Digital-Pen: An Interactive System for Correcting Writing Posture of Primary School Students

Yousheng Yao[1,2], Jiacheng Lou[3], Guanghui Huang[1(✉)], Xuesong Li[1], and Yingrui Li[2]

[1] Macau University of Science and Technology, Avenida WaiLong, Taipa 999078, Macau, China
120752037@qq.com
[2] Zhongkai University of Agriculture and Engineering, Guangzhou 510225, China
[3] Hubei University of Technology, Wuhan 430068, China

Abstract. People who write for a long time often cause shoulder-neck pain and high-low shoulders because of the unconscious and irregular writing posture, and the problem of myopia which will affect people's eye health because of being too close to the writing carrier. In this paper, we designed an interactive system for Digital-Pen, which can support writing users, especially primary school students aged 6–12, to keep the distance between the head and the writing carrier paper within a reasonable range, thereby promoting eye's healthy and protecting good eyesight, while correcting the writing posture of the writing user. Digital-Pen is a pen (smart hardware) with a sensor, it adopts infrared induction recognition technology and matches an application to record the writing posture, writing time, number of words written and the number of irregular writing behaviors, so as to remind and correct the writing posture of the writing user. Furthermore, the real-time date of writing can feedback score list sharing on the internet to alleviate and improve boredom of writing. We also received preliminary user experience feedback of Digital-Pen. The results showed that most writing users have high interest in and acceptance of the Digital-Pen, and they gain more confidence to correct their writing posture.

Keywords: Digital-Pen · Sensors · User healthy · User testing · Interactive system

1 Introduction

Today or in the future, people's troubles caused by health problems will always entangle our hearts. We feel helpless or even hopeless for many times. And let the health problems rage on and there is nothing we can do. For example, the current COVID-19 has made the world instantly tense, and has greatly changed the way people live and work. Another example is that the various health problems in the process of children's education, training and growth also make many new parents helpless and bring them great psychological

Y. Yao and J. Lou—The first two authors contributed equally to the article.

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confusion. With the high development of science and technology, more and more digital products have entered people's lives, using technology to change life and improve health will help people solve some of the confusion and problems. Through life experience and observation, it is not difficult to find that most writing users (especially primary school students) have always had a series of health problems in terms of writing willingness, writing strength, writing habits and writing posture. In this article, we introduced the Digital-Pen, a smart module composed of sensors and circuit boards, equipped with an application (the smart module and the application can be connected by Bluetooth or WI-FI), which was combined in the pen tube with the artistic aesthetic, and which was an interactive system designed for communication between people and the pen naturally. In the process of interacting with the Digital-Pen, the user performs face learning and inputs related information on the application, setting the corresponding healthy writing program, such as writing time, writing posture.

and writing ranking. Meanwhile, the intelligent hardware also judges whether the user's posture, the distance between the eyes and the pen, and the writing force are within a reasonable range based on the infrared sensor face image recognition technology learned by the sensor and neural network. If the user performs wrong posture and writing habits, the Digital-Pen will remind the user to correct the posture, control the duration and improve the disgust through indenting pen tip automatically and the real-time feedback from the application. In order to design and create an effective Digital-Pen interactive system, we conducted in-depth interviews, discussions with experts, and made a prototype of the system. Also, In order to evaluate user's views of the Digital-Pen interactive system, we selected 5 pairs of parent-child users and conducted preliminary user tests. The results show that parents are willing to use the Digital-Pen for their children during the writing process, and find that the design of the automatic indentation of the pen tip after infrared recognition of the face can help children correct their writing posture and protect their eyesight, and while providing feedback on the writing time and correcting posture ranking will greatly improve children's aversion to writing. After about 30 days of sample testing experiments, parent-child users generally reported that the Digital-Pen interactive system had greatly improved children's writing posture, writing effect and writing mood. The main contributions of our work are: (1) Created an interactive system, including an intelligent module and an application, which improved users' healthy writing posture and protected their eyesight with real-time feedback when primary school students were writing; (2) Cultivated children's interest in writing through feedback on writing content, writing effect and leaderboard on the internet; (3) In order to demonstrate the effectiveness of the Digital-Pen interactive system, we not only interviewed medical experts and design professors, but also obtained positive feedback from parent-child users in the process of using prototype of the system. (see Fig. 1).

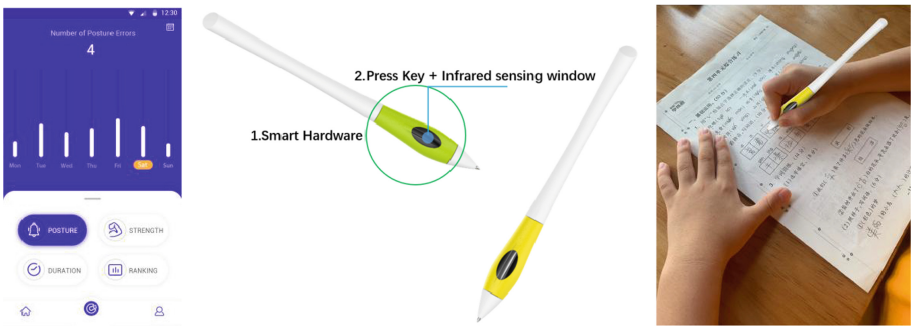

Fig. 1. App, Smart hardware, and Writing posture.

2 Related Work

In this section, we briefly review three relevant studies, including the smart pens, the issue of health hazards in children's writing, and data and explanations on correct writing posture in primary school students.

2.1 Research on Smart Pen

There have been some researches on the application of smart pens in related systems in the world. There are two fields here, one is the field of intelligent technology, and the other is the field of technical application. Goonetilleke R S et al. discussed the impact of pen design on drawing and writing performance, and he believed that speed, comfort and writing ability are important indicators for evaluating a pen [1]. Romat H, et al. designed the Flashpen, a digital pen for VR whose sensing principle provided accurate digitized handwriting and complex drawing, including small, fast turns [2]. Stocco L J, et al. designed a hybrid robot called the Twin-Pantograph. Since the Twin-Pantograph produced the best results, its design has been improved to address practical limitations, and it was implemented as a haptic pen [3]. Heimann-Steinert A, et al. studied digital pen technology for cognitive assessment of older adults, compared the difference in recognition performance between a digital pen and a regular pencil in performing the Trail Making Test [4]. Abidin N R, Anggoro S. studied the impact of Smart-Pen on students who must have the skills on the 21st century, namely collaboration, communication, critical thinking and creativity (4Cs) [5]. Wu P, Fei L, Li S, et al. specialized researched in recognition network on Pen Holding Pose (PHHP) [6]. St-Pierre N R. carried out research, design and analysis of pens in the field of animal science [7]. Shintani M, et al. designed the handwritten letter recognition digital pen, which is a new digital pen that contains multiple miniature force sensors, the force information, accelerometer and gyroscope sensors applied around the tip of the pen during the writing process are used for real-time recognition character, measured the force vector of the pen tip [8]. On the basis of previous work, we further explored the benefits of sensor technology for smart hardware pens. The interactive system is designed to provide real-time feedback to correct posture and share the function of writing grades, so as to help primary school students solved the hidden health risks in the writing process.

2.2 Research on the Hidden Health Problems in the Writing Process of Primary School Students

Focusing on the writing posture of primary school students, the research team randomly collected and investigated about 300 writing samples of primary school students in primary schools in Guangzhou and Shenzhen, and conducted a certain number of interviews with primary school students, parents and teachers. When observing the writing process of primary school students repeatedly, there were general problems for most of them, which are that the eyes are too close to the surface of the paper, that may lead to myopia, the wrong posture of writing and sitting, skeletal deformities, and psychological problems such as boredom and resistance to writing behavior. Lin Wenjian, vice-principal of Binhai Primary School in Bao'an District, Shenzhen, believed that the long-term incorrect writing posture of primary school students was prone to myopia, sloping shoulders, hunched back, and curvature of the spine, which affected the eyesight, bone health and learning efficiency of primary school students [9]. From the perspective of writing and reading, myopia may be caused by the interaction between poor habits on eyes and poor reading posture when reading and writing [10]. Dutta S. believed that the ergonomic design of writing desks may pose health hazards to primary school students in classroom activities [11]. A review of the literature found that there is almost still a blank in the related research fields on that poor writing habits will affect the eye health and skeletal deformities of primary school users. Inspired by the above-mentioned articles by experts and scholars, this paper aimed to explore the possibility of design and technology of Digital-pen to solve the hidden health problems in children's writing process, so as to support parents to guide their children to write more comfortably in a healthy sitting posture, as well as to improve children's healthy habits of writing and develop their interest in writing, etc. (see Fig. 2).

Fig. 2. Health hazards in children's writing process.

2.3 The Data and Explanation of the Correct Writing Posture of Primary School Students

According to the content of the first grade Chinese textbook and writing songs of the Chinese Education Edition, the writing posture is emphasized: when writing, pay attention to sitting upright, and the stroke order rules are from top to bottom, first horizontal and then vertical [11]. Lin Wenjian suggested that the correct writing posture can refer to the method of calligraphy educator Hu Yifan: (1) While reading and writing, keep your eyes one foot away from the book. (2) The finger holding the pen should be one inch away from the tip of the pen. The tip that is too short should be discarded. (3) Readers and writers must sit upright, and keep a one-punch distance between the chest and the desk [9]. (see Fig. 3).

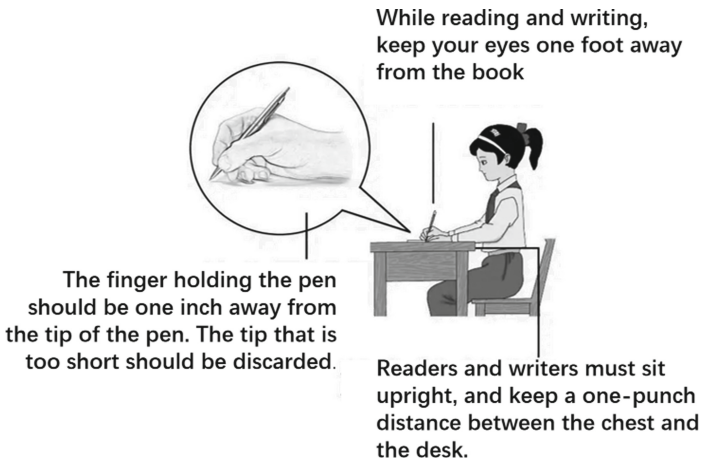

Fig. 3. The explanation of the correct writing posture of primary school students.

3 Design Process of the Digital-Pen Interactive System

In the process of designed and built the Digital-Pen interactive system, we invited ophthalmologists, orthopaedics and design experts to jointly conduct the design exploration.

3.1 Design Exploration with Experts

We conducted in-depth discussions with 3 experts (1F, 2M, average age = 45) who are Ophthalmologist D1 from China Guangzhou Eye Center, Orthopedics Center Doctor D2 and Design Professor D3 from Zhejiang University, there were many years of work experience in related fields for them. Design study sessions usually lasted more than 90 min, starting from the introduction of preliminary design concepts, to discussions and exchanges with experts, sharing their previous work experience and their views on

our design prototypes, one by one. They agreed with the starting point of the design: "The impact of primary school students' writing posture on vision and bone health is an objective problem, and it will be more feasible and effective to design and practice through the way of technology and interaction." and made recommendations as follows: (i) D1 and D2 recommended to carry out education and training for primary school students on the correct posture for writing. (ii) D1, D2 and D3 all proposed that when primary school students writing with too much force and their eyes being too close, error correction feedback should be given timely. (iii) D1, D2, and D3 all found that children were resistant and bored with writing. (iv) D3 stated that parents expect to know the data related to children's writing, and suggested that we reduce the production cost of the product system and improve the design aesthetics. (v) D1, D2 and D3 expressed how to improve the interest of primary school students in writing behavior will become a difficult point in the interactive system, because parents often require children to write while children always have resisting behaviors.

3.2 Design Goals

In order to solve the hidden health problems of primary school students in the process of writing, based on the problem discussion meeting with experts and previous related work, we set several key goals for the design of an interactive system: (1) Real-time feedback of data during the writing process to avoid constant wrong postures that affect children's vision and bone health. As shown in (ii) in 3.1, timely error-correcting feedback may be an important means of guiding children's writing posture and eyes health. (2) More intuitive interaction, data presentation and game-style leaderboards in the application, which not only enhance parent-child interaction, but also help to enhance children's interest in writing. As proposed in (iii) and (v) in 3.1, the conflicting psychological interaction between parents and children about writing behavior is an important innovation way, because it improves children's psychological health problems caused by resistance to writing. (3) It is an important issue for reducing the production cost of the product system and improving the design aesthetics, because it involves the manufacturing and acceptance from market of the interactive system.

4 System Design

Based on in-depth discussions with experts, we developed the prototype of Digital-Pen. The Digital-Pen consists of both hardware and software (see Fig. 4). The hardware was a pen with infrared sensing, force point detection, duration detection functions, pressing structure and the appearance of small tadpole design. The software was an application that provides real-time feedback on correctly writing habits, wrong behaviors and writing rankings. Software and hardware are connected via Bluetooth or Wi-Fi.

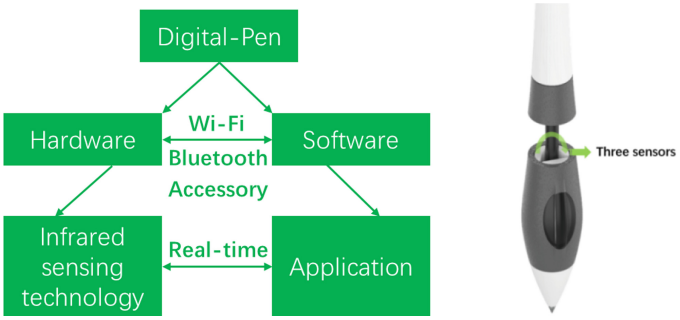

Fig. 4. Conceptual framework of Digital-Pen.

4.1 Application Design of the Software System

The application (APP) sets the parent terminal and the actual running terminal to work together. The parent sets the goal through the parent terminal, and the child completes the goal through the actual running terminal, thereby realizing the behavior of guiding the child to start writing (posture, strength, duration, and sharing the ranking page) by using the application (APP) to select the smart hardware mode (see Fig. 5).In addition, the app works in conjunction with smart hardware, and when the parent operates, the app will display real-time data and pop-up error times reminders according to the parent's request (see Fig. 5a). For example, if the smart hardware recognizes a wrong gesture from a child's writing, it will send a signal to the app, showing real-time reminders of the problem and corrections. At the same time, after the child's writing is completed, both parents and children can use the application (APP) to grasp the transcript of the writing time and the number of times of correcting wrong postures, and obtain the Internet score ranking list and publish it to the personal self-media platform for sharing, so as to improve adverse mental health emotions caused by children's resistance to writing(see Fig. 5d).

Fig. 5. Interface of Digital-Pen APP (a) Number of Posture Errors (b) Writing Strength Chart (c) Writing Times of the day (d) Your Ranking.

4.2 Design of Smart Hardware Pen

The smart hardware of Digital-Pen is entirely made of silicone material that satisfies relative hardness, and integrates a force sensor, an infrared sensor (when the wrong posture occurs, the pen tip will automatically retract to stop writing) and a mechanical pressing structure (re-pull the pen tip out)) to achieve the functionality of multiple components (see Fig. 6a). At the same time, we have carried out ergonomic considerations for the correct posture of holding the pen. The thumb, index finger and middle finger clamp the holding position of pen, and the pen holder rests on the tiger's mouth of the hand to fix the pen state (see Fig. 6b). In terms of the shape of the smart hardware of Digital-Pen, we took inspiration from small tadpoles, which are unique, smart, cute, round and soft to meet children's emotional and psychological demands (see Fig. 6c).

Fig. 6. Design of Smart Hardware Pen (a) Smart hardware of Digital-Pen (b) Correct posture for holding a pen (c) Colorful Tadpoles.

4.3 Communication and Data Processing of Hardware and Software

We used KEEP-REAL Sensors (Guangzhou KEEP-REAL Digital Technology Co., Ltd.) to provide miniature custom board-mounted digital output pressure sensors and infrared sensors as development boards, which can collect and transmit sensor data and infrared sensor face recognition. After KEEP-REAL Sensors sent digital conversion signals to the back-end server through the Wi-Fi module, and the front-end page on the mobile phone obtained the digital conversion signals on the back-end server through HTTP requests, the smart hardware and application started to work. As the infrared sensor face recognition in smart hardware, we used KEEP-REAL Sensors customized miniature infrared sensors on both the left and right sides of the mechanical buttons (which can meet the writing habits of users written by left and right hands).When the user was too close and exceeded the threshold, the infrared sensor recognizes the face and the pen tip will automatically retract and stop writing. The real-time state outputted was switched to an electrical signal. We can judge whether the user's face was recognized according to high level or low level, so as to remind the user whether the writing posture was corrected. It will be fed back to the app to display the number of wrong postures for both parents and children to learn and reference.

5 Preliminary User Research

We conducted a preliminary user study to confirm how parents and children interacted with the Digital-Pen interactive system and their perceptions of the Digital-Pen. We randomly invited 5 groups of parents and child users A, B, C, D, E (3F, 2M, average age = 30.5) in the local community, and all parents who evaluated the design of interactive systems(pA, pB, pC, pD, pE) had the experience of accompany the child to write. All steps were carried out under the guidance of designers and experimenters.

5.1 Procedure

Experiments were conducted in a writing scene. First, we introduced the situation and design prototype of this study and how to use the system to the participants briefly. Next, participants had 60 min to experience and learn using the Digital-Pen interactive system. During this 60-min period, participants were observed fully. After Experiment, we supported participants to take the Digital-Pen home to continue the experience for 30 days. A month later, we used the Likert Scale Questionnaire (Table 1) to summarize the opinions and the experience of the participants focusing on several aspects: (1) the relationship between them and the Digital-Pen interactive system; (2) Suggestions for improvement of the Digital-Pen interactive system; (3) The difference between the traditional writing method and the Digital-Pen interactive system; (4) Whether the Digital-Pen interactive system enables users to develop correct and healthy writing habits.

5.2 Results

As the Table 1 (five-point Likert scale) showed, all participants were willing to use the Digital-Pen interactive system during writing and showed a high willingness to use the Digital-Pen interactive system. However, they showed little confidence in using the Digital-Pen interactive system to improve children's eye health and correct writing posture while writing. For example, all of A, C, D, and E indicated that the effective evaluation of a new product requires a larger base of user testing and market information feedback. A, C, and E gave 4 points in Q(ii), that they think the interaction mode of Digital-Pen is too complicated. Five groups of parents and children noted that real-time feedback was valuable during the writing process (The average score is 4.8). At the same time, They confirmed it will be particularly interesting to share the ranking of writing information on the self-media platforms (The average score is as high as 4.6). However, A and D indicated that it needs more testing and feedback to verify the effect of improving children's resistance to writing. When the participants were asked about their relationship with the Digital-Pen and suggestions for improvements, B said the Digital-Pen will be a particularly interesting new thing to remind him when making a wrong writing posture, and he can't wait to use it to record daily writing. But D was worried that the child may be curious to the real-time data of the application during the writing, which will affect the development of good writing habits. A, C and E confirmed that it was really good to remind in time, and suggested us to make more comfortable for the ergonomics of intelligent hardware. They also worried that it may be some problems in the battery life of the interactive system. Overall, all participants were willing to use

the Digital-Pen interactive system during writing, and Digital-Pen interactive system had improved the children's writing posture, writing performance and writing mood during the 30-day user test period. (See Fig. 7) The results of the study showed that the Digital-Pen interactive system was a feasible and effective way for parents to effectively obtain real-time data on children's writing and for children to develop healthy writing habits.

Table 1. Results of user questionnaire.

Questions	Female A	Female B	Female C	Male D	Male E	Average
i. Are you willing to use Digital-Pen interactive system while writing? (1:unwilling-5:willing)	**5**	**5**	**5**	**5**	**5**	**5**
ii. Is it easy for you to understand how to use Digital-Pen interactive system? (1:difficult-5:easy)	**4**	**5**	**4**	**5**	**4**	**4.4**
iii. What do you think of Digital-Pen's real-time feedback and error correction reminder when you make an incorrect action? (1:useless-5:helpful)	**5**	**5**	**4**	**5**	**5**	**4.8**
iv. Do you think writing data rankings can improve children's resistance to writing? (1:useless-5:helpful)	**4**	**5**	**5**	**4**	**5**	**4.6**
v. Do you have confidence that you can improve your child's eye health and correct writing posture by using Digital-Pen interactive system while writing? (1:unconfident-5:confident)	**4**	**5**	**4**	**4**	**4**	**4.2**

Fig. 7. Digital-Pen interactive system enabled users to develop correct and healthy writing habits during the 30-day user test period.

6 Current Limitations and Future Work

Within the presented study, we found some limitations: (1) For the cause of the epidemic, we only invited three experts as the sample to take part in our discussion. In the future, it is necessary to invite more experts to collect more important information and health knowledge; (2) It is possible that the system cannot make further design revisions based on users' feedback, because the duration of the experiment and the base of users are not enough, which may be unable to keep Long-term experience and observation of the Digital-Pen interactive system. In the future, we will improve the design of system and collect more users' experience and feedback to the Digital-Pen interactive system to make the users' experience more natural and effective. It is expected that the system production cost will be further reduced, the system functions will be simplified, and the battery life will be lengthened in the future design. We will continue to apply digital art to solve the health risks of more users who will use the product, and we will try to recruit more users to participate in the research.

7 Conclusion

A interactive system used for the Digital-Pen is studied and introduced in this paper. The system can help parents to encourage their children of primary school to form healthy writing posture when they are writing, and has real-time data feedback function to achieve Internet interaction and sharing. The Digital-Pen provides real-time feedback and error-correction based on children's writing behavior, to improve their writing habits in real-time when they are writing homework, thereby protecting vision and bone health. A preliminary study on the Digital-Pen user show that interactive system for the Digital-Pen is an important tool for parents to effectively obtain children's writing data and children to form healthy writing habits. Compared with previous work, the prototype is based on real-time data feedback and score list sharing on the internet, which supports the identification of users unhealthy writing posture and call their attention to correct. The work would provide more references for the health research of primary school students. It can be believed that the Digital-Pen can play an effective role to primary school students in solving more physical health problems such as myopia and skeletal deformities, and mental health problems caused by the new crown epidemic (COVID-19).

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