# Enhancing Usability and Cognitive Engagement in Elderly Products Through Brain-Computer Interface Technologies

Daijiao Shi*, Chao Jiang, Chenhan Huang
School of Arts, Anhui University of Finance and Economics, Bengbu 233030, China

***Abstract*—This study addresses the limitations of traditional elderly care products in terms of intelligence and user experience by integrating human-computer interaction (HCI) principles into a product design framework for the elderly. This study explores the importance of feature extraction in human-computer interaction systems, emphasizes its key role in enhancing user adaptability and interaction efficiency, and deeply analyzes its impact on brain-computer interface (BCI) technology. At the same time, the study conducts simulation experiments to evaluate the effectiveness of various algorithms in processing two types of motor imagery tasks. Finally, the obtained results provide a comparative evaluation of the algorithms and highlight their respective strengths and limitations.**

***Keywords*—Big data; human-computer interaction; the elderly; product design**

## I. Introduction

The opening of the digital age has brought about rapid changes in the entire human society. For the elderly, the most fundamental change compared to the past is not the decline of their own physical and psychological functions, but the disappearance of the polar opposite ways of thinking they once used to understand the world, which accelerates their loss in modern society. This "lost" is precisely the uncertainty caused by the complexity and constant movement changes at the intersection of the current digital and aging society, the movement process of social development and the aging process of the elderly [1], the uncertainty across age and culture as opposed to precision, and the interpenetration of the overall and local relationships between the society as a whole and the aging population, elderly groups. Its basic spirit is to oppose the binary assertion of "either or that" in classical logic, and to recognize the fuzzy state of the existence of "this or that" between things. Moreover, it focuses on treating the ambiguity between things as a whole, and processing them to eliminate the ambiguity [2]. At present, the technology, culture, experience and other elements of the products used by the elderly are becoming more and more complex, and the consumption concept, cognitive ability and aesthetic awareness of the elderly are also changing. While they show some similarities, there has been a gradual shift from a group style to an unpredictable individualistic style. Understanding and viewing the uncertainty of thinking and thinking of the elderly from the perspective of fuzzy theory, the fusion of new and old ideas, and the multiple symbiosis become the rationalization of the overall needs of the elderly, is a necessary supplement to the humane care for the elderly [3].

With the progress of social civilization, digital products gradually tend to focus on humanized and personalized design in the process of design exploration. The commonality and individuality of the elderly are dialectically unified and interpenetrating, which is mainly reflected in their universal commonality, that is, the basic requirements for the function, safety and interaction of products, but they also have their own individuality, that is, their character, ability, emotional and aesthetic specificity. In the process of designing digital interactive products, it is necessary to start from the commonness and personality of the elderly. First, it is necessary to consider the commonness of the elderly contained in their personality, and reflect the cultural diversity and people-oriented thinking of products in a personalized way. Secondly, in the commonness on this basis, it is necessary to humanize the personality of the elderly in a flexible way, so as to reflect the humanistic care and emotional respect of the products, and enable the elderly to meet their individual needs in the commonness of the products. From the perspective of the vague demands of the elderly, it is necessary to emphasize the use of holistic and dialectical, common and individual, universal and special ways to understand people, explain products and solve problems in digital interactive products for the elderly, and integrate them into product design. The relationship between the elderly and digital interaction is full of flexible features.

In the design research of digital interactive products, emotional communication and interaction design are inseparable, so the emotional experience between interactive products and the elderly is particularly important. Nowadays, interactive design products for the elderly should not only meet the functional needs, but should stimulate their positive emotions and establish an emotional connection between the products and the elderly. The emotions of the elderly have become stable and complex through the development of society and the precipitation of time. In this case, there may be positive emotions such as joy, happiness, etc., and negative emotions such as disappointment may appear, sadness, loneliness, etc. With the continuous maturity of today's digital technology, interactive products for the elderly, on the basis of technical support, have begun to slowly seek the fuzzy appeals of the elderly's emotions. Meanwhile, technology allows the elderly to have a strong emotional resonance while enjoying high-tech and intelligent interaction, so as to maximize the positive emotions of the elderly and eliminate the sensitivity and anxiety brought by social development.

The purpose of this article is to improve the intelligence and reliability of elderly product design, solve the problems of inconvenient interaction and insufficient intelligence in traditional elderly products, enhance the emergency response capability of elderly products in emergency situations, and improve the multi-source information fusion effect of elderly products.

This study addresses the limitations of traditional elderly care products in terms of intelligence and user experience by integrating human-computer interaction (HCI) principles into a product design framework for the elderly. Moreover, this study explores the importance of feature extraction in HCI systems and emphasizes its key role in enhancing user adaptability and interaction efficiency.

This paper integrates human-computer interaction (HCI) concepts to analyze the product design system for the elderly, aiming to enhance user experience and service effectiveness. First, the introduction discusses the background, significance, and objectives of elderly care products, while the related work section reviews the current state of such products and the integration of intelligent technologies. Secondly, the algorithm section presents the development and integration of algorithms into the proposed model, followed by the experimental section, where the constructed model is evaluated through experiments, and the results are analyzed and discussed. Finally, the conclusion summarizes the study's key contributions and provides insights for future research directions.

## II. Related Work

The design of elderly products needs to meet the living needs of the elderly, while also having certain emergency functions that can achieve real-time interaction with the elderly. Next, we will analyze the design needs of elderly products and the current research status of their intelligence.

### A. *Elderly Interactive Product Experience Needs*

Form and function are the basic elements for the existence of products, but with the advent of diversification, digitization, and non-material society, the synergistic relationship between the "old-fashioned" in form and the "support for the elderly" in function of elderly products has been synergistic in the past, and is heading for an indeterminate demise. The rapid development of material technology and the emotional scarcity of the elderly make the relationship between the morphological, semantic and functional development of elderly products constantly changing. Especially, for the elderly products in the digital form, their form has long been beyond the shackles of function, showing a flat and homogeneous trend [4]. The functional definition of elderly products has gradually expanded from a single use category such as "helping the elderly", and "entertaining the elderly" to the cultural functions, aesthetic functions, social functions, emotional functions and other fields of high-level needs of the elderly. So far, the form of the product function for the elderly and the function of the form are interdependent, and its conceptual definition and relationship development have shown a vague and uncertain state in the movement change [5].

Before retirement, the elderly showed positive and progressive functional social roles as unit leaders or staff. After retirement, they take on the role of taking care of the family as grandchildren and grandparents of parents, including the superposition and transformation of roles such as patients, and their original social roles are gradually replaced by emotional roles. Moreover, as they grow older, their explicit behaviors become more diverse due to changes in the content and nature of their roles. The nature and complexity of elderly products will eventually generate multiple demands on the functions, forms, interactions, emotions, etc. of elderly products [6]. It is undoubtedly difficult to accurately describe the diverse needs of the elderly at different stages. However, if people can dialectically connect the causal thinking of the elderly's role transformation from a holistic rather than a partial perspective, so that the contours of the environment, culture, form, color and other parts related to elderly products disappear in the ever-increasing interconnection and re-form a unified whole, it will undoubtedly be easier for people to accurately define the conceptual attributes of elderly products and expand new innovation horizons [7].

The cognitive, behavioral, cultural, and psychological characteristics of the elderly are no longer simply personal attributes, but are more likely to become a component of a product. Products are no longer just "products" in the traditional sense, but must rely on basic conditions such as the elderly's interactive behaviors, physiological and psychological characteristics. The mutual penetration of advantages and applications between the elderly and products, and the complementarity of disadvantages, will form a new development form of elderly products [8]. The "interpenetration" between the elderly and the product makes the design focus shift from focusing on the function of "material objects" to the elderly's own participation and creation. Such products are open to the elderly, and are also very "Self-conscious" and "Conceptual". The interpenetration characteristics of elderly users and products can undoubtedly provide more personalized humanistic care for the elderly [9].

The functional diversity of digital products means that their functions are not unique, and they do not deliberately highlight or emphasize what the product can do. Simply put, it can basically meet the needs of life without considering the particularity of other users. With the development of society, economy and culture, the emotional and artistic expressions of the elderly in their later years have gradually enriched, and the need for basic living security has gradually transitioned to spiritual and cultural life sustenance [10]. In response to this artistic ambiguity in life, it is considered to give the elderly a higher spiritual level from an artistic perspective, add artistic design to interactive products for the elderly, make the products more humane and emotional, and to a certain extent eliminate the tension and indifference brought to them by digital products [11]. By integrating modern life concepts, namely the art of living, into elderly products, digital elderly products can be made inseparable from the daily lives of the elderly. On the basis of interactivity, the most appealing artistic means can be used to enhance the value and art of elderly products and the lives of the elderly. In addition, penetration and overlap can enable the elderly to realize an artistic life and resolve their ambiguous artistic demands [12].

### B. Big Data and the Interaction Needs of the Elderly

Reference [13] suggested that the layout and design of health information websites need to be fully considered to meet the search and acquisition of health information by the elderly population. Reference [14] suggested that the use of online health information tools by the elderly can greatly improve the efficiency of health information communication and exchange among the elderly. At the same time, it can further enhance the level of self-care. According to [15], computer course training for the elderly can effectively reduce anxiety and improve self-identification, which is very helpful for the elderly to search for health information through the Internet. Reference [16] found through observation experiments on nearly 20 elderly people that they are not particularly skilled in constructing and modifying search formulas and keywords during information search, and are not particularly familiar with the use of different search tools, browsers, etc. In addition, elderly people also lack relevant knowledge and experience in judging the authenticity of online health information. Reference [17] conducted a questionnaire survey on more than 400 elderly people through the Internet. The content of the survey is the health information search behavior of elderly people using Internet channels. The research results show that demographic factors, subjective attitudes and other factors will have a significant impact on the health information search behavior of elderly people. Reference [18] suggested that some elderly people with computer operation experience will be more flexible in constructing, modifying search equations, and selecting appropriate search terms to achieve the goal of searching for health information. Reference [19] suggested that compared to the elderly population who have not received a good education and have a lower level of education, those with higher education and better education tend to easily search for and obtain the online health information they need.

Overall, the research status is shown in Table I:

TABLE I. SUMMARY OF RELATED WORK

| Research contents | Related work |
|---|---|
| Elderly product demand | Digitization |
| | Function, form, interaction, emotion |
| | Environment, culture, form, color |
| | Interactive behavior, physiological and psychological characteristics |
| | The artistic quality of the product |
| | Humanization and Emotion |
| Intelligent products for the elderly | Information communication and exchange |
| | Self care |
| | Reduce anxiety and enhance self-identity |
| | Search for health information |
| | Intelligent emergency response |

## III. METHODOLOGY

### A. Event-Related Synchronization / Desynchronization (ERS/ERD) Phenomenon

In human-computer communication operation, there are mainly two types of errors: cognitive errors and subconscious errors. (1) Cognitive errors are often the lack of people's cognitive ability and cognitive degree, which is a type of error caused by people's knowledge ability failing to meet the needs of product use. For example, when people use a new lock, they often try several times to open it with the key. Moreover, cognitive errors are often unexpected errors, which are related to the user's early cognition and learning ability of the product. However, designers can reduce the probability of cognitive errors through reasonable guidance and prompts in product design. (2) Subconsciousness is defined in psychology as people's unconscious behavior tendency, and subconsciousness refers to unconscious and unconscious psychological activities. Unconscious errors are also inadvertently generated. They are the user's involuntary operation errors under the guidance of common sense cognition.

The aging of the elderly leads to the aging of the metabolism and organ functions of the elderly to varying degrees, and also leads to a large gap between their physical condition and learning ability and the young and middle-aged people in their prime of life, making the elderly more likely to make mistakes in one way or another when using products. Based on the physiological conditions of the elderly, the analysis of the fault tolerance elements of the elderly group can understand the error prone rules of the elderly when using products, so that the fault tolerance design for the elderly group is more targeted. There are two aspects of decline in the physiological function of the elderly: (1) decreased sensory ability. It is mainly reflected in the decline of the five senses, and the resulting decline in the perception of things. For example, color weakness, cataracts, glaucoma and other problems caused by visual deterioration are also the main inducements for the elderly to make mistakes when using the product. Visual deterioration leads to their poor understanding of functional zoning, prompt signs, button layout and other aspects of the product when using the product, which is prone to operational errors or improper use. The decline of hearing ability makes the voice of the elderly very sensitive. At the same time, the voice below the hearing threshold is likely to lead to cognitive or subconscious errors in operation due to the inability of the elderly to hear, while the voice above the hearing threshold or sharp and harsh sound will frighten the elderly. In addition, the decline of the sense of smell, taste and touch of the elderly will reduce their perception of the outside world, which is easy to cause scald, frostbite and other problems when using the product. (2) Decreased behavioral ability. It is mainly reflected in the decline of action ability and cognitive ability. Compared with young people, the elderly usually have problems such as deterioration of human quality, slowness of movement and decline of physical strength, which makes them prone to some unintentional mistakes. For example, the old mercury column sphygmomanometer needs to press the air bag vigorously to obtain a measurement data. The elderly's ability to move decreases, resulting in insufficient pressing force, which is likely to lead to deviation errors in the measurement results. On the other hand, aging physical functions of the elderly are prone to slow reaction and cognitive decline. At the same time, due to the relatively closed life of the elderly, it is also easy to have a sense of emptiness and reject new things. This has led to the decline of the learning ability and adaptability of the elderly when they are exposed to new products, resulting in boredom and rejection of new products. For example, the product does not work due to incorrect operation due to unclear understanding of the product's instructions, or gives up the operation due to impatience with the use of the product.

Event-related synchronization/desynchronization can be used to analyze and distinguish different motor imagery EEG signals to control the motion control system of the robot.

When the cerebral cortex is stimulated by endogenous or exogenous events, it induces changes in the physiological state of some functional areas, resulting in changes in the rhythm of certain brain wave frequency bands. The energy of the frequency band in the cerebral cortex is reduced, and the brain has a brief pause.

The formula for calculating ERS/ERD (Event related synchronization/desynchronization) is [20]:

$$ERD = \frac{A-R}{R} \times 100\% \tag{1}$$

In the above formula, R represents the power of a specific frequency band in the training signal, and A represents the power of a specific frequency band in the test signal.

*B. Feature Extraction of EEG (Electroencephalogram) Signals*

The average energy extracted in the 8-16Hz frequency band is calculated by the following formula [21]:

$$P = \frac{1}{N}\sum_{i=1}^{N} x^2 \tag{2}$$

In the above formula, N represents the number of extracted frequency band data in each group, x represents the extracted 8-16Hz frequency band data, and P represents the average energy of 140 extracted frequency bands.

It is suitable for feature extraction for binary classification tasks. Fig. 1 shows the CSP algorithm flow.

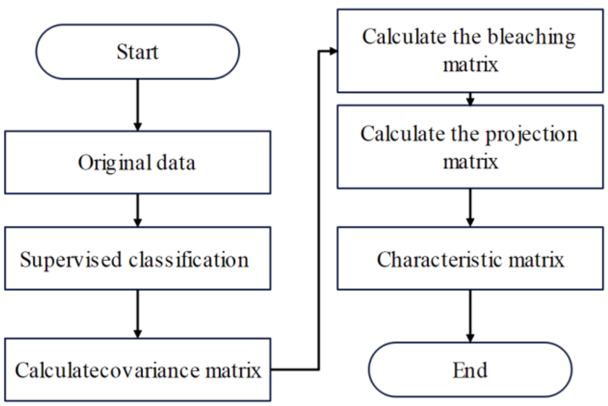



Fig. 1. Flow of the co-space pattern.

The process of CSP is explained as follows:

*1)* The algorithm classifies the raw data according to categories. Two types of sample data E can be classified into $E_1$ and $E_2$. $E_1$ is the first type of sample data, and $E_2$ is the second type of sample data.

*2)* The algorithm calculates the covariance matrix of the segmented original data, and the calculation formula of the covariance matrix is:

$$C_i = \frac{E_i \cdot E_i^T}{trace\left(E_i \cdot E_i^T\right)}, (i = 1,2) \tag{3}$$

$trace(E)$ means to find the trace of matrix E.

The algorithm calculates the covariance matrix of the classified raw data separately. $C_C$ is the sum of the spatial covariance matrices of the two types of data, then there are:

$$C_C = C_1 + C_2 \tag{4}$$

*3)* The algorithm performs orthogonal whitening transformation and simultaneous diagonalization, where $C_C$ is a positive definite matrix, and according to the singular value decomposition theorem:

$$C_C = U_C \Lambda_C U_C^T \tag{5}$$

$U_C$ is the eigenvector matrix, $\Lambda_C$ represents the diagonal matrix of eigenvalues, and the eigenvalues are arranged in descending order. By whitening transformation $U_C$, it can be obtained:

$$P = \frac{1}{\sqrt{\Lambda_C}} \cdot U_C^T \tag{6}$$

For $U_C^T$, the corresponding eigenvector matrix after the eigenvalues are in descending order should also be sorted in descending order, and when the matrix P is applied to $C_1$ and $C_2$, it can be obtained:

$$\begin{cases} S_1 = PC_1P^T \\ S_2 = PC_2P^T \end{cases} \tag{7}$$

$S_1$ and $S_2$ have common eigenvectors:

$$\begin{cases} S_1 = B\Lambda_1 B^T \\ S_2 = B\Lambda_2 B^T \end{cases} \tag{8}$$

$$\Lambda_1 + \Lambda_2 = I \tag{9}$$

Among them, I is the identity matrix. From it, it can be seen that the sum of the eigenvalues of $S_1$ and $S_2$ is equal to 1.

*4)* The algorithm computes the projection matrix.

The classification of two types of problems can be realized by using the matrix Q, and the projection matrix can be obtained:

$$W = \left(Q^T P\right)^T \tag{10}$$

*5)* The algorithm obtains the feature matrix through projection.

$$Z_{M\times N} = W_{M\times N} \tag{11}$$

*6)* Features are normalized.

$$y_i = \frac{log\left(var\left(Z_i\right)\right)}{\sum_{n=1}^{2m} var\left(z_n\right)} \tag{12}$$

Among them, $y_i$ is the normalized feature matrix of the i-th sample.

The obtained feature matrix is normalized to obtain the feature vectors $F_l$ and $F_r$ of the left and right motor imagery EEG signals.

$$\begin{cases} F_l = \left[v_1^l, v_2^l, ..., v_j^l, ...v_{2m}^l,\right] \\ F_r = \left[v_1^r, v_2^r, ..., v_j^r, ...v_{2m}^r,\right] \end{cases} \tag{13}$$

In order to maximize the recognition accuracy in classification and recognition, usually when m=2, the data of the first m rows and the last m rows are selected as the optimal feature vectors.

In general, The AR model can be represented as [22]:

$$x(n) = -\sum_{i=1}^{p} a_i x(n-i) + \mu(n) \tag{14}$$

Among them,

$$\mu(n) = \sum_{k=0}^{q} b_k w(n-k) \tag{15}$$

Both sides of Formula (14) are simultaneously multiplied by x(n+m), x(n) autocorrelation function.

$$R_x(x) = \begin{cases} -\sum_{i=1}^{p} a_i R_x(m-i), m>0 \\ -\sum_{i=1}^{p} a_i R_x(m-i) + \sigma^2, m=0 \end{cases} \tag{16}$$

By substituting Formula (15) into Formula (14) and performing Z transform,

$$\sum_{i=0}^{p} a_i X(z) z^{-i} = \sum_{k=0}^{q} b_k X(z) z^{-k} \tag{17}$$

We set:

$$\begin{cases} \sum_{i=0}^{p} a_i X(z) z^{-i} = A(Z) \\ \sum_{k=0}^{q} b_k X(z) z^{-k} = B(Z) \end{cases} \tag{18}$$

## IV. Model Design and Validation

### *A. Experimental Environment and Methods*

Traditional digital interactive products often give people a sense of technology and indifference. In particular, for the elderly with physical decline and inner sensitivity, these digital products cannot make them feel comfortable and pleasant to use, but will aggravate their inner anxiety to a certain extent and have a bad impact. Therefore, it is necessary to take advantage of the ambiguity characteristics of interactive products, add the characteristics of the perspective of the elderly, and use flexible processing to transform traditional digital interactive products into a product form that the elderly is happy to accept. Moreover, digital interactive products for the elderly need to subvert the traditional concept. Behind the improvement of the overall function, the design concept of people-oriented and flexible emotions is integrated to obtain the recognition of the elderly, so as to give the elderly more care and care. Fig. 2 is an analysis diagram of the design concept of this product. Behind it is an ecological chain service that cares for the elderly in a multi-faceted and humanized manner. Through online surveys, it is found that most elderly people worry that those “weird-looking devices” will make other elderly people feel “that they are unable to take care of themselves”. Therefore, the appearance design of digital interactive products must fully consider the psychological and emotional reactions of the elderly.

The simulation model in this article includes a nursing module, a motion control module, and a vital sign information detection module. The intelligent interactive terminal motion adopts a DC servo motor, which can not only withstand high load operation, but also has high operating accuracy. If conditions permit, it can be equipped with a high-performance main control chip. The nursing function of intelligent interactive terminals mainly includes cleaning and caring for urine and feces, including processes such as cleaning the spray bar, extending and closing it with warm water, and drying it with warm air. The human vital sign monitoring function of intelligent interactive terminals real-time transmits the human vital sign parameters collected by sensors, such as temperature, heart rate, etc., to the human-computer interaction interface, or through the establishment of a wireless local area network, enables family members or nursing staff to monitor the patient's physical condition in real time.

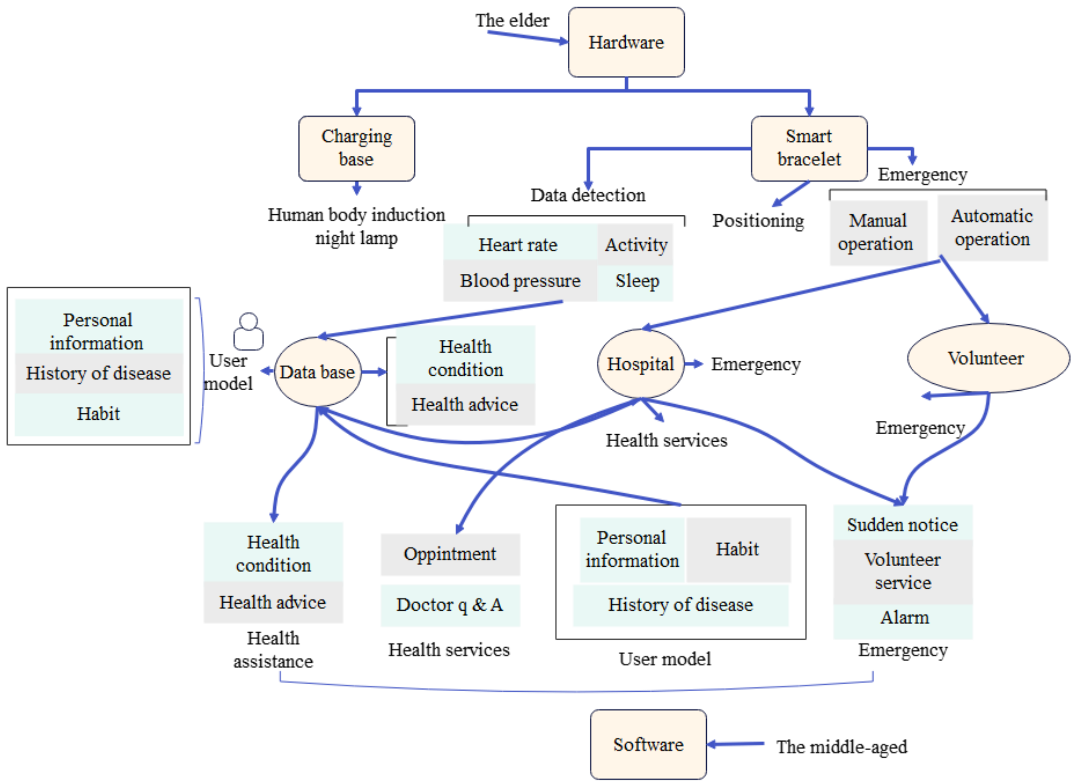


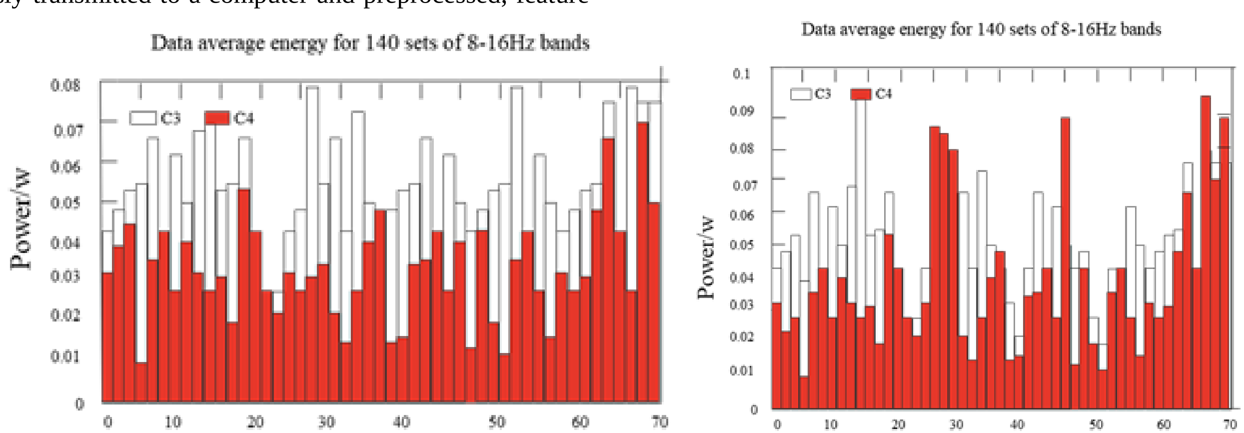

Fig. 2. Analysis diagram of the design concept.

Due to the limitations of the laboratory environment, EEG data is collected and recorded in a designated environment and sent to a computer through the BCI interface. The EEG signal preprocessing, feature extraction, and classification recognition algorithms are developed using MATLAB R2018a software for processing. Then, this paper uses VC++ language to write the module program and adds the MATLAB R2018a calling engine so that the module program can call MATLAB R2018a to process data and send it to the main controller through the wireless communication module to control the interactive terminal. Therefore, for the processing of collected EEG data, the laboratory currently uses an offline BCI system to record and save EEG data in real time. The collected EEG signals are wirelessly transmitted to a computer and preprocessed, feature extracted, and classified using MATLAB pre-programmed processing algorithms.

The default setting of the model in this article is the elderly mode, which is verified by nursing staff or family members and granted system data access permission. The data in this article cannot be uploaded to online platforms by default. To obtain the data in this article's model, the user's own verification and consent are required, making it more reliable in protecting the user's personal privacy.

## B. Test Results

The Energy simulation (Example 1) and DWT feature extraction are shown in Fig. 3 and Fig. 4.




(a) Imagination of the left-hand movement

(a) Imagination of the right hand movement

Fig. 3. Energy simulation example 1.

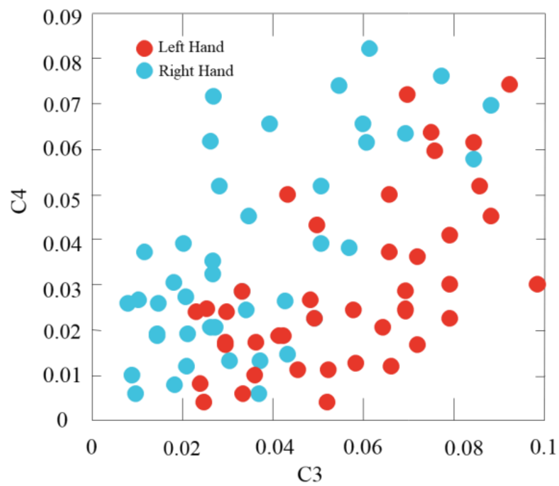
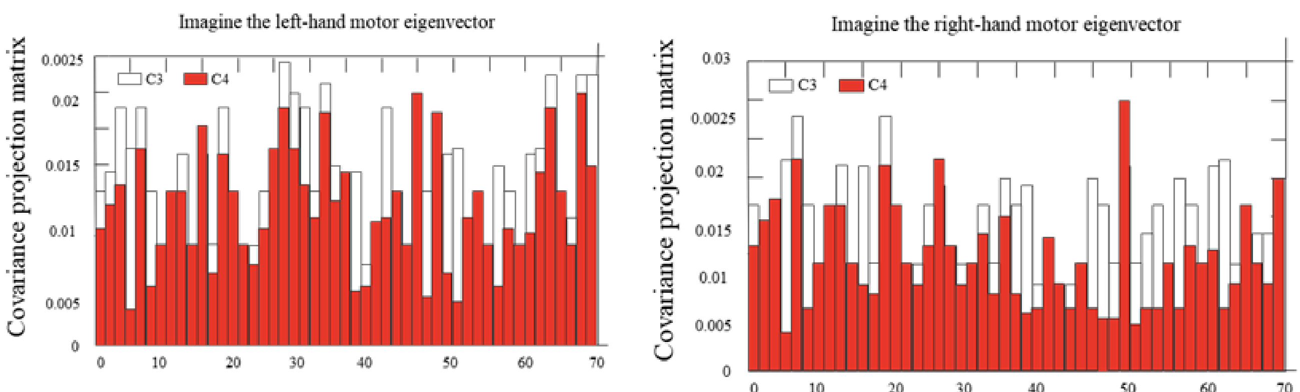



Fig. 4. DWT feature extraction.

Since CSP is used alone to extract EEG features and seriously lacks feature information in the time and frequency domains, the feature vector obtained by feature processing will have defects. Firstly, the EEG signal is decomposed into the EEG frequency bands of ERS/ERD phenomenon containing alpha wave and mu rhythm by DWT. Then, the extracted frequency bands are extracted by CSP, as shown in Fig. 5 and Fig. 6.

As shown in Fig. 7 and 8, the model has been validated to have good convergence through data.

Fig. 9 is the Feature extraction of AR model. Usually, energy simulation example 4 is shown in Fig. 10.




(a) Imagination of the left-hand movement

(b) Imagination of the right-hand movement

Fig. 5. Energy simulation example 2.

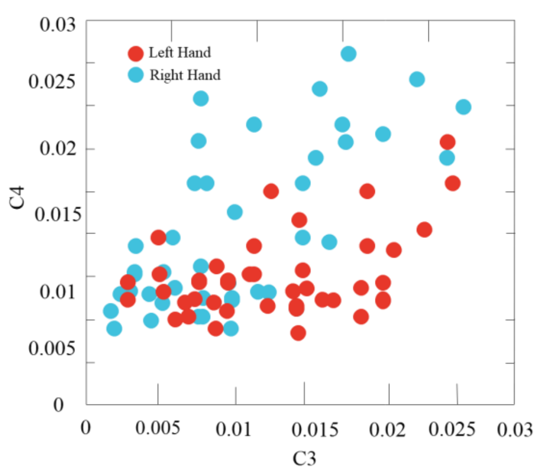
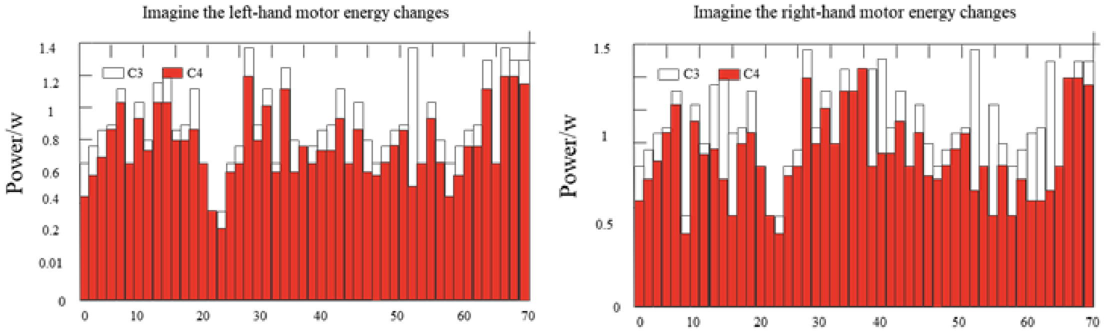



Fig. 6. CSP Feature extraction.




(a) Imagination of the left-hand movement

(b) Imagination of the right-hand movement

Fig. 7. Energy simulation example 3.

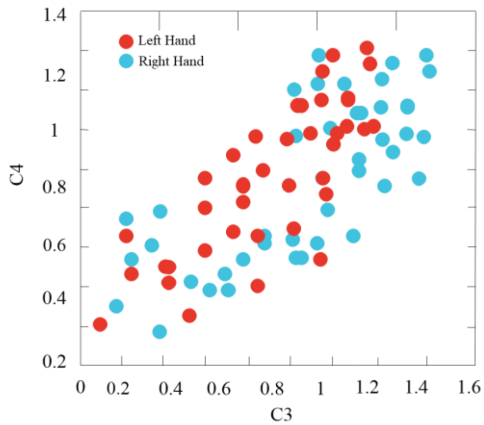
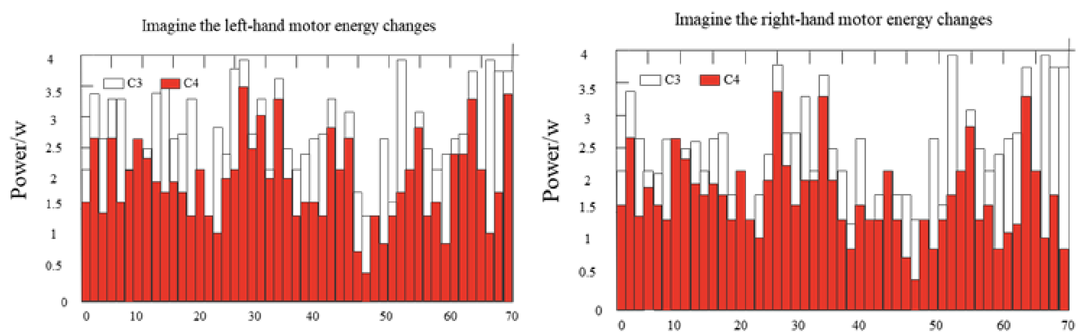



Fig. 8. Feature extraction of AR model.




(a) Imagination the left-hand movement

(b) Imagination the right hand movement

Fig. 9. Energy simulation example 4.

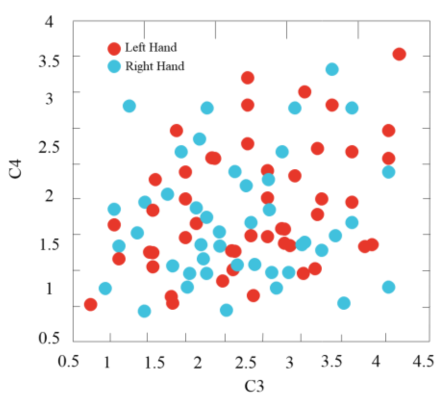



Fig. 10. Feature extraction of PSD.

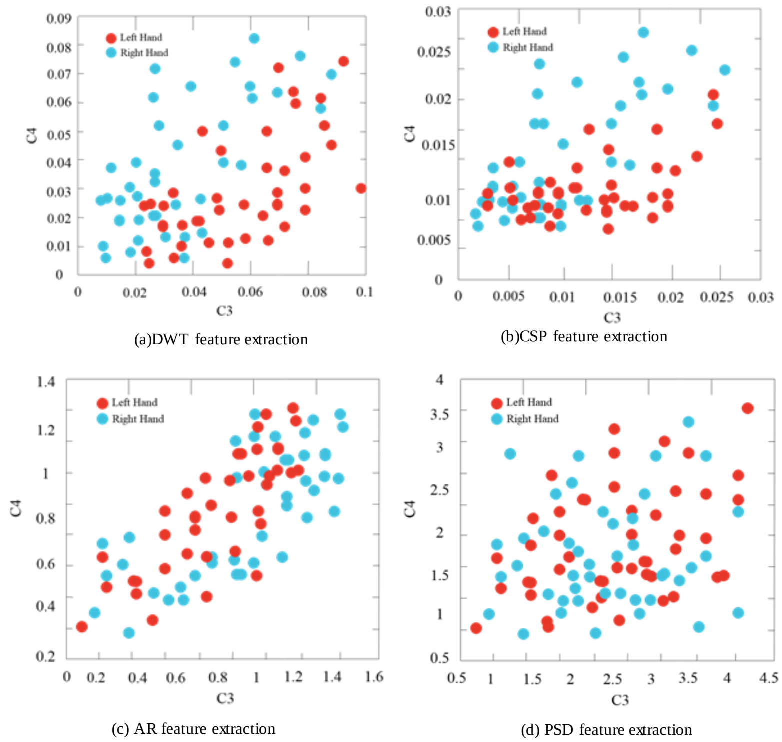



Fig. 11. Feature extraction quantification scatter plot.

In this paper, taking the EEG signals of C3 and C4 channels as an example, this paper converts the extracted eigenvectors into energy entropy ratios. Its size reflects the complexity of motor imagery, as shown in Fig. 11.

In order to further verify the effectiveness of the method proposed in this paper, experiments are conducted on a wheelchair prototype and some elderly people are invited to use the product. After trying out the product, evaluations are made using a percentage evaluation method, and the experimental results are shown in Table II.

TABLE II. USER EXPERIENCE EVALUATION RESULTS

| No. | User Experience | No. | User Experience | No. | User Experience |
|---|---|---|---|---|---|
| 1 | 90.42 | 9 | 90.17 | 17 | 92.18 |
| 2 | 89.14 | 10 | 90.97 | 18 | 90.03 |
| 3 | 87.08 | 11 | 86.76 | 19 | 87.15 |
| 4 | 90.72 | 12 | 91.71 | 20 | 86.19 |
| 5 | 89.36 | 13 | 88.79 | 21 | 86.30 |
| 6 | 88.13 | 14 | 91.62 | 22 | 92.85 |
| 7 | 86.20 | 15 | 92.97 | 23 | 91.63 |
| 8 | 89.36 | 16 | 86.73 | 24 | 92.78 |

The model is compared and verified with [5] (emotion perception model based on tactile recognition), [6] (intelligent virtual assistant), and [18] (human-computer interaction combined with optical fiber sensor). Its intelligence, humanization, and user experience are evaluated through expert evaluation. A total of five groups of experiments are conducted, and the results are shown in Table III:

### C. Analysis and Discussion

*1) Analysis of experimental results:* Four frequency bands are obtained. The third layer of detail coefficients represents the 8-16Hz frequency band of the original EEG signal, including alpha waves and mu rhythms (Fig. 3).

Fig. 4 illustrates the detailed relationship between imagination and information features, which is also an important foundation of human-computer interaction and the basic setting of theoretical research in this article.

As shown in Fig. 5 and 6, DWT and CSP are combined to extract the features of motor imagery EEG signals, and the feature information of time domain, frequency domain and spatial domain fusion is obtained.

TABLE III. COMPARISON RESULTS OF MODEL PERFORMANCE

| Test parameters | Reference [5] | Reference [6] | Reference [18] | Model in this article |
|---|---|---|---|---|
| Intelligent | 81.80 | 78.92 | 74.52 | 91.26 |
| humanization | 79.22 | 73.01 | 77.08 | 88.84 |
| User Experience | 82.57 | 75.77 | 76.67 | 90.85 |

From Fig. 7 and 8, it can be seen that the model proposed in this paper has good convergence and also verifies the reliability of the model data in this paper.

As shown in Fig. 9, the autocorrelation function $\hat{R}x(m)$ at point $(2m-1)$ of a piece of EEG signal sequence x(n) collected, with length N, is calculated.

From Fig. 10, it can be seen that the model proposed in this paper performs well in data feature extraction and has a significant clustering effect.

As shown in Fig. 11, the frequency bands containing the ERS/ERD phenomenon extracted by DWT are extracted by CSP, and the feature information includes not only time-frequency domain information, but also spatial information, which is suitable for two types of motor imagery tasks.

Through the above research, it is verified that the interactive design method of products for the elderly based on human interaction proposed in this paper has a good effect, and can effectively improve the design effect of products for the elderly.

As can be seen from Table II, the user experience evaluations of the model products proposed in this paper are all above 86 points, and the highest score reaches 93 points. Therefore, the product proposed in this article has received good feedback from the user group, which also verifies the effectiveness of the model and the practical effect of the model method proposed in this article.

In Table III, the model proposed in this paper is superior to the existing models in terms of intelligence, humanization and user experience, and the user experience is far superior to the existing models. This shows that the model not only has good performance, but also has significant application advantages.

*2) Product design needs for the elderly:* The product design must determine the user's use needs according to the demand analysis, define the product's functions and characteristics based on the needs, and create a conceptual design scheme. After that, the scheme needs to be evaluated by human-computer interaction experts or actual users, and effective feedback should be put forward to facilitate design improvement. The concept of interaction design is involved here, and interaction design is a design field that defines or designs the behavior of artificial systems. It defines the content and structure of communication between multiple interactive individuals, so that interactive individuals can cooperate with each other and achieve certain goals.

For example, the smart home service terminal is designed to provide people with a healthy, safe, comfortable, environment-friendly and convenient living environment. Its design concept basically follows the concept of ease of use, reliability, standardization and humanization, which can create a comfortable living environment for the elderly in their later years. In the application of interpersonal interaction, smart home service terminals must be easy to use and convenient for the elderly. In fact, many elderly people's understanding of scientific and technological products, such as smart phones, is still in the era of button phones. The elderly often have no idea how to use smart phones, so the market is full of large screen button phones suitable for the elderly. The purpose is to facilitate their use, and smart home service terminals also need to meet the needs of facilitating the use of the elderly. In order to ensure the safety of the elderly when using these service terminals, it is necessary to ensure the reliability of terminal operation. Therefore, if there is a problem with the product, it must be able to solve it as quickly and efficiently as possible. In addition, the designed products must conform to the national or industrial standards. If there is no standard, quality cannot be guaranteed. Furthermore, according to the above analysis, the cognitive and receptive abilities of the elderly will deteriorate as they age. Smart home service terminals should improve the humanized experience in a simple and easy-to-use way, so that the elderly can easily use modern digital household appliances. Therefore, the following functions are designed on the smart home service terminal.

It includes intelligent reminder function. For example, when the elderly are alone at home, they may fall asleep while watching TV on the sofa. When a certain time is reached, relevant sensors (such as pressure sensors) installed on the sofa and intelligent video terminals at home will feed back information to the terminal system, and the system will send out reminders (including voice reminders and slight vibration reminders). If the elderly do not follow up after the reminder, they need to determine whether to notify their family members (this function is an advanced application and is currently difficult to implement). The automatic control of smart home appliance control functions, such as air conditioning, lighting, air purifiers, humidifiers, etc., is achieved by using temperature and humidity sensors. When the indoor temperature and humidity reach the set value, the service terminal automatically controls relevant equipment to adjust the indoor environment. For the automatic detection and alarm function, such as using surveillance cameras and some wearable medical devices, when the elderly encounter some abnormal situations indoors, the terminal system will automatically connect to the Internet to alarm and notify the guardian. In addition, it uses motion recognition, voice recognition and other technologies to achieve more convenient interpersonal interaction control, which is convenient for the elderly to use. For example, when the elderly want to watch TV, they cannot operate the smart flat-screen TV. At this time, they can choose to use the human-computer interaction intelligent control function of the service terminal to control the operation of home appliances by voice. The service terminal should remind the elderly how to operate modern household appliances in the form of voice, and give clear steps and precautions. The service terminal connects to the home broadband network, automatically downloads the driver or patch on a regular basis, and automatically installs the maintenance system. When the system has problems, it automatically sends information to notify the maintenance personnel for remote maintenance or on-site maintenance.

*3) Limitations of the study and follow-up work:* The demand for elderly products is very high, especially with the increasingly severe aging population. People have a higher demand for intelligent elderly products, and the high cost and requirements of elderly products also pose certain challenges to the design of elderly products.

The amplitude of EEG signals is very low, only at the millivolt level, and is susceptible to interference. Pre-processing is necessary before analyzing EEG signals, which can affect the effectiveness of feature extraction. Select scientific and objective preprocessing methods to minimize interference in the signal to the greatest extent possible. This article simulates the extraction of EEG signals through simulation, but there may be some systematic errors in reality. Therefore, further improving the accuracy in the future is the key to applying the model in practice.

Based on the current popularity of intelligent products and 4G/5G networks, the communication needs of elderly products have been guaranteed. Therefore, improving the anti-interference ability of the model in this article can further enhance the intelligence of the designed product. Moreover, the method in this article does not require high production costs and has certain universality.

In addition, this paper needs to further integrate psychological factors, consider the actual needs of the elderly, and combine the needs of the elderly with psychology to further improve the practical effectiveness of the model in this article.

## V. Conclusion

Aging is the trend of world population development and a symbol of the continuous advancement of human civilization. At the same time, social and cultural trends such as digitalization, multiculturalism, experience economy, and postmodernism are sweeping in. Its core is dematerialization, emotionalization, individuation and diversification. The projection of these cultural trends has profoundly affected the life, entertainment, social interaction and other aspects of the elderly group. As the development carrier of human civilization, aged products are showing the characteristics of the times such as “exclusion”, “contradiction” and “integration”. This paper combines the idea of human-computer interaction to analyze the product design system for the elderly, so as to improve the user experience and service effect of the product for the elderly. Moreover, the experimental study verifies that the interactive design method of products for the elderly based on human interaction proposed in this paper has a good effect, and can effectively improve the design effect of products for the elderly.

Due to the current theoretical research stage of brain computer interfaces, many scientific and technological problems have not yet been solved. The paper proposes that the research on intelligent interactive terminal control based on EEG is an important topic. Although certain achievements have been made in the simulation verification of algorithms such as EEG signal preprocessing, feature extraction, and classification recognition, there are also some problems that need further improvement: the amplitude of EEG signals is very low, only at the millivolt level, which is susceptible to interference. Pre-processing is necessary before analyzing EEG signals, and the results will affect the effectiveness of feature extraction. At the same time, it is necessary to select scientific and objective preprocessing methods to minimize interference with the signal. Secondly, data processing is in an offline state, so it is necessary to study online brain computer interface systems to verify the effectiveness of the theoretical methods proposed in the paper.

Based on the above analysis, the main research needed in the future is to improve the system error of the model proposed in this paper and construct an online model to further enhance the online intelligent interactive simulation effect of the model.

## References

[1] Li, S. (2021). Synesthetic design of digital elderly products based on big data. Wireless Communications and Mobile Computing, 2021(1), 5596571-5596583.

[2] Li, Y., Ghazilla, R. A. R., & Abdul-Rashid, S. H. (2022). QFD-based research on sustainable user experience optimization design of smart home products for the elderly: A case study of smart refrigerators. International Journal of Environmental Research and Public Health, 19(21), 13742-13755.

[3] Liu, Y., & Wang, W. (2022). Research on quality evaluation of product interactive aging design based on kano model. Computational Intelligence and Neuroscience, 2022(1), 3869087-38699.

[4] Mohammed, Y. B., & Karagozlu, D. (2021). A review of human-computer interaction design approaches towards information systems development. BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 12(1), 229-250.

[5] Lu, J., Liu, Y., Lv, T., & Meng, L. (2024). An emotional-aware mobile terminal accessibility-assisted recommendation system for the elderly based on haptic recognition. International Journal of Human–Computer Interaction, 40(22), 7593-7609.

[6] Liu, N., Pu, Q., Shi, Y., Zhang, S., & Qiu, L. (2023). Older adults' interaction with intelligent virtual assistants: the role of information modality and feedback. International Journal of Human–Computer Interaction, 39(5), 1162-1183.

[7] Wu, J., & Song, S. (2021). Older adults' online shop** continuance intentions: Applying the technology acceptance model and the theory of planned behavior. International Journal of Human–Computer Interaction, 37(10), 938-948.

[8] Ma, Z., Gao, Q., & Yang, M. (2023). Adoption of wearable devices by older people: Changes in use behaviors and user experiences. International Journal of Human–Computer Interaction, 39(5), 964-987.

[9] Sakaguchi-Tang, D. K., Cunningham, J. L., Roldan, W., Yip, J., & Kientz, J. A. (2021). Co-design with older adults: examining and reflecting on collaboration with aging communities. Proceedings of the ACM on Human-Computer Interaction, 5(CSCW2), 1-28.

[10] Ma, Q., Chan, A. H., & Teh, P. L. (2021). Insights into older adults' technology acceptance through meta-analysis. International Journal of Human–Computer Interaction, 37(11), 1049-1062.

[11] Ryu, H., Kim, S., Kim, D., Han, S., Lee, K., & Kang, Y. (2020). Simple and steady interactions win the healthy mentality: designing a chatbot service for the elderly. Proceedings of the ACM on human-computer interaction, 4(CSCW2), 1-25.

[12] Li, Q., & Luximon, Y. (2023). Navigating the mobile applications: The influence of interface metaphor and other factors on older adults' navigation behavior. International Journal of Human–Computer Interaction, 39(5), 1184-1200.

[13] Fu, Y., Hu, Y., Sundstedt, V., & Forsell, Y. (2022). Conceptual design of an extended reality exercise game for the elderly. Applied Sciences, 12(13), 6436-6448.

[14] Dong, Y., & Dong, H. (2023). Design empowering active aging: a resource-based design toolkit. International Journal of Human–Computer Interaction, 39(3), 601-611.

[15] Tang, X., Sun, Y., Zhang, B., Liu, Z., Lc, R. A. Y., Lu, Z., & Tong, X. (2022). " I Never Imagined Grandma Could Do So Well with Technology" Evolving Roles of Younger Family Members in Older

Adults' Technology Learning and Use. Proceedings of the ACM on Human-Computer Interaction, 6(CSCW2), 1-29.

[16] Lyu, Z. (2024). State-of-the-art human-computer-interaction in metaverse. International Journal of Human–Computer Interaction, 40(21), 6690-6708.

[17] Su, T., Ding, Z., Cui, L., & Bu, L. (2024). System development and evaluation of human–computer interaction approach for assessing functional impairment for people with mild cognitive impairment: A pilot study. International Journal of Human–Computer Interaction, 40(8), 1906-1920.

[18] Ren, B., Chen, B., Zhang, X., Wu, H., Fu, Y., & Peng, D. (2023). Mechanoluminescent optical fiber sensors for human-computer interaction. Sci. Bull., 68(6), 542-545.

[19] Werner, L., Huang, G., & Pitts, B. J. (2023). Smart speech systems: A focus group study on older adult user and non-user perceptions of speech interfaces. International Journal of Human–Computer Interaction, 39(5), 1149-1161.

[20] Li, Y., Abdul-Rashid, S. H., & Raja Ghazilla, R. A. (2022). Design methods for the elderly in Web of Science, Scopus, and China National Knowledge Infrastructure databases: A Scientometric analysis in Citespace. Sustainability, 14(5), 2545-2557.

[21] Schomakers, E. M., & Ziefle, M. (2023). Privacy vs. security: trade-offs in the acceptance of smart technologies for aging-in-place. International Journal of Human–Computer Interaction, 39(5), 1043-1058.

[22] Rienzo, A., & Cubillos, C. (2020). Playability and player experience in digital games for elderly: A systematic literature review. Sensors, 20(14), 3958-3970.