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Digital Radio: A One-Touch Interactive System for Elderly Companionship

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Abstract. With the intensification of the aging problem, many elderly individuals, both in families and those living alone for extended periods, are confronting challenges such as loneliness, social isolation, and communication difficulties. To enhance their connection with the external world and address their needs for voice companionship, emotional interaction, and mental and physical well-being, this study introduces an interactive system named "Digital Radio." This system integrates a radio host, a voice-controlled sensor pendant, an external battery, and an application, aiming to provide the elderly with an easy-to-use interface and voice companionship. The system is capable of monitoring users' usage habits, emotional states, and other relevant data in real-time. It displays emotional fluctuations and location information, which are derived from the frequency of use and the content listened to, within the application. Preliminary tests indicate that the system has been well-received by its users, not only helping to alleviate the loneliness experienced by the elderly but also strengthening their emotional connections with their families.

Keywords. Digital radio, elderly, companionship, one-touch interaction, communication system

1.Introduction

With the intensification of the global aging trend, China faces a population aging challenge similar to that of Japan, raising concerns about a "lost decade" [1]. It is projected that by 2033, China will enter a "super-aged society," and by 2035, the population aged 60 and above will reach 400 million, representing 30% of the total population [2]. In response to this challenge, comprehensive policy measures, including medical reform and the strengthening of social security, have become top priorities. Notably, the issue of companionship for the elderly has increasingly become a primary concern, posing significant challenges for families with elderly members.

The World Health Organization's definition of healthy aging emphasizes the integrity of physical, mental, and social adaptability. In this context, the "Decade of

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Healthy Aging" initiative (2021-2030) was launched with the aim of optimizing the quality of life for older people, their families, and communities. This initiative encourages cities and communities worldwide to share experiences and collaboratively address the needs of older residents. Consequently, focusing on the mental health of the elderly, enhancing communication and interaction, providing companionship, and preventing diseases are of paramount importance.

Driven by digital technology, human-computer interaction products are increasingly becoming part of people's daily lives. The application of technological solutions has made it more efficient to focus on and address the mental health needs of the elderly. This study introduces a one-click interactive system named "digital radio." The system comprises digital radio hardware, a voice-controlled light-sensing system positioned around the speaker, and an application that provides real-time feedback on radio information. Users can select their preferred method of receiving information through the application and interact with the digital speaker. Additionally, the device features positioning functionality to offer users a more convenient communication experience.

2. Relevant Work

In recent years, research on elderly companion products has garnered increasing attention, particularly in the realms of technological application, human-centered design, psychological support, social interaction, as well as sustainability and innovation. Among these, the digital companion radio, as a novel concept, integrates audio playback and interactive sound sensing technology, aiming to fulfill the entertainment and social needs of the elderly. This product not only features functions such as voice interaction, remote control, audio playback, and information inquiry but also interacts with users in real-time through sound sensing technology. Although this interactive function bears some resemblance to existing voice assistants and smart speakers, its integration into a digital radio provides a more intimate and innovative option for the elderly.

2.1. Products with Elderly Companion Functions in the Technological and Application Fields

Over the past five years, research on products with elderly companion functions and their application in rehabilitation technology has seen a significant increase. Zhou et al. (2022) explored the impact of Online Social Interactions (OSIs) on the life satisfaction of Chinese elderly people, employing fixed-effect and cross-lagged structural equation models to delve into the role of OSIs. By comparing different forms of online participation, the study discerned varying impacts of online activities on the life satisfaction of the elderly. This research underscores the need for public digital interventions to focus on social functioning that benefits the elderly [3]. Torous and Keshavan (2018) discussed the role of technology in mental health research, highlighting both the challenges and opportunities it presents. The authors examined how technology enhances mental health research through new tools and methods, while also acknowledging potential limitations and ethical considerations [4]. Liu, Li, and Zhang (2021) investigated the relationship between the mental health status of elderly people in China and their health expenditure, aiming to understand how mental health

status influences healthcare utilization patterns among the elderly [5]. Xujie Lang and Zhiquan Feng, et al. (2022) proposed a system for understanding the intentions of the elderly based on language, gestures, and posture, aiming to improve the quality of elderly care and make human-machine interaction more natural [6]. These studies highlight the potential applications of social and interactive devices in the companionship and care of the elderly, emphasizing the importance of personalized services. These insights are instrumental for further optimizing the design and application of social devices to cater to the needs of the elderly.

Furthermore, additional studies include: Ngiam, K. Y., Chew, L. M., & Tan, C. S. (2022), which examines the impact of a volunteer-led, one-on-one, home-based digital literacy program on the digital literacy and health-related outcomes of low-SES elderly people, using digital technology to improve their quality of life and social connections [7]. Almeida, T., & Silva, B. (2020) conducted a systematic review on the application of the Internet of Things (IoT) and voice assistants in elderly care. The authors aimed to explore the potential benefits and challenges of these technologies in improving the well-being and quality of life of the elderly. The review also identified privacy and security concerns due to the collection and sharing of personal data involved in the use of IoT devices and voice assistants, emphasizing the importance of ensuring data protection and user consent [8]. Abeer Alessa, Hend Suliman Al-Khalifa (2020) proposed a conversational companion system based on ChatGPT to provide companionship for the elderly, reducing loneliness and social isolation [9]. Mohan & Verma (2019) discussed various aspects of proposed assistive systems, including fall detection, location tracking, cough detection, robotic assistive wheelchairs, companion robots, mechanical arms for object manipulation, smart tags for tracking personal items, wireless body area networks (WBAN), smart home automation, and gesture control of appliances. These studies all highlight the potential value of technology in addressing loneliness, depression, and health issues in the elderly, with a focus on providing companionship, emotional support, and health guidance to enhance the quality of life for the elderly

2.2 Research on Voice and Sound Assistants for Elderly Products

In recent years, research on elderly companion technology has gradually matured. Zhang and Wang (2020) proposed a design for an IoT-based voice interaction system for the elderly. The authors recognized the increasing need for technology that can assist the elderly in their daily lives and improve their overall health. They proposed an integrated voice interaction system with IoT devices to provide personalized assistance and monitoring for the elderly [11]. Ning Yang (2021) emphasized that intelligent products should not only have mechanical functions but also bring emotional satisfaction to users, achieve high personalization, and thus enhance user experience [12]. Hen, K., Chan, A. H., & Ngai, E. W. (2019) explored the application of voice interaction technology in elderly care. Customization and adaptability are crucial for meeting the specific needs and preferences of individual users. Factors such as language proficiency, cognitive ability, and physical limitations should be considered to ensure system accessibility and user-friendliness [13]. Gary G. Liu and Nathan Malkin (2022) explored the privacy issues brought by the popularity of intelligent voice assistants and their third-party applications, and how certain privacy measures enhance their acceptability [14]. Sarah Johnson (2020) discussed the effectiveness of music therapy for the elderly. The research found consistent evidence supporting the

positive impact of music therapy on the health of elderly people. Specifically, music therapy has a significant impact on emotional health and can reduce symptoms of anxiety and depression [15].

Overall, these studies demonstrate the potential of voice assistants in the companionship for the elderly, emphasizing the importance of humanization, personalization, and intelligence, while also considering the impact of privacy and user behavior

3. Design Process

In the process of designing and developing the digital insight interaction system, we collaborated with experts in psychotherapy, AI engineers, design professors, and technical personnel from radio manufacturers to discuss design and technology

3.1. Discussion with Experts on Design and Technology

We conducted in-depth discussions with experts in elderly mental health from five medical institutions in Guangdong Province, along with authorities in AI and design fields. The discussions focused on design concepts, elderly mental health, sound therapy, interactive technology, and design experience. The consensus was as follows:

- Design a more user-friendly and intuitive user interface to meet the operational needs of the elderly.
- Simplify operations using AI's voice interaction technology.
- Develop emotional companionship and intelligent interaction systems to alleviate loneliness.
- Recognize that AI technology has enormous potential in elderly health management.
- Ensure that the convenience and effectiveness of the product are key, and provide personalized recommended content and services.

This discussion highlighted the important value and application prospects of interaction technology in the field of elderly mental health.

3.2. Design Goals

To effectively alleviate the loneliness of the elderly, we have defined the following design goals based on expert research, analysis, and recommendations:

- User-friendly Interface: Targeting the characteristics of the elderly, we aim to design a simple and intuitive user interface that allows for easy understanding and operation of the interactive device. As mentioned in Section 3.1, items IV and I, the importance of one-touch interaction is emphasized.
- Auditory Companionship: Considering the positive impact of sound and storytelling on the physical and mental health of the elderly, we have chosen the radio as the primary device carrier.

- Enhanced Interactive Experience: By utilizing data feedback and content selection to improve the effectiveness of interaction, we aim to increase the interest and trust of the elderly in digital radios. As mentioned in Section 3.1, items 2, 3, and 5, the cognitive aspects, user experience, and applicability of the interaction system will be the core goals of our design, as these directly relate to the success of the product.

In summary, our design goals are aimed at providing the elderly with a practical and humanized interaction system that meets their actual needs and expectations.

4. Description of Interactive Systems

The harmful effects of loneliness on the elderly are primarily evident in areas such as physical health, mental health, and social life. To mitigate these effects, we have designed a digital radio that not only adheres to aesthetic standards but also incorporates functions tailored for elderly companionship. This digital radio comprises two interconnected components: hardware and software.

- Hardware Component: The hardware includes a one-touch control system featuring key functions and a voice-controlled light interaction system. This design facilitates ease of use and accessibility for the elderly.

- Software Component: The software system is an application that enables users to browse information and monitor data. The radio offers 20 listening modes and includes a feature for analyzing application frequency data.

The two components, hardware and software, are designed to be independent yet interconnected, allowing for seamless integration via Bluetooth or Wi-Fi. The design's rationality and innovation have been validated through in-depth discussions with experts and user interaction experience testing.

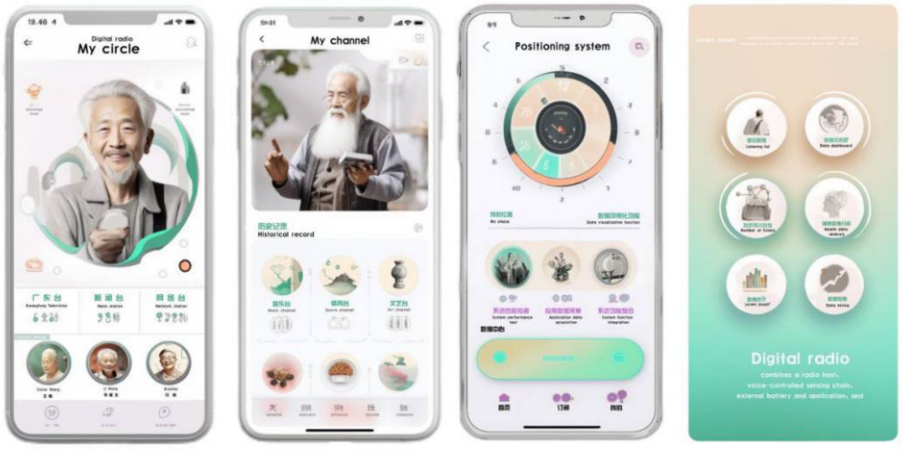

Figure1. interface of digital insulin app

4.1. Application of APP Design

The application is designed to provide an easy-to-use companionship and interactive experience, centered around the unique needs of the elderly. It features a simple and intuitive interface, ensuring convenient operation. The application integrates multi-modal interaction methods, including touch, sound, and visual feedback. This integration encompasses voice control and touchscreen operation, facilitating effortless device control by the users.

The application is both intelligent and personalized. It automatically adjusts content based on user habits, such as recommending programs based on listening history. The main interactive interface of the application offers a variety of functions. These include knowledge expansion, call selection, and modes for health and friendship information. Its intuitive design and straightforward operation process are specifically tailored to ensure easy access and usability for the elderly, thereby creating a safe and comfortable interactive environment. (Refer to Figure 2 for a detailed view of the interface.)

Figure 2.the design of hardware system

4.2. Hardware System Design

The "One-Touch Elderly Interaction System" is powered by rechargeable batteries, ensuring continuous operation. It features a voice-controlled, light-sensitive soft belt that responds to voice commands and provides visual feedback. The integrated voice-controlled radio module facilitates playback control through voice commands, thereby

increasing interactivity. Usage data is collected by sensors to analyze user habits. The system also includes a button and vibration feedback mechanism, providing a tangible operating sense and enhancing the overall user experience. These components collectively form an intuitive and user-friendly elderly companion system.

The specific workflow of the system involves utilizing customized voice control sensors and micro-sensing development boards, provided by Guangdong Kelon Electrical Holdings Company. These components capture and recognize the intensity of external sounds. The sound signals are then converted into corresponding light signals, which are displayed through a soft light strip, synchronized with the sound intensity. Concurrently, the sound data is transmitted to the mobile system. The sound sensor relays the digital signal to the backend server via a Wi-Fi module, while the mobile application retrieves this data from the backend service through HTTP requests. This design facilitates the synchronous conversion of sound and visual signals, thereby enhancing the user's interactive experience.

The digital conversion signal is adept at capturing and converting the device status in real time, outputting it as an electrical signal. The intelligent hardware and application are seamlessly integrated to ensure smooth start-up and operation. The sound sensor, strategically placed, can accurately recognize the user's mood and behavioral status, providing a personalized interactive experience. This technological arrangement supports a smooth and intuitive user interaction system, aimed at enhancing the effectiveness and comfort of the user experience.

4.3. Human-Computer Interaction and Data Processing

The system leverages customized voice control sensors, supplied by Guangdong Kelon Electrical Holdings Company, capable of accurately capturing and recognizing external sounds. This capability enables the system to achieve synchronous interaction between light and sound, thereby enriching the user's sensory experience. Concurrently, the system is designed for real-time transfer of sound data to the backend server, working in tandem with the mobile application to ensure smooth data transmission and processing.

The strategic layout of the sensors is meticulously planned to accurately capture the user's emotional and behavioral patterns. This design consideration provides a simple, intuitive, and efficient interactive experience. The integration of these elements within the system underscores the commitment to creating a seamless and user-friendly human-computer interaction environment, particularly tailored for the elderly demographic.

5. Preliminary User Study

In our preliminary user study, 15 community users participated in a one-hour experimental session with the Digital Insight Interaction System. The experiment involved users engaging with the system to complete a series of tasks designed to evaluate key functionalities such as voice recognition accuracy, user interface usability, and system response speed. Researchers observed and documented user interactions throughout the process, noting operation methods and challenges encountered.

Post-experiment, participants completed a questionnaire assessing their experience, focusing on their intuitive understanding of the system, overall satisfaction, and any issues faced. They were also queried about their willingness to continue using the system in their daily lives and provided suggestions for improvements.

Three days subsequent to the experiment, a Cronbach's Alpha reliability test was conducted on the collected data to assess the internal consistency of the questionnaire responses. The results indicated a total reliability coefficient of 0.92, with Cronbach's alpha coefficients for each dimension and item exceeding 0.8, demonstrating high reliability of our research data and reflecting consistently positive user evaluations of the system.

Despite the high reliability demonstrated in the preliminary user study, the Digital Insight Interaction System faces significant challenges in implementation. Paramount among these is the need for robust privacy protection, particularly in the capture and transmission of sound data, necessitating enhanced data encryption and security protocols. Additionally, explicit user consent is imperative prior to processing user data, requiring clear user agreements and privacy policies, and ensuring users have the ability to manage and withdraw their data at any time. Lastly, given the diversity in user backgrounds and technological proficiency, the system's operational interface and content design should be intuitive and user-friendly. This may necessitate further user testing and feedback during the design phase to accommodate the varied needs of different users.

The test results, as indicated by the Spearman correlation analysis in the table, reveal a significant positive correlation between general radio usage and the user experience in listening, interface friendliness, personalized services, and companionship effectiveness. All correlation coefficients are greater than 0 and statistically significant ($p<0.05$). This suggests that these dimensions not only positively impact radio usage individually but also synergistically enhance the overall user experience. The interplay of these factors is crucial in improving the quality of life for the elderly, particularly in mitigating feelings of loneliness.

For the elderly, a positive listening experience can offer emotional solace, especially for those who frequently experience loneliness. Engaging with preferred content can provide psychological comfort and relaxation. A simple and user-friendly interface reduces operational challenges and increases user willingness to engage. Personalized services foster a sense of involvement and care, effectively diminishing feelings of isolation. The importance of companionship effectiveness is underscored by the radio's role as a source of emotional support, offering continuous companionship and interaction, thereby enhancing the elderly's quality of life.

Table1. Linear regression results

Dependent variables	User interface friendliness for Personalized service	B	Beta	P-Value	Adjusted R 2
independent variable	Personalized service	3.52	0.99	0.00**	0.97
	radio usage	3.46	0.96	0.00**	0.93
	Listening and reception experience	1.35	0.98	0.00**	0.97
	Companion effectiveness	2.94	0.99	0.00**	0.97

In the regression analysis assessing the impact of radio usage on the companionship function for elderly individuals with autism within the "One-Touch Elderly Interaction System," several key factors were identified as significantly influencing the usage experience of this specific user group.

Firstly, the regression coefficient for interface friendliness was found to be 0.99 ($p<0.05$), suggesting that its influence on the radio usage situation is not significant. This implies that despite the user-friendly interface design, its impact on the decision of elderly individuals with autism to use the radio is limited. Consequently, there is a need to focus more on interface designs that cater specifically to the needs of this group.

Secondly, both the listening experience (regression coefficient of 0.96, $p<0.05$) and personalized services (regression coefficient of 0.98, $p<0.05$) demonstrated a significant positive impact on the radio usage situation. This finding indicates that a quality listening experience and personalized services are crucial in reducing loneliness and providing emotional support for elderly individuals with autism.

Furthermore, the regression coefficient for companionship effectiveness was 0.99 ($p<0.05$), indicating a significant positive impact on the usage situation. This aspect is particularly vital for elderly individuals with autism, as an effective companionship can substantially reduce their feelings of loneliness and provide necessary emotional support and comfort.

Based on these insights, plans are underway to further optimize personalized services, enhance sound quality and content relevance, and improve the companionship effect to better the usage experience for elderly individuals with autism. Concurrently, special consideration is being given to the interface design to more effectively meet the specific needs of this demographic, ensuring that they can utilize this system with greater ease and comfort.

6. Limitations and Future Work

In our study, we identified several limitations of digital radios, particularly in terms of technology and user adaptability, with a special emphasis on the unique needs and declining abilities of the elderly. To effectively address the loneliness experienced by the elderly, we advocate for continuous technological innovation. This includes the introduction of advanced features such as voice recognition and artificial intelligence companionship functions. Additionally, optimizing the user experience and interface design from the perspective of the elderly is crucial. This could involve using larger fonts and simplifying operations to provide more humanized and user-friendly companionship tools.

7. Conclusion

We have designed, implemented, and evaluated the Digital Insight Interaction System, which effectively provides companionship to the elderly and offers real-time feedback on their mental health data. Utilizing digital computing technology for mental state monitoring and health prevention, the digital speaker offers real-time companionship and care through a one-touch multi-link solution. This system is based on the frequency of selection, repetition of selected content, data feedback, and real-time positioning monitoring. User test results indicate that the Digital Insight Interaction System is a

significant tool for combating loneliness in the elderly, addressing issues of "social isolation" and "causing physiological symptoms." It also improves the correct cognition of elderly people's mental health therapy. This research may provide more possibilities and reference data for further design, development, and research in the field of elderly mental health. We believe that the Digital Insight Interaction System demonstrates significant value in addressing the psychological health needs of the elderly and providing companionship.

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