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A Type of Human-Computer Collaborative Device Suitable for Children's Reading

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Abstract. In 2023, addressing the critical challenge of global children's reading difficulties, this study introduces an innovative, device-based interactive reading solution tailored for children with reading and arithmetic challenges. This device, integrating human-computer collaboration technology, aims to offer an intuitive and personalized learning experience to over 90% of developmentally challenged children in low- and middle-income countries [1]. The study elaborates on the usage of "human-computer collaborative children's books" and the interactive devices designed for specific reading content. It details the software and hardware design and user experience, including real-world usage scenarios. Compared to existing methods, this approach not only enhances children's reading and comprehension skills but also increases their engagement and interest through interactive games and activities. The effectiveness of the reading device is demonstrated through user experience and feedback.

Keywords. Children,Reading Difficulties, Human-Computer Collaboration, Interactive Reading, Interactive Devices

1. Introduction

In traditional children's reading methods, the process involves recognizing words, understanding meanings, decoding, and encoding. However, children with reading difficulties often struggle in these areas. Despite the assistance of illustrations, they may still find it challenging to grasp the context and meaning of texts, necessitating more time and effort to process information. Such challenges can impact their confidence, motivation to learn, and ultimately, their physical and mental health.

The development of reading materials for children with reading difficulties, both domestically and internationally, has primarily focused on digital interactive reading and non-digital child reading. Related applications include theories of reading mental delay, reading content therapy, and the application of psycholinguistics. At the technical implementation level, developments include interactive reading social devices, interactive books, digital interactions, and picture interactive methods involving joint reading by adults and children. J. Cortazar (2023) explored the use of an interactive social robot table to aid children with ADHD in maintaining focus during reading,

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offering a tool that operates independently of teacher or parent involvement. Mücahit Durmaz and Fatih Çetin Çetinkaya (2022) investigated the effects of interactive reading activities on narrative skills, noting improvements in children's expressive language skills and vocabulary expansion. [2] N. Kucirkova (2019) examined the use of digital books by children and the resulting changes in parent-child interactions, providing new insights into digital book utilization. [3] Our survey research indicates that a low-cost, small-scale production model can rapidly offer solutions to enhance children's reading efficiency. This model also provides design and services for those unable to afford high-cost electronic books, with reading difficulties being addressed through human-computer collaborative interactions.

In Section 2, we introduce somatosensory reading materials based on human-computer interaction, focusing on the main characteristics and challenges faced by children with reading difficulties. We also emphasize the ethical considerations and protective measures for participants' identities during the experimental process. Section 3 details the design process of the human-computer collaborative children's book. Section 4 elaborates on our conceptual framework and the development of hardware and software. In Section 5, we present actual user research, demonstrating user interactions with the application and their responses and feedback during usage. Finally, Section 6 discusses the limitations of the current design of human-computer collaborative children's books and offers insights and future research directions.

2. Human-Machine Collaborative Reading

The advancement of human-computer interaction technology has broadened its application in medical and educational fields. Notably, in treating childhood autism, attention disorders, depression, and anxiety, this technology has demonstrated significant potential [4][5]. However, reading difficulties remain a commonly overlooked issue in everyday life and learning. Despite the effectiveness of psychological counseling, many parents remain hesitant about it. With societal and economic development, and the rising awareness of education and mental health, there is a growing demand for innovative solutions. To address this, we propose a novel concept: "human-machine collaborative children's literature." This concept integrates human-computer interaction technology to enhance children's reading interest. Unlike traditional books, it incorporates synesthetic interaction technology, offering a unique, enjoyable, and interactive reading experience. Our user research, including on-site investigations and interviews, indicates a strong interest in this new e-book format. Our research focuses on three key areas: (1) designing the appearance and inner pages of the literature, incorporating sensing systems; (2) developing interactive features like temperature-sensitive color changes, pressure-sensing, light-controlled deformations, and olfactory interactions, alongside app-based interactions such as audio, video, and images; (3) constructing a comprehensive interactive system to support all functionalities of the literature. We believe these interactive experiences will significantly aid in overcoming reading difficulties, enhancing reading interest and skills, and offering personalized learning for children with special needs, thereby positively impacting the educational sector and society.

3. Design Process

Prior to the development of interactive paragraphs, we engaged in extensive discussions with experts to validate the rationality and feasibility of our concepts. We also consulted mentors on various design options to align our approach with our research objectives. To cater to the diverse needs of children with reading difficulties, we conducted detailed user research to understand their specific needs and expectations. This research and dialogue informed our design process and objectives, ensuring the development of a product that meets the needs of our target audience.

3.1. User Survey

Consultations with five child mental health experts (average age 46, with over 5 years of experience) from three medical institutions in Guangzhou highlighted the importance of reading in enhancing children's cognitive and thinking abilities. They recommended incorporating engaging animations, pictures, interactive games, and instructional videos to foster children's reading interest and knowledge. Additionally, they suggested creating platforms for children to engage in creative activities like story writing, voice dubbing, and coloring. A progress feedback system for parents and teachers was also proposed to monitor children's learning progress and reading habits, enabling more targeted support.

3.2. Design Objectives

Our research emphasizes knowledge acquisition through synesthetic interactive experiences and focuses on user preferences for this mode of interaction. Based on preliminary data and discussions with child psychologists, we established two key objectives: (1) providing interactive experiences and real-time feedback during reading; (2) developing a portable, everyday-integrated reading tool to minimize constraints related to reading conditions.

4. Design Process

In our initial design research, we developed a textual story model to outline the conceptual framework of the reading content, comprising hardware and software components. The hardware aims to engage users in reading and creation through various synesthetic interactive modes, while the software facilitates access to reading resources and enables real-time user feedback collection, such as reading chapters, duration, and efficiency. These components are interconnected via Bluetooth technology.

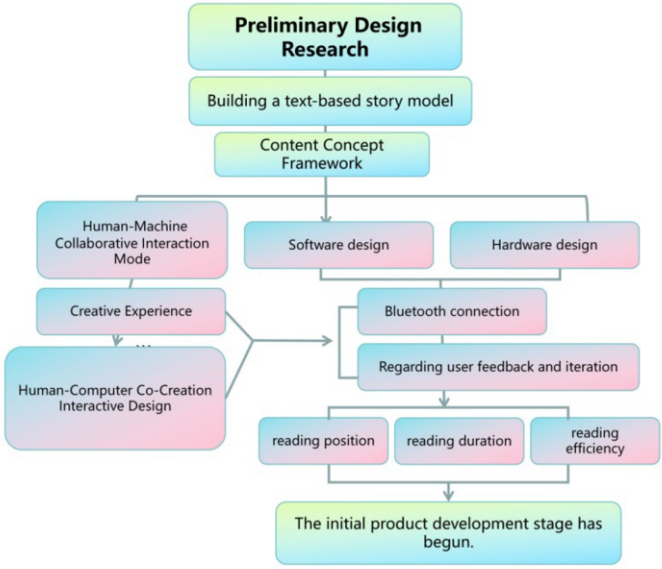

Figure 1: Conceptual Framework of Content and Design

4.1. Software Design

We developed an application offering resources like videos, music, and images to aid reading progress. Its standout feature is a gamified testing function, enabling children to assess their knowledge and generate personalized learning data. The app also supports user interaction and experience sharing. Our multisensory interactive books, designed for use in a relaxed environment, aim to enhance reading interaction by combining mobile technology with traditional books, thereby improving educational resource distribution for children with reading disabilities.

Figure 2: App Interface Processing Options and User Feedback

4.2. Hardware Design

To provide a novel human-computer interactive multisensory feedback experience, we designed a hardware device primarily composed of various sensing technologies embedded in books. These technologies include temperature-sensitive color-changing materials [4], touch-sound generation mechanisms [5], [6], sound-image alignment, and text integration [7], as well as a card-joining game that continues the story through olfactory elements. All these features aim to simulate real-life objects and natural laws in the form of stories. To further enhance this experience, we introduced app digital technology to provide interactive presentations of videos, music, images, and games for users through computers, software, and database tools. To achieve these functions, we adopted sensor technologies such as Strain Gauge Pressure Sensors [11], reversible thermochromic materials [12], and olfactory visualization techniques [13].

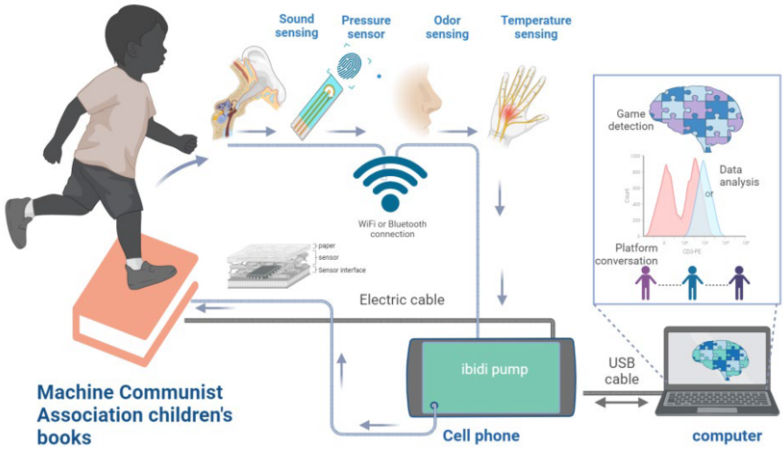

Figure 3: Hardware Design and Structural Drawings

Figure 4: User Experience Scenario

4.3. Function and Principle

In the design of human-computer collaborative children's reading materials, the integration of embedded sensor technology has emerged as an innovative method to

enhance the user's reading experience. This technology utilizes vibrations of sound waves, variations in light intensity or wavelength, specific chemical reactions, and changes in color through liquid crystal thermal induction and thermochromic ink to create a diverse range of sensory experiences. For instance, when a user touches the book, the embedded sensors can produce sounds corresponding to the objects or scenes depicted, thereby stimulating the user's imagination. This imaginative experience is further augmented by comparing and associating these sounds with the images in the book, as well as through their rearrangement.

To facilitate this profound interactive experience, sensors embedded within the book are capable of tracking the user's reading progress in real-time and establishing a deep connection with the videos, images, and sound information presented in the accompanying app. Additionally, the app offers test mini-games related to the reading content and enables interactive communication among users. Utilizing software development tools, we can directly access and analyze user data.

In this human-computer collaborative reading experience for children, users require only a suitable reading environment and a mobile app. By activating the Bluetooth or WiFi function on their mobile device, the app can record the user's reading status and interact with the book's sensors in real-time. The recognition of content within the book is primarily achieved through pressure sensing information when pages are turned, which can be synchronized with the app's content. This synchronization facilitates a deep interaction with the book's sound, temperature, and olfactory data.

5. Initial User Research

To further investigate the relationship between sensor technology and user experience in human-computer collaborative interactive books, we conducted a series of preliminary user studies. [4] The study involved 15 representative child users, selected in collaboration with a children's attention medical training institution. This group comprised 7 boys (designated as B1 to B7) and 8 girls (designated as G1 to G8), with an average age of 5 years. Among these participants, 5 children exhibited typical features of reading disabilities, facing significant challenges in word recognition, understanding sentence structure and text meaning, and in the decoding and encoding processes. These difficulties impacted their reading fluency and comprehension. Additionally, they struggled with maintaining focus and retaining the content they read, further exacerbating their reading challenges. Emotional and motivational aspects were also considered; children with persistent reading difficulties often experienced frustration, leading to decreased interest and motivation in reading activities. Through observation and analysis of these children with special needs, we aimed to gain a deeper understanding of the potential and effectiveness of human-computer collaborative interactive books in addressing these reading challenges. With the participants' informed consent, we meticulously recorded their entire experience with the interactive books.

The data collection process was as follows:

- Preparation Stage Before Use: Prior to the children's engagement with the interactive books, we recorded their basic information, including age, gender, past reading experiences, and concentration levels.

- Observation of the Interaction Process: While the children interacted with the interactive books, we observed and documented their methods of interaction, reactions, and behavioral patterns. This included their responses to the sensing technology, changes in concentration, and reading behaviors.
- Collection of User Feedback: Post-interaction, we gathered direct feedback from the children and their guardians regarding their experiences with the interactive books. This feedback was collected through interviews or questionnaires and may include overall impressions, preferences, any difficulties or challenges faced, and suggestions for improvement.
- Data Analysis: All collected data were systematically organized and analyzed to assess the user experience of the interactive books and the effectiveness of the sensing technology, as well as its impact on the children's reading and concentration abilities.

Through this research, we aimed to gain a deeper understanding of the application potential and effectiveness of human-computer collaborative interactive books in enhancing children's reading and attention skills.

During our interactions with users, B1 and B5 commented, "After using this book, I felt as if I had immersed myself in the story, experiencing an adventure with the characters." B3's feedback was particularly insightful: "This book provides a unique feeling, as if it were tailored for me, allowing a personal connection with the content." G1 and B2 expressed high expectations for future interactive books, desiring richer story content and more diverse interactive forms. B3 elaborated, "The book not only allows me to visualize the story but also to hear the sounds and music, offering a novel reading experience." G4 and G6 shared similar sentiments: "I could almost smell the fragrances and taste the food described in the book, which was a delightful experience." However, G5 had a different perspective, noting, "The story length is a bit short, and some images are challenging to comprehend." Other participants, such as B7, B4, and B6, found the experience "quite interesting," while G2, G3, G7, and G8 felt that "the illustrations could be improved." Additionally, we consulted the parents of these children and the book's publishing distributor. The parents generally appreciated the product's ability to provide timely feedback as a major advantage. The distributor suggested that reducing material costs while maintaining effective interactive experiences could significantly enhance the market potential of such books.

5.1 Research Methods

In our study, we developed a specific process for the human-computer interactive book experience, tailored for children, with the aim of providing a seamless and enjoyable reading journey. This process encompassed establishing a tranquil and comfortable reading environment within the therapy area, offering clear instructions on product usage, enabling children to independently explore interactive books, and conducting non-intrusive observations. We meticulously recorded the children's behavioral and emotional responses and gathered feedback from both the children and their parents post-experience. This data was instrumental in assessing the efficacy of the interactive books and identifying areas for improvement, particularly for children with reading disabilities.

To gain deeper insights into user sentiments and opinions, we conducted a series of interviews. The primary focus of these interviews included: (1) users' overall assessment and impressions of human-computer collaborative interactive books; (2) their anticipations regarding future development trends and the potential value of such books; (3) their perspectives on the key differences and advantages of traditional paper books, e-books, and interactive books that utilize human-computer collaboration technology [15]. The feedback obtained from these interviews was invaluable, providing user-centric perspectives that aided in further refining our product design and enhancing its functionality.

5.2 Research Process

Table 1. Participant Scores Across Each Dimension

Participant	Sensory Experience (Questions 1-9)	Enjoyment (Questions 10-12)	Other Issues (Questions 13-14)	Total Average Score
B1	4.01	4.27	3.5	4.06
B2	3.87	4.00	3.0	3.63
...	...	...	...	...
G8	3.56	5.00	3.5	4.02
Total Average Score	3.85	4.39	3.22	3.78

Based on the data presented in Table 1, we can derive the following conclusions, exploring its potential benefits for users with reading difficulties, the educational sector, and society, while also demonstrating the rigor of our research:

We employed a quantitative scoring method, allowing participants to evaluate interactive books across four dimensions: enjoyment, sensory experience, usability, and other issues. The scoring range was from 1 to 5 points, where 1 point indicates 'very dissatisfied' and 5 points 'very satisfied'. The collected data were subjected to statistical analysis to compute the average scores for each dimension and the overall average score.

The enjoyment dimension scored the highest, with an average of 4.39 points, suggesting that children are highly satisfied with the enjoyment aspect of interactive books. This is pivotal for fostering an interest in reading. The sensory experience dimension followed with an average score of 3.78 points, indicating effective results in visual, auditory, and other sensory stimuli. The 'other issues' dimension scored the lowest, averaging 3.22 points, which may highlight areas requiring improvement in product design.

The high score in the enjoyment dimension suggests that these interactive books are effective in stimulating the reading interest of children with reading difficulties, an essential step in aiding them to overcome reading challenges. The rich sensory stimulation provided by these books can enhance children's comprehension and retention of reading material.

In summary, our research offers objective and quantifiable data support through the application of a quantitative scoring system and statistical analysis. The study encompasses multiple evaluation dimensions, thoroughly considering various aspects

of interactive books, thereby ensuring a comprehensive evaluation. Collaboration with professional children's attention medical training institutions has ensured the representativeness of the participants and the practicality of the research.

6. Limitations and Future Work

While human-computer collaboration technology has demonstrated potential in educational applications, it faces several challenges in practical implementation. One significant issue is the potential for user rejection due to its novelty, or the influence of user states within the educational environment. Additionally, limitations in sensor accuracy and data collection range may lead to suboptimal immersion experiences and compromised data integrity. Content limitations also pose a risk of insufficient data samples. To overcome these challenges, we plan to iteratively update our product, enhancing its functionality for readers with reading difficulties. This will include expanding more immersive interactive book content and continuously optimizing the application system based on user feedback, aiming to improve the overall user experience.

7. Conclusion

This research introduces a novel concept in addressing children's reading difficulties: "physical reading." This approach, integrating the application of daily life environments and comprehensive data collection feedback mechanisms, offers a unique reading and attention training method that can be implemented at home. The potential benefits of this approach are manifold, including significant enhancements in children's attention, improvement in reading difficulties, and positive impacts on children's mental health. The further development of this technology holds promise for revolutionary changes in the global field of children's mental healthcare, offering new perspectives and possibilities for treatment and educational methods.

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