Character Alive: A Tangible Reading and Writing System for Chinese Children At-risk for Dyslexia

Min Fan
Simon Fraser University
250-13450 102 Ave, Surrey, B.C. Canada
minf@sfu.ca

Jianyu Fan
Simon Fraser University
250-13450 102 Ave, Surrey, B.C. Canada
jianyuf@sfu.ca

Alissa N. Antle
Simon Fraser University
250-13450 102 Ave, Surrey, B.C. Canada
aantle@sfu.ca

Sheng Jin
Communication University of Zhejiang
998 Xueyuan St, Hangzhou, Zhejiang, China
sjin@zjicm.edu.cn

Dongxu Yin
Communication University of Zhejiang
998 Xueyuan St, Hangzhou, Zhejiang, China
yindongxv@gmail.com

Philippe Pasquier
Simon Fraser University
250-13450 102 Ave, Surrey, B.C. Canada
pasquier@sfu.ca

ABSTRACT

This paper presents Character Alive, a tangible system designed to improve early Chinese literacy acquisition for Mandarin-speaking children at-risk for dyslexia by enabling high-level interaction. Character Alive uses the multisensory training method to teach children the reading and writing of Chinese characters and words. The core design features of our system are dynamic color cues, 2D radical cards and handwriting cards with tactile cues, and multimedia content such

CHI'19 Extended Abstracts, May 4-9, 2019, Glasgow, Scotland, UK.

ACM ISBN 978-1-4503-5971-9/19/05.
https://doi.org/10.1145/3290607.3312756

CCS CONCEPTS

• **Human-centered computing →Interaction design;** *User interface design* • **Applied computing →Education**; *Computer-assisted instruction.*

KEYWORDS

Tangible user interfaces; reading and writing acquisition; children with dyslexia; Chinese acquisition; color cues; tactile cues

Figure 1: Different kinds of vehicles in Chinese are written as 轿车 (car), 自行车 (bike), 公交车 (bus), etc. These words share an identical morpheme 车, which means 'vehicle'. At the character level, the majority of Chinese characters include a semantic radical and a phonological radical. The characters 树 (tree), 林 (forest) and 植 (plant) share an identical morpheme 木 (the semantic radical, which means wood), while the character 妈 (mother), 吗 (what) and 蚂 (ant) have an identical phonological radical 马, which is pronounced /ma3/ (number indicates tone).

as character animations. Character Alive was built on our previous work on designing tangible and augmented reality reading and writing systems for children at-risk for dyslexia in English. Our previous work has demonstrated that dynamic color cues can draw children's attention to key characteristics of letter-sound-correspondences, whereas the two-hand actions with tangible letters help children to better solve spelling tasks. We present the design rationale, the design and implementation of the Character Alive system, and the future plan on evaluating the system.

INTRODUCTION

Theories of Causes of Dyslexia in Chinese

Reading and writing competence is important for children. However, approximately 8.0% of children in China are reported to have difficulty in reading and writing Chinese characters and words [6] This specific difficulty is also referred to as dyslexia [6]. Chinese can be written in traditional and simplified characters. Regarding speaking, there are dialects such as Mandarin, Cantonese and etc. We focus on the simplified characters and Mandarin that all Chinese children need to learn at school according to the policy of Ministry of Education of China. Chinese is a morphosyllabic language [11] with 90-95% of commonly-used characters containing two or more morphemes (i.e., the smallest units that represent meanings) [7] (Fig. 1). It has four basic pitched tones. In order to read and write Chinese, children have to learn visual character symbols and their pronunciations and tones, the knowledge of which is referred to as orthography-phonology-correspondences (analogous to letter-sound-correspondences in English).

Although the causes for dyslexia in Chinese have been debated, most researchers have agreed on four poor cognitive-linguistic skills associated with dyslexia [7]. The first skill is phonological awareness (i.e., the ability to manipulate sounds in speech). Previous empirical research shows that most Chinese children with dyslexia performed significantly worse than typical children on phonological tasks such as onset and rime tasks [11]. Second, poor morphological awareness (i.e., the ability to reflect on and manipulate morphemes and word formation rules in a language) is also suggested to cause children's reading difficulties [8]. Children with dyslexia may not be able to identify patterns such as morphemes or phonological radicals within characters. Third, poor knowledge of Chinese visual orthography (i.e., how characters are visually constructed) increases children's difficulties in reading and writing [7]. Many Chinese characters look similar, which increase their visual complexity (Fig. 2). Lastly, children with dyslexia appear to have poor performances in rapid automatized naming (RAN) tasks (i.e., tasks asking children to identify items such as colors as quickly as they can) [7]. Researchers argue that RAN is related to reading fluency; and children with dyslexia need longer time to access orthographic representations from memory [7]. In addition to these cognitive-linguistic causes, other potential causes such as ADHD (attention deficit hyperactivity disorder) may reduce their learning efficacy [11].

Traditional Multisensory Instructions

Many instructions that target on one or more aspects of the cognitive linguistic skills have been

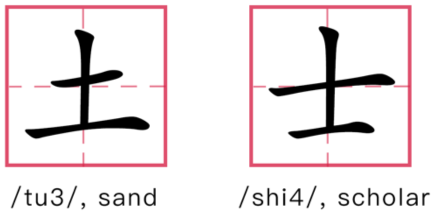

Figure 2: It is difficult for children to distinguish 土 (/tu3/, sand) and 士 (/shi4/, scholar).

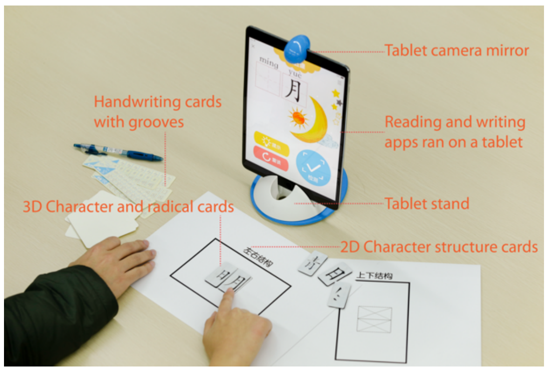

Figure 3: The Character Alive system.

Figure 4: Examples of the color cues used in lessons containing morpheme 日 (semantic radical), 青 (phonological radical), and 氵 (semantic radical).

designed for children at-risk for dyslexia [3,10]. The multisensory strategy is often used to help these children during instructions [4]. The multisensory approach uses tactile, kinesthetic, auditory, and visual senses to attract children's attention and explicitly teach them phonological, morphological and orthographic knowledge [4]. For example, one useful practice is having children trace the contours of characters on physical cards to help children memorize the character patterns by using motor memory [13]. Moreover, teachers often group characters using one radical with different components to help children learn identical morphemes or phonemes [8]. During these interventions, teachers may also use other cues such as associated graphs or colors to draw children's attention and help children to memorize orthographic representations [3,9,13]. However, traditional multisensory programs do not involve computational materials and rely on highly-trained teachers, which is resource intensive.

Computational Applications Designed for Learning the Chinese Language

There are several computational applications designed to help children learn Chinese. For example, several commercial apps (e.g., 麦 田 认 字 <www.mytian.com.cn>; 悟 空 识 字 <gonfubb.com>) use game-based narratives to teach children character reading and writing. In these apps, children first watch the animation that introduces characters and then play a set of games to select the correct characters based on the sounds. This type of design does not fully leverage the use of tactile and kinesthetic senses to teach children reading and writing.

Recent research suggests that tangible user interfaces may support children in learning to read [1,12]. Compared to mobile-based apps, tangible interfaces enable two-hand actions on physical letters associated with multisensory cues [1]. The multisensory learning experience better draws children's attention and benefits them in learning to read and write [5]. Lin et al. [5] presented the evaluation of a tangible and augmented reality app that aims to support Chinese word recognition for children with ADHD and reading difficulties. Children can use the character cards to view animation, 2D character and sound. The 3-month study with two fifth-grade primary school children in Taiwan showed that the children's reading scores increased considerably during the intervention and maintenance phrases. However, children in Taiwan learn Zhu-Yin-Fu-Hao (i.e., an invented alphabetic system to teach children how to read) and traditional Chinese, while children in Mainland China learn Pinyin (a different alphabetic system) and simplified Chinese [6]. The two versions of Chinese have different phonological and orthographic systems. Wen [12] presented the design and evaluation of a tangible system called ARC that aimed to support collaborative learning of traditional Chinese character composition for non-native speaking children. The ARC system consists of a set of radical cards associated with Near-Field Communication (NFC) tags, an NFC reader, and an app running on a tablet. Children can place two radical cards near the NFC reader so as to compose a Chinese character, and the digital character and sound will be shown and played on the tablet. The results of a quasi-experiment indicate that ARC is an effective system for improving Chinese character learning and collaborative learning quality. However, this system was not specifically designed for dyslexic children; therefore, it does not incorporate learning activities such as letter tracing which are important for dyslexic children.

Figure 5: The 3D models of the radical cards 日 (/ri4/, sun) and 月 (/yue4/, moon). We chose the Kai font which is used in Chinese textbooks.

Figure 6: The 3D printing of the radical cards 日 (/ri4/, sun) and 月 (/yue4/, moon) in the size of 4*2*1cm. We printed out one white layer and one black layer and glued them together.

Figure 7: Handwriting cards with grooves.

SYSTEM DESIGN

Learning and Design Goals

The learning goal was to help Mandarin-speaking children at-risk for dyslexia, aged 5-7 years old, to improve their understanding of morphological knowledge. Specifically, we aim to improve children's reading and writing abilities for Chinese characters and words.

Our main objective was to create a tangible system that we could use as a research instrument to explore the benefits of using color, tactile cues and animations to support children at-risk for dyslexia to learn to read and write Chinese characters and words (Fig. 3). Based on the theories of the causes and interventions for dyslexia in Chinese [7,8,11] and our previous work [1,2], we had three specific design goals: **(1) Dynamic color cues on physical representations**: design color cues to highlight orthographic patterns such as semantic radicals or phonological radicals; design color cues based on metaphoric approach that human beings may associate a radical and its meaning to certain objects and colors in daily life (e.g., one may code the semantic radical 日 (/ri4/, sun) to red and code phonological radical 青 (/qing1/, green) to green, Fig. 4); **(2) Tactile and kinesthetic cues**: design 2D physical character and radial cards whose contours are easily traceable (Fig. 5 and 6); design handwriting cards with grooves, the physical constraints of which may guide children's handwriting actions as they practice (Fig. 7); design physical cards so that children can physically manipulate them using two hands in space; and **(3) Multimedia cues**: design sounds and animation associated with the characters [9].

The Character Alive System

Character Alive consists of a tablet that runs a reading app and a writing app, a tablet camera mirror that allows the camera to capture video from the table area, a tablet stand, and three types of physical objects: a set of 2D plastic character and radical cards, four types of 2D character-structure cards, and handwriting cards with grooves (Fig. 3). The main interaction of the system can be seen in Fig. 3, 8 and 9. We have implemented four of 10 lessons in both reading and writing apps. Each lesson contains 3-5 characters. We selected characters from the 1-3 grade textbooks and divided them in different lessons based on their phonological or morphemic radicals. The instruction starts with simple lessons including simple characters (e.g., 山 (/shan1/, mountain)) and gradually passes to complex lessons containing compound characters (e.g., 明 (/ming2/, bright)).

In the *reading app*, there are three structured learning steps in each lesson. First, a child watches an animation which explicitly teaches the characters one-by-one in the lesson. A multisensory strategy is used during the instruction (e.g., a child composes the characters and watches the color-coded visual character symbol while tracing the character card and/or pronouncing the character sound). We designed several pause moments to ensure that the child has enough time to follow the instructions. Multiple cues such as color (e.g., highlight radicals) and animation (e.g., demo of how the character was evolved from a graph) are used during the instructions (Fig. 8).

Second, the child performs several character composition tasks. For each character, the system provides the pronunciation of a word that contains the character. The child is asked to compose the character using the correct radical cards (or select the correct character card if the answer is a

Figure 8: A lesson in the reading app that teaches the characters containing the semantic radical 日 (/ri4/, sun). An animation first demonstrates how the character 明 (/ming2/, bright) is evolved from the graphs of sun (日) and moon (月). The system asks the child to trace the radical cards 日 and 月 and pronounce the character /ming2/. The semantic radical 日 has the red color (*top figure*). Bottom left and right figures show the interfaces of two-character composition tasks: composing a character within a word and within a sentence, respectively.

simple character such as 山). A character card recognition module in the system detects whether the character is correctly constructed. If it is correct, the digital contents will be shown on the screen, including a 2D colored character, character sound, and visual/auditory rewards. If the answer is incorrect, the child will get feedback and three levels of hints. The first-level hint provides auditory prompts with animation cue (e.g., could you recall the graph associated with this character?); the second-level hint shows part of the answer with a color cue; and the third-level hint displays the correct answer. Lastly, the system asks the child to practice the characters within sentences. The child composes the characters to fill in several blanks of a given sentence. The system will detect if the answer is correct or not and provide feedback (Fig. 8).

In the *writing app*, there are two learning steps. The child first watches an animation that shows how to write each character stroke by stroke (Fig. 9). Similar to the reading instructions, a multisensory strategy with multiple cues is used. Secondly, the child copies the characters on a handwriting card that has grooves. If the card is put under on the table area in the camera capture area, the system automatically detects whether the child finished the task or not. If so, associated digital contents will be displayed on the screen, including a 2D colored character, character sound, and star rewards. If, not the child will receive auditory feedback that suggests re-watching the instruction animation and practicing again. We used a disappearing ink pen so that the child can reuse the handwriting cards.

Technical Solution

The system was designed on an Android platform. The animations were made in Adobe After Effects. The character and radical cards were 3D printed. The handwriting cards were printed using an online printing service. All computational tasks, such as frame processing and data storage are handled by the device. The reading app contains a character card recognition module, which was built on a Convolutional Neural Network trained on an annotated dataset composed of pictures of character cards. When the character card recognition task starts, the app captures camera frames at a rate of 24 frames per second. If three or more consecutive results indicate that the input character card matches the target answer, the system screen will show the correct answer. In the writing app, when children are asked to copy the dash strokes of the characters on the character writing sheet, the app takes the real-time camera image as input, performs image binarization, and computes the pixel values to detect whether the child has finished the task or not.

DISCUSSION AND FUTURE WORK

We present Character Alive, a tangible system that supports children's Chinese reading and writing skills. Compared to previous apps, our approach has four main advantages. First, our system uses various dynamic color cues based on the lesson requirements to draw children's attention to phonological or semantic radicals. For example, in a lesson that teaches children the characters that contain the morpheme 日 (e.g., 时, 明, 暗), we used red to highlight the semantic radical 日; in another lesson that teaches the characters containing the phoneme 青 (e.g., 晴, 清, 情), we used green to indicate the phonological radical 青. By adding dynamic color cues, we aim

Figure 9: This is an interface of the writing app that teaches children to write each character stroke by stroke. The child watches the animation that demonstrates how to write the character (e.g., 明 (/ming2/, bright)) and copies the characters on a handwriting card that has grooves.

to make it easier for children to notice the common patterns among the similar characters and effectively use morphological knowledge to learn how to read and write. Second, we provided 2D cards that enable a tactile and kinesthetic learning experience. The edge of the radicals allows children to trace contours of characters and helps them to memorize orthographic patterns. We also provide handwriting cards with grooves. The physical constraints facilitate children's handwriting actions. Third, we designed animations to draw children's attention to the composition of the characters [9]. We produced an animation for each character to demonstrate how the character was resolved from a graph. We also designed animations to demonstrate how to write a character stroke by stroke. We intend to use multiple information channels to help children efficiently retrieve characters from memory.

Our next step is to continue building the system based on our conceptual design and then to run usability testing with at-risk children to refine our design. We then will conduct a study with children at-risk for dyslexia at an elementary school. The children will receive a 15-20min intervention daily with our system in a small group with a trained tutor who provides support. We will evaluate the effectiveness of the system in supporting children's early literacy acquisition.

REFERENCES

[1] Min Fan, Alissa N. Antle, Maureen Hoskyn, Carman Neustaedter, Emily S. Cramer. 2017. Why tangibility matters: A design case study of at-risk children learning to read and spell. *In Proceedings of CHI '17*, 1805-1816.

[2] Min Fan, Alissa N. Antle, Shubhra Sarker. From Tangible to Augmented Reality: Designing a PhonoBlocks Reading System Using Everyday Technologies. In *Proceedings of CHI EA '18*, LBW555, 1-4.

[3] Gattegno, Caleb. 2010.*Teaching Reading with Words in Color: A Scientific Study of the Problems of Reading. Educational Solutions World*.

[4] Connie Suk-Han HO, Eugene Yiu-Chun LAM, and Agnes AU. 2001. The effectiveness of multisensory training in improving reading and writing skills of Chinese dyslexic children. *Psychologia* 44, 4: 269–280.

[5] Chien-Yu Lin, Wen-Jeng Yu, Wei-Jie Chen, Chun-Wei Huang, and Chien-Chi Lin. 2016. The effect of literacy learning via mobile augmented reality for the students with ADHD and reading disabilities. *International Conference on Universal Access in Human-Computer Interaction*, Springer, 103–111.

[6] Liu, Li, Ran Tao, Wenjing Wang, Wenping You, Danling Peng, and James R. Booth. 2013. Chinese dyslexics show neural differences in morphological processing. *Developmental cognitive neuroscience* 6: 40-50.

[7] Catherine McBride, Ying Wang, and Leo Man-Lit Cheang. 2018. Dyslexia in Chinese. Current Developmental Disorders *Reports* 5, 4: 217–225.

[8] William E. Nagy, Amy Kuo-Kealoha, Wu Xinchun, Li Wenling, Richard C. Anderson, and Chen Xi. 2002. The role of morphological awareness in learning to read Chinese. Chinese children's reading acquisition. Springer, 59–86.

[9] Berney, Sandra, and Mireille Bétrancourt. 2016 Does animation enhance learning? A meta-analysis. *Computers & Education101 (2016)*: 150-167.

[10] Li-Chih Wang. 2017. Effects of Phonological Training on the Reading and Reading-Related Abilities of Hong Kong Children with Dyslexia. *Frontiers in psychology* 8: 1904.

[11] Wenjing Wang and Hongyu Zhao. 2009. An Analysis of the Deficits of Reading Disabled Children on Neural Mechanism and Cognitive Skills. *Chinese Journal of Special Education*. 60-64.

[12] Yun Wen. 2018. Chinese Character Composition Game with the Augment Paper. *Educational Technology & Society* 21, 3: 132–145.

[13] Xuemei Wu and Ying Feng. 2011. A case report of a Chinese child with dyslexia (一例读写障碍儿童的咨询报告). *Journal of Inner Mongolia Normal University (Education Science)*, 24, 04: 43–46.