Design and Research of a 3D Game Wearable Interaction System Based on the Bidirectional Mapping between EEG Focus and Game Parameters

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Abstract*—As a comprehensive medium integrating narration and interaction, games, with their instant feedback mechanisms and virtual reality features, have gradually become an essential carrier for emotional expression and experience. With the upgrading of users' emotional needs, the concept of how to construct an emotional feedback system based on physiological signals has become a research focus. Currently, emotional interaction technologies based on physiological signals in the gaming field generally face problems such as single interaction modes, significant feedback delays, and logical disconnection between virtual and real worlds. This research proposes a design scheme for a 3D game wearable interaction system based on the bidirectional mapping mechanism between electroencephalogram (EEG) focus and game parameters. Through the real-time acquisition, analysis, and processing of EEG signals, the player's focus is dynamically mapped to the in-game resource collection efficiency, establishing a correlation mechanism between the focus level and game parameters. As the game progresses, the system gradually increases the focus determination threshold, forming a progressive challenge mechanism that enhances the user's sense of immersion and emotional investment. Different from traditional competitive games, this system establishes a self-motivating interaction framework, where the focus duration accumulated by players in daily life can be automatically converted into game virtual resources, thus achieving the neural signal bridging of the interaction between real-world focus behavior and virtual resources. Experimental results show that this interaction system effectively improves the user's emotional experience and sense of immersion, and expands the application boundary of brain-computer interface technology in the interactive entertainment field. The research results not only break through the limitations of traditional game interaction models but also provide practical references for the integrated research of EEG-based affective computing and game interaction system design.

***Keywords*—EEG focus, Bidirectional mapping model, Game parameters, 3D game design, Wearable interaction system**

I. Introduction

Emotion, as one of the important factors influencing human behavior, has increasingly attracted the attention of academia and industry. Scherer (2005) pointed out that emotion encompasses cognitive and physiological responses triggered by external or internal events, involving complex states of sensation, thought, and behavior.[1] Izard (2009) further emphasized that emotion has a profound impact on interpersonal communication, life pursuits, and work status, and it is particularly important to study its cognition and regulation.[2] In the field of emotion recognition, emotion recognition based on electroencephalogram (EEG) signals shows significant advantages due to its high ecological validity and neurophysiological specificity. Liu et al. (2021) pointed out that EEG signals have unique advantages in the analysis of emotional states and have been widely applied in fields such as human-computer interaction and medical diagnosis.[3] The progress of this technology provides the possibility for scientific management of emotional states and the realization of emotional well-being. Brain-computer interface technology is extending from the medical field to the entertainment industry. The “Implementation Opinions on Promoting the Innovation and Development of Future Industries” issued by the Ministry of Industry and Information Technology and other seven departments clearly states that key technologies such as brain-computer interfaces should be broken through to promote the innovative development of multi-modal sensing devices.[4] The game industry, is an important field for emotional connection, according to the “Annual Report on the Development of Digital Gaming Industry in China （2024）”, the scale of China’s game users reached 674 million, with a year-on-year growth of 0.94%, also reaching a new high in history.[5] The integration of brain-computer interface technology and game design has opened up a new paradigm for deepening the emotional immersion experience.

Focus as a core indicator for measuring mental concentration, is closely related to attention control and emotion optimization. Khosravi et al. (2020) proposed that individuals with strong focus control abilities are better at adopting adaptive emotion regulation strategies, thereby enhancing psychological resilience and well-being.[6] Shahmoradi et al. (2022) systematically reviewed the effects of serious games on attention rehabilitation and pointed out that gamified design has significant potential to enhance attention.[7] This further indicates that games, through their interactivity and immersion, provide a unique platform for training focus. Especially in EEG-based games, players can enhance the training effect of focus through real-time feedback. Existing research mainly focuses on the application of EEG in the medical rehabilitation field, and there are few studies on its potential for emotional optimization in entertainment games. This research aims to fill this gap by verifying the effectiveness of the bidirectional mapping mechanism between EEG focus and game parameters in enhancing the user's emotional experience through a 3D game wearable interaction system based on this mechanism.

II. RELATED WORK

Focus, as a key emotional indicator for measuring players' mental concentration, can be directly related to game variables, promoting the evolution of the interaction form from one-way operation to two-way emotional dialogue.[8] In game design, the application of emotion recognition technology is mainly reflected in the following three aspects: dynamic difficulty adjustment, emotion-driven plot advancement, and personalized game experience.

- Dynamic difficulty adjustment is a technology that automatically adjusts the game difficulty according to the player's real-time performance or emotional state, aiming to optimize the game experience and extend the player's participation time. For example, when the player is in a low-mood or frustrated state, the system can reduce the difficulty to alleviate the sense of frustration; when the player is in a high-mood state, the system can increase the difficulty to maintain the challenge and fun. The following table (Table 1) shows representative game cases that adopt dynamic difficulty adjustment:

TABLE I. RELEVANT GAME CASES OF DYNAMIC DIFFICULTY ADJUSTMENT

Game Name	Game Type	Interaction Mode	Purpose	Game Mode
Focus Pocus	Attention training game	Use the Neuro Sky Mind Wave headband to collect EEG signals and calculate focus and relaxation states in real-time.	Aimed at children with ADHD to enhance cognitive regulation ability.	Players control the movement of objects through focus or generate patterns through the relaxation state, and the task difficulty is dynamically adjusted according to EEG feedback.
Affective Space Shooter	Emotion-driven shooting game	Recognize emotions through frequency domain features, and the emotion signals assist keyboard or joystick input to adjust game parameters.	Study the impact of EEG emotion recognition on players' performance.	The relaxation state enhances the shield, the stress state increases the firing rate but reduces the accuracy, and the enemy difficulty changes with emotional fluctuations.
Invaders Reloaded	3D space shooting game	The focus measured by the EEG headband improves the weapon speed and power, combined with traditional controls.	For entertainment and brain training, aimed at shooting game enthusiasts.	The higher the focus level, the stronger the weapon performance and the game difficulty is adaptively adjusted.

- Emotion-driven plot advancement realizes the dynamic switching or unlocking of plot branches when the player's emotions fluctuate by correlating the player's emotional changes with plot nodes, enhancing the user's sense of substitution and deepening emotional resonance. Emotion-driven plot design deepens the emotional connection between the player and the game world. (Table 2)

TABLE II. RELEVANT GAME CASES OF EMOTION-DRIVEN PLOT ADVANCEMENT

Game Name	Game type	Interaction Mode	Purpose	Game Mode
Brain-Computer Music Interfacing	Music narrative game	Use the Muse or Emotiv EEG headband to analyze α waves and β waves and classify emotional states.	Explore emotion-driven music interaction for music therapy.	Relaxed emotions generate soothing music, and excited emotions trigger intense melodies, affecting the game environment.
MindLight	Adventure-type serious game	Use the Neuro Sky Mind Wave 2 to monitor α waves and β waves and control the light brightness.	Train children's emotion management and reduce anxiety symptoms.	The relaxed state enhances the light brightness, illuminating the path or dispelling monsters; the stress state makes the light dim, increasing the threat.

- Personalized game experience. By recognizing players' emotions, customized game content and interaction methods are provided for different players to meet their personalized needs. (Table 3)

TABLE III. RELEVANT GAME CASES OF PERSONALIZED GAME EXPERIENCE

Game Name	Game Type	Interaction Mode	Purpose	Game Mode
Jurassic Golf	Competitive game	Maintain focus through the EEG headband to optimize game performance and traditional input is used for direction selection.	For entertainment and brain training, add fun with the dinosaur theme.	The game is set in a Jurassic world. Players need to control themselves not be distracted by dinosaurs and focus on golf to optimize their hitting performance.
Neuro Tower Defense	Tower defense game	Use the EEG headband to generate game energy for controlling the placement of towers and resource management.	Test players' focus ability under pressure.	Players need to use the energy generated by focus to build and charge defense towers to fight against waves of enemies. The higher the focus level, the more sufficient the energy of the defense towers, and the difficulty gradually increases.
EEG Mindroid Blink Bird	Action game	The NeuroSky MindWave Mobile controls the actions of the bird through brainwaves and blinks.	Provide a unique EEG - controlled experience.	Players control the jumping or flying of the bird through the blinks detected by the EEG headband, and can adjust gravity, column spacing, and speed.

The high ecological validity and neurophysiological specificity of EEG signals give them unique advantages in game design. By integrating EEG - based focus and other indicators into emotion recognition, the game system can capture players' emotional states in real-time. This ability not only enriches the interaction methods of games but also significantly enhances players' sense of immersion. However, existing EEG neurofeedback games still have limitations in multi-dimensional emotion analysis, dynamic adaptability, and hardware accessibility. Early EEG neurofeedback games represented by commercial products such as "Shenning Horse Racing" usually only directly map a single focus indicator (such as the intensity of β waves) to specific game parameters (such as the speed of horse racing), lacking multiple feedback mechanisms such as difficulty adaptation and plot changes. As a result, when players' emotions fluctuate, the system cannot respond through difficulty reduction, plot expansion, or reward mechanisms, leading to a disconnection between players' emotional demands and the game process and making it difficult to achieve deeper emotional interaction. Researchers are actively exploring the deep integration of multi-channel EEG devices, emotion recognition algorithms, and wearable technologies, and developing more complex signal analysis models and adaptive difficulty adjustment algorithms to construct new forms of two-way emotional dialogue and immersive interaction. This is expected not only to enhance the fun and diversity of neurofeedback games but also to bring new possibilities for the interdisciplinary application of emotion recognition technology in the interactive entertainment field. Through technology integration, the development of adaptive algorithms, and hardware optimization, the development of EEG neurofeedback games will be further promoted, helping games to achieve personalization, emotionalization, and wearability while being challenging and immersive, bringing a richer gaming experience and psychological benefits to players.

III. Design of the 3D Game Wearable Interaction System

A. Bidirectional Mapping Model between EEG Focus and Game Parameters

This paper proposes a bidirectional mapping model for EEG focus training. In the forward mapping direction, the model uses the real-time collected EEG focus data to dynamically adjust the game difficulty parameters; in the reverse mapping direction, the player's game progress and the cumulative performance of their focus are fed back to the focus assessment module. Through the interactive mapping in these two directions, the system forms a closed-loop adjustment mechanism between the player's focus state and the game environment, as shown in Figure 1.

In the forward mapping process, the system adaptively adjusts the game parameters (such as task difficulty, rhythm speed, etc.) according to the player's focus level. Specifically, when the player's EEG focus level is detected to increase, the game difficulty will be appropriately increased to provide more challenging tasks; conversely, when the focus level decreases, the game difficulty will be reduced to prevent the player from giving up due to a sense of frustration. Such dynamic difficulty adjustment helps to maintain the match between the game challenge and the player's focus ability, avoiding anxiety caused by excessive difficulty or boredom caused by too low difficulty, thus continuously maintaining the player's sense of investment and immersion.

In the reverse mapping process, the system uses the player's performance indicators in the game for focus assessment. The cumulative information such as the player's progress in completing game goals and the time or frequency of maintaining a high-focus level during this process is used to update and calibrate the focus evaluation model. By analyzing these feedback data, the system can evaluate the improvement of the player's focus level with training and adjust subsequent game training strategies accordingly (such as gradually increasing the target focus threshold or optimizing game guidance). This mechanism of using game results for feedback focus assessment ensures that the training system can be adaptively optimized according to the actual changes in the player's focus ability.

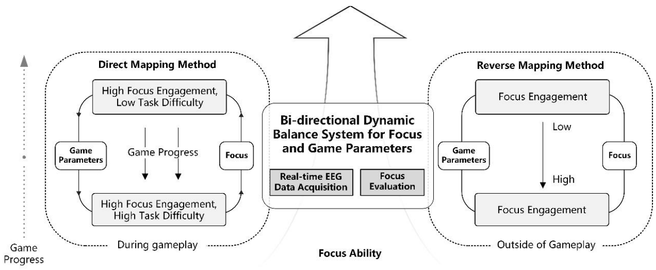

Fig. 1. Bi-directional Dynamic Balance System for Focus and Game Parameters models

This model forms a dynamic balance system through the two-way interaction between focus and game parameters. The forward mapping rewards focused behavior, and the reverse mapping adjusts the challenge according to the game process, ensuring that players can not only enjoy the game but also obtain training effects through changes in focus.

B. 3D Game Wearable Interaction System

This research designed and implemented a 3D game interaction system based on wearable EEG devices, aiming to achieve multi-dimensional dynamic game control by real-time monitoring of users' focus. The system is centered around the bidirectional mapping model and includes three main components: the wearable EEG detection module, the game control module, and the user feedback interface, as shown in Figure 2.

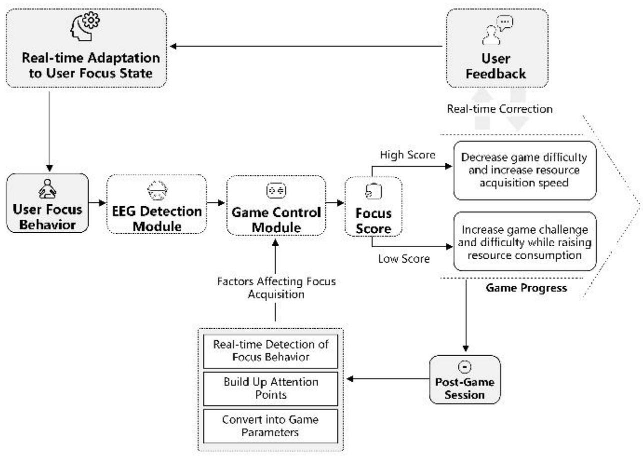

Fig. 2. Interactive System Diagram

The wearable EEG detection module, the system's core input device, collects and transmits EEG signals. To balance portability and comfort, this research uses the Neuro Sky TGAM lightweight brainwave module, which can be worn in the form of a headband or helmet. Its electrodes mainly cover the forehead area (such as the Fp1 position) to capture the frontal lobe activity signals related to focus. The original EEG data is sent to the signal processing unit in real-time via Bluetooth, ensuring data stream transmission under low-latency and high stability conditions. The design goal of this module is to provide stable and reliable EEG acquisition capabilities and be adaptable to the head shapes of different users to meet the needs of diverse application scenarios.

The game control module is the execution and logic processing layer of the system, mainly responsible for mapping focus data into specific game parameters and performing corresponding dynamic difficulty adjustments. Based on the results of brainwave extraction, a focus score (for example, in the range of 0-100) is calculated, and the game difficulty is adjusted in real-time according to the focus score through the bidirectional mapping model: when the focus is high, the system will reduce the resource consumption rate or the enemy strength; when the focus is low, it will increase the challenge. After the game is closed, if the player's focus behavior (such as reading or studying) is detected, the system will generate a "focus accumulation value" based on the focus duration and intensity, and convert it into relevant in-game parameters (such as extra health points or items) when the player re-enters the game. This module runs on the ESP32 development board and exchanges data with the game through UDP communication to ensure efficient and seamless parameter adjustment in the 3D game scene. The system pays attention to flexibility at both the hardware and software levels, facilitating application in different types of 3D game scenarios.

The user feedback interface is used to achieve the reverse influence of the game on the player, thus forming a closed-loop interaction. During the game, the current focus state and difficulty adjustment situation are fed back to the player through visual indicators or prompt sounds. After the game ends, the interface automatically generates a focus curve, the usage of focus duration, accumulation value, helping the player to timely evaluate their own attention performance. When the system detects that the player's focus level is consistently low, it provides short prompts or lightweight rewards to encourage the user to restore or enhance their attention while avoiding excessive disruption of the game immersion. During the operation of the system, the wearable EEG detection module continuously acquires EEG signals and sends them to the signal processing unit for preprocessing and feature extraction to generate a focus score. After the player exits the game, if they continue to engage in attention-required activities (such as reading or studying), the EEG module continues to monitor and record the focus data to generate a focus accumulation value. When the player enters the game again, the accumulation value is converted into in-game resources or auxiliary items, enhancing the player's advantage in the initial stage of the game. Through the player feedback interface, the focus statistical curve and reward acquisition situation are displayed, guiding the player to self-regulate the focus state and increase emotional investment. The 3D game wearable interaction system proposed in this research, through the collaborative interaction of the wearable EEG detection module, the game control module, and the user feedback interface, forms a forward and reverse mapping closed loop of focus both inside and outside the game, achieving the dual optimization of focus training and game experience.

IV. 3D Game Wearable Interaction System Based on the Bidirectional Mapping between EEG Focus and Game Parameters

A. *Game Framework Construction*

The game framework of this study is based on the dynamic impact of players' focus on the game environment and the real-time feedback of the system on players' physiological signals, aiming to break through the limitations of traditional emotion recognition games. To achieve this goal, the system uses the NeuroSky TGAM sensor to obtain users' EEG signals, quantifies and maps the degree of focus, and takes it as the core driving parameter for game interaction, as shown in Figure 3.

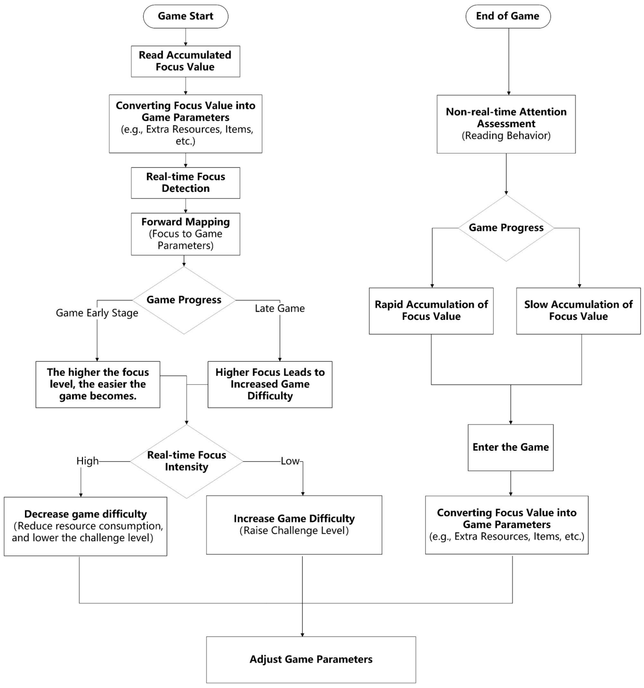

Fig. 3. Game Flow Framework Diagram

The system uses the TGAM sensor to monitor players' attention levels in real-time during daily life (such as the continuous focus duration during in-depth learning or work, or the intensity of α-waves during meditation), and converts these behavioral data into key in-game resources. Through headphone-style or head-band-style EEG devices, players' EEG signals can be integrated into the game process without their awareness, thus achieving a higher level of immersion and personalized interaction in the 3D environment. To continuously stimulate players' focus and emotional fluctuations, this study pays attention to the organic combination of challenge and reward mechanisms in level and plot design. Specifically, the system provides players with diverse challenge goals, and through the reasonable distribution of rewards and feedback, it forms a predictable (yet with a certain degree of uncertainty) exploration and familiarization mechanism, as well as a challenge-and-reward cycle. This design not only enhances the fun and uniqueness of the game but also provides a measurable experimental scenario for verifying the emotional interaction model based on EEG-based focus. According to the pyramid structure of game interaction design[9], a rich and complete interaction mechanism needs to meet three levels from the basic level, the mechanism level to the emotional level when designing interactions. At the basic level, the design focus is to ensure that users can smoothly input and operate, and provide necessary feedback to ensure the smoothness of interaction; at the mechanism level, it is necessary to maintain players' continuous interest and goal orientation through reasonable system rules and challenge settings; while at the emotional level, it emphasizes guiding players to establish a deeper emotional connection and immersive experience during the game through narrative elements, visual interpretations, and sound effects. Only when these three levels support each other and cooperate organically can a game interaction system with both playability and emotional depth be created, as shown in Figure 4.

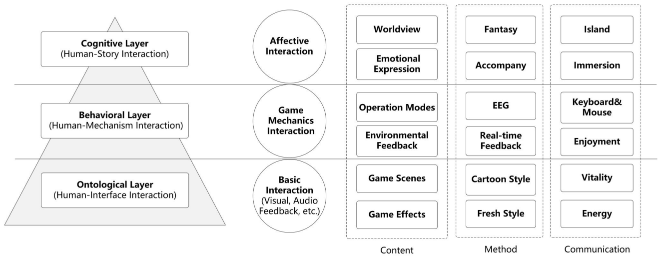

Fig. 4. Interactive Design Relationship Diagram

B. Game Player Usage Process

At the game startup stage, the system will use progressive guiding tasks to help players familiarize themselves with the operation interface and the focus control mechanism. Players need to engage in focused activities in real life to accumulate relevant focus energy. The TGAM sensor quantifies the duration and quality of focus, accumulates "focus energy", and converts it into virtual resources when the game is launched next time. During the game, the system provides dynamic positive and negative feedback by real-time monitoring of players' focus levels; a high-focus state triggers a "flow burst", manifested as an improvement in resource production efficiency and the unlocking of hidden narratives; while distracted attention leads to "cognitive entropy increase", resulting in accelerated resource consumption and dynamic scene deterioration. At the same time, obtaining important resources in the game requires consuming a corresponding amount of "focus energy". When players collect a small amount of "focus energy", the development of the game will be severely restricted, forcing players to engage in focused behaviors. As the game progresses, the system gradually increases the requirements for players' focus levels and maintains the balance between challenge and game experience through a nonlinear resource conversion curve (initially, 1:3 (minutes: energy units), later 3:1) and a dynamic difficulty adjustment mechanism.

When it is detected, that players have accumulated focus energy in daily life, the energy in the game is continuously converted into resources, and these resources participate in most survival behaviors in the game; when players click on a building, they can use focus energy to increase the production efficiency of resources related to the current building. At the same time, in the main town buildings, focus energy can be used to increase the number of NPCs in the game to expand the scale of the game. At the same time, the improvement of players' focus levels during the game can also correspondingly increase the efficiency of collection activities in the game. This data interaction process realizes the real-time synchronization between players' focus levels and game content, enhancing the interactivity and immersion of the game, as shown in Figure 5.

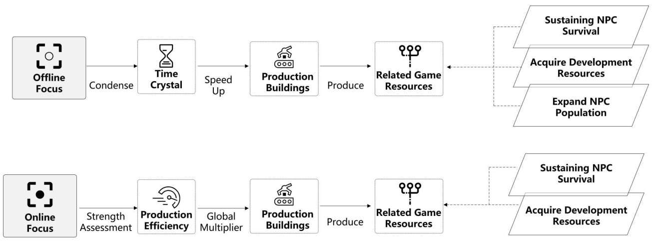

Fig. 5. Diagram of Focus Influence on Game Content in Different Modes

C. Interactive Interface and Character Scene Construction

The game is set in a fantasy-filled island world. Players act as the controllers of the island elves and influence the game's resource development efficiency and acquisition through their own focus levels (Figure 6). The game emphasizes players' independent exploration and emotional experience, weakens competitiveness, and encourages players to immerse themselves in the game world in a relaxed and free atmosphere, interact deeply with NPCs, and feel the close integration of emotions and experiences in the game. The game uses the simulation business game Demo "Cropout" in UE5 for secondary development. Cropout is an isometric view casual RTS game example project that demonstrates the best practices for building cross-platform works. It adopts a farm management game style suitable for all ages, suitable for beginners, educators, and anyone who wants to learn to make such games. Functions related to focus collection and detection are introduced into Cropout, and the relevant characters and scenes are modified as needed. The interaction logic between characters and scenes and the AI behavior is also modified to adapt to the impact of focus.

The interactive interface is designed to be simple and intuitive, with the focus display highlighted. In the interface, two icons are used to represent the menu and the connection status of the device, and a color block above the screen is used to represent the fluctuations in the player's focus energy detected, visually displaying the player's focus value in real-time, so that players can clearly understand the impact of their emotional states on the game. A numerical slot for relevant focus energy is also added to the resource quantity component in the upper left corner. The character design pays attention to details and expressiveness, enhancing the vitality of the characters and emotional transmission through rich actions.

D. Adaptation and Optimization of EEG Focus Recognition Devices

This study selects the TGAM module as the EEG signal acquisition device. This module integrates components such as Bluetooth communication, brain-wave processing, and ear-clip sensors, and has the characteristics of small size, low power consumption, and stable data transmission, which can meet the requirements of mobility and real-time in the game scene. To ensure a seamless connection between the hardware and the game system, the system is equipped with an ESP32 development board , a dedicated adaptation program is developed for quickly collecting, parsing, and transmitting EEG data.

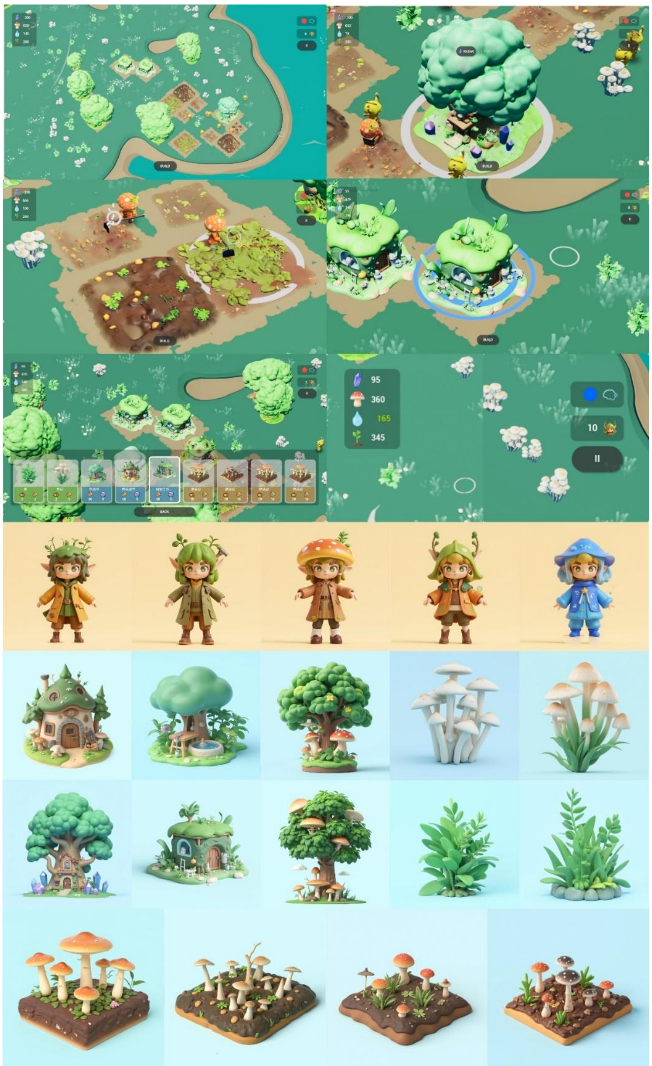

Fig. 6. Game scene design

At the hardware communication level, the TGAM sends the preprocessed EEG data to the ESP32 via Bluetooth. The ESP32 encapsulates the data into UDP packets and transmits them to the game server or host. After receiving the data, the game end can immediately parse it and feedback on the corresponding interaction instructions. Although UDP is an unreliable transmission protocol, in the application scenario of this study, by sending data at short time intervals and in an incremental manner, the impact of packet loss on the overall interaction performance can be reduced while maximizing real-time performance. If there is a requirement for the reliability of key data, a simple resending or verification mechanism can be added to the application layer for supplementation. To make the EEG signal acquisition more accurate and reduce noise interference caused by improper wearing, this study has iterated and tested the fixing methods of the headband or ear-clip of the device many times. Finally, a head-band-style wearing scheme that conforms to ergonomics is selected, and an adjustable positioning structure is added at the contact position between the sensor and the skin to meet the requirements of stable wearing under different head shapes and hairstyles. In actual tests, by optimizing the electrode contact area and pressure distribution, the noise interference caused by signal jitter during movement and poor skin contact is effectively reduced.

Some of the code for this program is as follows:

```
void read_serial_data()
{
   while (true) {
    if (ReadOneByte() == 0xAA) {
    if (ReadOneByte() == 0xAA) {
    payloadLength = ReadOneByte();
     if (payloadLength == 0x20) {
     generatedChecksum = 0;
     for (int i = 0; i < payloadLength; i++) {
     payloadData[i] = ReadOneByte();
     generatedChecksum += payloadDa-ta[i];
          }
     checksum = ReadOneByte();
     generatedChecksum = (~generatedChecksum) &
0xff;
     if (checksum == generatedChecksum) {
     signalquality = 0;
     attention = 0;
     signalquality = payloadData[1];
     attention = payloadData[29];
     meditation = payloadData[31];
     accumulatedAttention += attention; #endif }
          break;}
        }
      }
   }
}
void udpTask(void *pvParameters)
{
   char localPacketBuffer[MAX_PACKET_SIZE + 1];
   for (;;) {
   int packetSize = Udp.parsePacket();
   if (packetSize) {
      if (packetSize > MAX_PACKET_SIZE) {
      Serial.println("Received packet size exceeds buffer
size.");
         Udp.flush();
         continue;}
     memset(localPacketBuffer, 0,
sizeof(localPacketBuffer));
     int n = Udp.read(localPacketBuffer, pack-etSize);
     localPacketBuffer[n] = '\0';
     Serial.print("Received:");
     Serial.println(localPacketBuffer);
     if (strcmp(localPacketBuffer, "ESP32LightOn") == 0)
{
     for (int i = 1; i <= 6; i++) {
     digitalWrite(LED1, HIGH);
      vTaskDelay(pdMS_TO_TICKS(100));
      digitalWrite(LED1, LOW);
      vTaskDelay(pdMS_TO_TICKS(100)); }
     }
```

```
        char sendBuffer[50];
        snprintf(sendBuffer, sizeof(sendBuffer), "%lu", accumulatedAttention);
        if (Udp.beginPacket(ComputerIP, 3002) == 0) {
        Serial.println("Failed to start UDP packet.");
        continue; }
          Udp.print(sendBuffer);
          if (Udp.endPacket() == 0) {
         Serial.println("Failed to send UDP packet."); }
            accumulatedAttention = 0; }
         }
         vTaskDelay(pdMS_TO_TICKS(10)); }
    }
```

E. Wearable Product Prototype Making and Testing

This research iterated and tested the appearance and ergonomic design of the wearable EEG device multiple times. Based on the design concept of intelligent wearable devices and futuristic headgear, the system finally adopted a wrap- around headband structure, and a series of ergonomic, lightweight, and aesthetic improvement schemes were carried out on this basis, as shown in Figure 7. To ensure comfort after wearing and the accuracy of data collection, the layout and tightness of the electrodes on the left and right earlobes and the forehead were optimized.

Fig. 7. Wearable product prototype

The parts of the human body that need to be in contact for EEG extraction in the kit are the left and right earlobes and the forehead, which are ear clips and iron pieces respectively. In terms of function realization, after wearing, the brainwave state of the player is detected through the extended ear clips and the electrodes hidden in the headband. After the development board successfully connects the kit and the computer, the visualized EEG data and the converted focus values can be seen in the game program, and the strength of the focused brainwaves can be controlled at the required moments to interact with the game environment.

To verify the combined effect of the wearable EEG device and the game environment, this research conducted multiple rounds of tests on the following key modules, including the character movement module, emotion recognition module, data reading module, character interaction module, character skill module, and performance aspects. The comprehensive test results show that each module can operate stably and meet the prototype design goals. The feedback mechanism of character behavior driven by focus is logically clear and responds promptly. The wrap-around headband and ear-clip form can maintain good wearing comfort and data collection stability in most usage scenarios, laying a foundation for subsequent large-scale experiments and further human-computer interaction research.

V. CONCLUSION

This paper constructed a wearable interaction system for 3D games based on the bidirectional mapping model between EEG focus and game parameters. Through design practice and prototype testing, the effectiveness and feasibility of this system in balancing the game experience and attention training were verified. The game achieved real-time coupling with the player's attention level in terms of dynamic difficulty and resource allocation, and through a closed-loop incentive mechanism, it encouraged players to maintain a high level of focus in non-game scenarios, thereby enhancing the game immersion and the user's focus regulation ability. The research results show that this method has certain theoretical and practical value in the fields of cognitive training and educational games based on brain-computer interfaces.

Although this research has achieved preliminary results in model construction and system implementation, there are still the following deficiencies and challenges that need further in-depth research. EEG signal acquisition is affected by individual differences and noise, the universality of model parameters is insufficient, and single-channel device limitations pose challenges, resulting in fluctuations in focus scores, insufficient adjustment stability, and limited evaluation depth. In the future, more precise, immersive, and user-friendly game experiences will be created by optimizing hardware acquisition, improving the adaptive interaction mechanism, and expanding multi-modal perception, promoting the innovative development of brain-computer interface technology in the fields of interactive entertainment and affective computing.

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