sleeping environment. This part of the design comprehensively optimizes the smart pillow, lowering the barrier to use for the elderly and greatly improving the practicality and experience of the product.

Reflection layer. Emotional attachment and long-term value.This part is able to generate a sense of belonging and dependence in elderly users through emotional connection and deep experience, thereby enhancing the long-term value of the product. Health achievement feedback is the core of the level. Every morning, the pillow reports sleep improvement data to the user through an app or voice assistant, saying in a relaxed tone of voice, “Last night's deep sleep time increased by 20 minutes,” which enhances the interactivity between the product and the user. Goals such as accumulating 20 hours of deep sleep within a week can also be set, and upon completion, the user will receive a voice encouragement or a virtual medal as a reward, which enhances user engagement.

Data can be shared with family members, and the elderly person's children can send encouraging messages through the app to strengthen the emotional connection. Family interaction support further strengthens the emotional bond between elderly users and their families. The health sharing mechanism allows family members to view the user's current sleep status in real time and send voice or text greetings to remind them to pay attention to their rest and eating habits. To enhance a sense of social belonging, the pillow is connected via a health management platform, allowing users to join a virtual community, share sleep improvement experiences with peers, and participate in challenge activities to enhance a sense of participation and achievement. In addition, a sleep log function is also built in to record the user's progress from the first use to long-term improvement, and display it in the form of a video or voice, turning the user's health data into a “health story” to further enhance a sense of emotional belonging. All of these designs provide users with multi-level emotional support and long-term value, truly making the product a companion for the healthy living of the elderly.

4. Future Development Direction of Smart Pillows for the Elderly

The future development of smart pillows for the elderly should be improved from three levels: technology, emotion and health support, to meet the practical needs of the elderly in their daily lives, while also taking into account their psychological care and daily usage habits. The following are three design directions that are more in line with future needs:

Intelligent emotion recognition and soothing functions.Smart pillows of the future will feature non-invasive electroencephalography (EEG) technology to monitor brain wave activity and promptly recognize the emotional states of elderly users during sleep. If signs of stress or anxiety are detected, the pillow can provide relaxation through soft audio playback, temperature adjustments, or gentle vibrations. Furthermore, it can store personalized preferences to offer emotional comfort by playing familiar melodies or recordings of family members’ voices. This emotional care effectively meets the psychological needs of the elderly, contributing to improvements in both their physical and mental health.

Adaptive Support and Pressure Distribution Adjustment.Looking ahead, smart pillows might integrate advanced responsive materials and sophisticated adjustment systems, employing technologies such as flexible liquid air chambers or nanomaterials to monitor a user’s sleep posture, body heat, and head pressure in real time. These pillows would intelligently adapt their firmness and height to deliver customized support for the head and neck, eliminating the need for manual configuration. This intelligent design holds particular value for older adults who are bedridden for extended periods or experience issues with their cervical spine. By stimulating subtle muscle movement in the head and neck, it can help prevent the risks associated with prolonged immobility and reduce the chances of worsening neurological conditions. Compared to conventional memory pillows, this innovative support system offers smarter, more personalized adjustments, catering to the specific requirements of each individual.

Virtual companion and immersive experience.In the future. smart pillows will go beyond being single-function devices and become a tool that combines a virtual companion and emotional support. Solitude is a reality that most elderly people will encounter. In fact, loneliness is immensely harmful to the elderly, but it is also intangible. In order to reduce this sense of loneliness, the pillow can add holographic projection technology to display remotely recorded blessing videos from family members, or accompany them in real-time emotional interactions such as “conversations”, which can effectively reduce the elderly's feelings of loneliness. In addition, virtual reality technology can be used to create immersive experiences for the elderly, such as being in a quiet forest, by the sea, or in their familiar hometown from childhood, to relieve their psychological stress.

5. Conclusion

This study focuses on the design of smart pillows for the elderly based on the theory of behavioral and emotional design. It designs innovative design solutions that meet the needs of elderly users. In addition, the study addresses the shortcomings of existing smart pillows in the market and optimizes the product experience from three dimensions: instinct, behavior, and reflection. The design concept of behavioral and emotional design is implemented throughout the entire product development process. The smart pillow organically integrates functionality and emotional experience, improves user comfort and emotional resonance, and provides solutions tailored to the needs of the elderly. Although this study has achieved initial results, there is still room for improvement. In the future, long-term tracking studies will be conducted to further optimize product design details. In addition, emotional design can be applied to more smart products in the future to improve their quality of life.

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