Designing a Game for Pre-Screening Students with Specific Learning Disabilities in Chinese

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ABSTRACT

Most students with specific learning disabilities (SLDs) have difficulties in reading and writing. The SLDs pre-screening is crucial because the golden period for therapy is before six years old. However, many students in Hong Kong receive SLDs assessments after the golden period. Also, the SLDs pre-screening is challenging, especially in a language with the logographic script but without prominent sound-script correspondence (e.g., Chinese, Japanese). To make pre-screening SLDs in Chinese more effective and efficient, we designed a new comprehensive pre-screening game for SLDs in Chinese (i.e., dyslexia, dysgraphia, and dyspraxia). Notably, we designed a Chinese morphological awareness puzzle that challenges students to recognize different words made up with the first character that is identical and the second character that is different, such as 樹枝 (literally means tree branch), 樹幹 (literally means tree truck), 樹葉 (literally means tree leaves), and 樹根 (literally means tree root). We experimented with students, which showed that our game can effectively pre-screen students with SLDs in Chinese. Our work contributes an approach to quick SLDs in Chinese pre-screening, potentially useful for other logographic languages (e.g., Japanese).

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1 INTRODUCTION

Most students with specific learning disabilities (SLDs) have difficulties in reading and writing [11]. Global research shows SLDs are a cross-cultural issue across languages, alphabets, and scripts [7, 29, 37]. Previous research on SLDs pre-screening have been focusing on Latin script or alphabet [5, 24, 26–28]. However, the SLDs pre-screening is crucial because the golden period for therapy is before six years old [6]. Many students in Hong Kong receive SLDs assessments after the golden period [42, 43]. Also, the SLDs pre-screening is challenging, especially in a language with the logographic script, but without prominent sound-script correspondence, such as Chinese. For example, (the Cantonese pronunciation is maa1, the meaning is mother) and 騎 (the Cantonese pronunciation is ke4, the meaning is ride) share the same component of the logographic script, 馬 (the Cantonese pronunciation is maa5, the meaning is horse). However, the phonetic counterparts are different.

Currently, Hong Kong teachers observe the students' behaviour and learning performance in schools. To complete an assessment, either Special Education Coordinators (SENCOs) or Educational Psychologists (EPs) need to work with the student on a series of language tests after class. They pre-screen the learning issues caused by SLDs. They need to conduct the test multiple times, each taking a few hours. They also need to collect the evidence during the tests and then forward the student case and the evidence to the education bureau.

On the other hand, EPs only stay in school two to three days per week [40]. EPs also need to handle many administrative tasks, launch seminars and have meetings with parents and teachers [40], and conduct student assessments and therapies. Furthermore, one EP takes care of SENs students in seven schools [41], which is around 7,000 students. Therefore, EPs take a year to diagnose a few students with SLDs. Therefore, it still takes students two to three years to receive an assessment for SLDs [42, 43]. Although different

pre-screening tools are available in the market [8, 10, 12, 13, 21, 22, 24, 25, 30], they are not compatible with languages that have the logographic script but no prominent phonetic counterparts, such as Chinese. Therefore, we developed a new game to speed up the SLDs pre-screening process. The game contains multiple puzzles. Each puzzle focuses on one or two specific SLDs pre-screening aspects: dyslexia (reading), dysgraphia (writing), and dyspraxia (physical coordination).

To verify whether our game can effectively pre-screen students with SLDs, we invited ten students with SLDs and ten general education students to play our pre-screening game. Our experiment showed that our pre-screening game could successfully identify students with SLDs. In addition, our work can inspire SLDs pre-screening designers and developers to develop inclusive pre-screening games for students with SLDs for logographic languages, such as Japanese.

2 GAMEPLAY DESIGN

2.1 Game Prototype

We developed a game prototype that pre-screens students with SLDs in Chinese. We co-designed the gameplay with a professor who specialized in SLDs and co-designed the game interfaces with a professor who specialized in integrated design. This game consists of different puzzles (Figure 1), which focus on different aspects, including dyslexia (reading), dysgraphia (writing), and dyspraxia (physical coordination). In addition, the gamified learning environment on touchscreen interfaces employs large icons with all instructions supporting text-to-speech to deliver students user-friendly learning content. The prototype is developed using Unity, which can run on tablets like iPad Air. Students use the touchscreen to play the game. The game prototype records the running time, interactions with the touchscreen, handwriting screenshots, and audio recording inputs.

2.2 Gameplay Design Details

We designed the game based on an empirical analysis of errors written in Chinese by students with SLDs [14, 34] because errors reflect specific difficulties that comprise SLDs [17, 32]. We annotated the mistakes with general linguistic characteristics, as well as with word recognition [4, 9, 36], reading [1, 19, 23], and writing [20, 38, 39]. Students with SLDs perform significantly weak in these three areas.

Game 1: Orthographic Awareness. Orthographic Awareness is a prerequisite skill for reading and writing development [33]. In English, the pre-screening required participants to fill the missing letter in a word [24]. However, the word formation in Chinese is the logographic script. Chinese character is formed with different components. Therefore, our work adapts to the missing components instead of the letter. For example, in orthographic Awareness (Figure 1b), the last stroke of 可 (the meaning is can) is formed by a hook instead of a vertical line.

Game 2: Morphological Awareness. In Rello, Luz, et al. [24]'s work, they found the morphological error in a sentence from the participants. However, Chinese is made up of compound words, most of which consist of two or more characters, also known as lexical compounds [2]. Therefore, this game is more relevant to vocabulary knowledge and word recognition [21, 31]. Therefore, the work in English pre-screening is not fully adapted to Chinese. In our work, the vocabulary graphics are put in the same picture. It aims to test if students could recognize different words that are made up with the first character that is identical and the second character that is different. Figure 1c is an example of morphological awareness, such as 樹枝 (literally means tree branch), 樹幹 (literally means tree truck), 樹葉 (literally means tree leaves), and 樹根 (literally means tree root).

Game 3: Chinese Handwriting Component Structure. Visual working memory is a cognitive system that maintains a limited amount of visual information so that it can be accessed quickly to meet the needs of an ongoing task [3]. In English SLDs pre-screening, the participants would see for 3 seconds a sequence of letters and then write the discriminating targets [24]. However, Chinese is a language with a logographic script composed of different components. Therefore, our work would allow participants to see a part of the Chinese character and then write the discriminating part. An example of visual working memory is 女 (the meaning is girl). Normally, students with SLDs will write the discriminating target with a curve (Figure 1e) instead of angle (Figure 1d). Therefore, we can automatically detect it is wrong.

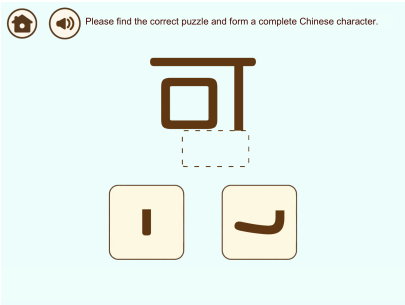
Game 4: Chinese Handwriting Spatial and Component Relationship. Chinese is a language with a logographic script but without prominent sound-script correspondence. As a result, the syllabic awareness [24] is not suitable for our work. In English pre-screening [24], handwriting may not be the essential SLDs indicator. However, the Chinese character structure and component proportions are the key indicators in differentiating SLDs [15, 18]. Usually, students with SLDs will copy three words (Figure 1g) with the disproportionate size of components, disproportionate spacing within components [35], inconsistent and violating the spatial orientation between character and grid [16]. On the other hand, general students without SLDs can have better control of Chinese handwriting spatial and component relationships (Figure 1f). Therefore, we can automatically detect it is incorrect.

3 EFFICACY EXPERIMENT

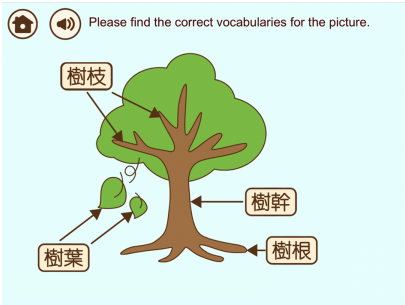
We recruited 20 students (8 females and 12 males) aged from 6 to 8 years old from a local primary school in Hong Kong (the average age is 7.55-year-old with a 0.56-year-old standard deviation). In addition, 10 students have SLDs; And another 10 general education students. The inclusion criteria for students to participate in this study were (1) studying in grade 1 to grade 2; (2) being able to read and write traditional Chinese characters and speak Cantonese, and (3) having no other medical or physical disabilities that might interfere with the handwriting ability and reading aloud ability. Also, all students have experience in using tablets. Before running the experiment, we obtained informed consent from the students' parents. Participation is entirely voluntary and based on consent. The University Institutional Review Board (IRB) approved the experimental protocol. We do not provide any remuneration to the participants.

Our student participants played one set of our pre-screening games per day, and the game had four sets. Thus, they played the

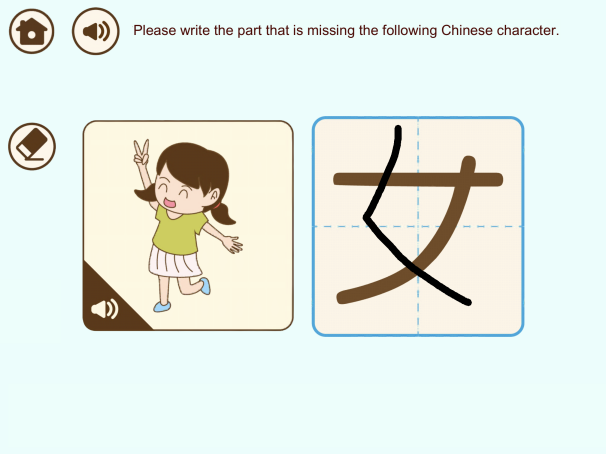
(a) The Pre-screening Game Overview.



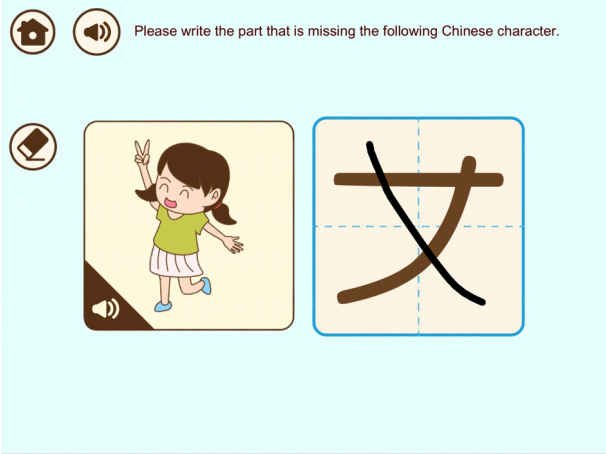
(b) Game 1: Orthographic Awareness.



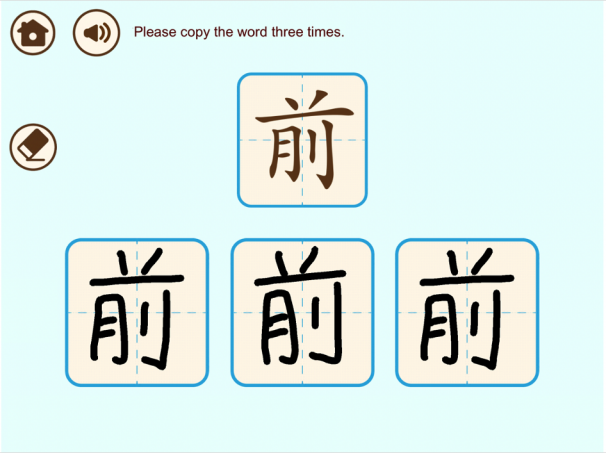
(c) Game 2: Morphological Awareness



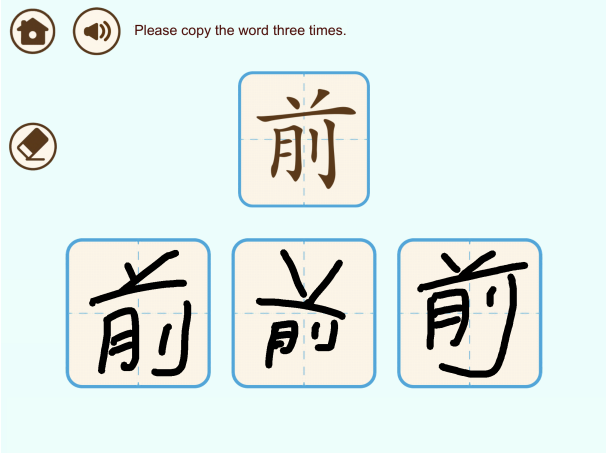
(d) Game 3: Chinese Handwriting Component Structure, done by a general student without SLDs. The general student wrote the discriminating target with an angle.



(e) Game 3: Chinese Handwriting Component Structure, done by a student with SLDs. The student wrote the discriminating target with a curve.



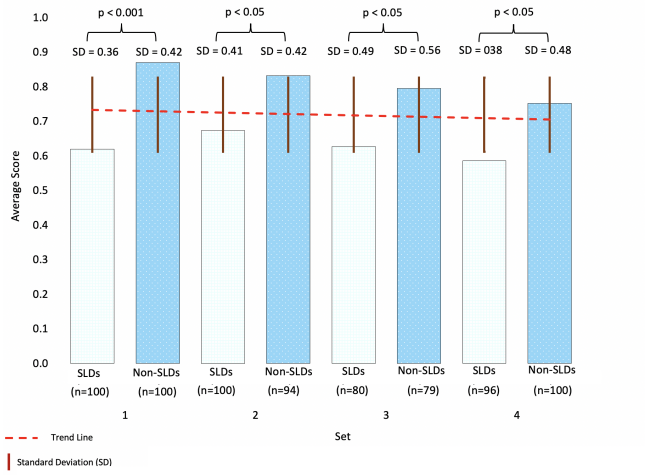
(f) Game 4: Chinese Handwriting Spatial and Component Relationship, a general student without SLDs. The student copy three words with proportionate size of components and spacing within components; consistent and following the spatial orientation between character and grid.



(g) Game 4: Chinese Handwriting Spatial and Component Relationship, done by a student with SLDs. The student copy three words with disproportionate size of components, disproportionate spacing within components, inconsistent and violating the spatial orientation between character and grid.

Figure 1: The User-Interface of Pre-screening Game, including Game Overview, Game 1: Orthographic Awareness, Game 2: Morphological Awareness, Game 3: Chinese Handwriting Component Structure, and Game 4: Chinese Handwriting Spatial and Component Relationship.

(a) We conducted the pilot test in a classroom setting. Participants were working on our pre-screening game.



(b) Our game effectively pre-screens students with SLDs. *n* denotes the number of in-game puzzles that the group of 10 students finished and the max number of puzzles is 10. Some *n* values are smaller than 100 because of data lost.

Figure 2: The pilot tests setting and game performance

whole game for four days. Each set has 10 games covering the testing of word recognition, reading, and writing, which needs about half an hour to finish. All the study participants played the game in a classroom setting simultaneously, and the study was under the premise of social distance (Figure 2a). We collected students' input data, and video recorded their body movements during the game.

4 EFFICACY VERIFICATION

As illustrated in Figure 2b, the difference in performance between students with and without SLDs is statistically significant. It is single-factor ANOVA for score performance. Y-axis denotes the score received. The X-axis depicts the performance of finishing four sets of our pre-screening game. The dotted red line represents the trend line.

We evaluated the performance by measuring their performance in 4 sets of the game. Set 1 and Set 2 focus more on word recognition and writing, and Set 3 and Set 4 focus more on reading and writing. Overall, all of the performances are significantly different:

- Set 1: The p-value is smaller than 0.001. Students with SLDs' average score is 0.62 with a standard deviation of 0.3561, while general education students' average score is 0.87 with a standard deviation of 0.4153.
- Set 2: The p-value is smaller than 0.001. Students with SLDs' average score is 0.6733 with a standard deviation of 0.415, while general education students' average score is 0.8324 with a standard deviation of 0.4150.
- Set 3: The p-value is smaller than 0.045. Students with SLDs' average score is 0.6269 with a standard deviation of 0.4908, while general education students' average score is 0.7948 with a standard deviation of 0.5560.
- Set 4: The p-value is smaller than 0.008. Students with SLDs' average score is 0.5859 with a standard deviation of 0.3758, while general education students' average score is 0.7523 with a standard deviation of 0.479.

When it comes to the evaluation of average time spent on finishing one puzzle, students with SLDs spent more time on a puzzle than general-education students but we only observed a statistically significant time difference in Set 3:

- Set 1: Students with SLDs' average solving time is 15 seconds with a standard deviation of 11.16, while general education students' solving time is 14 seconds with a standard deviation of 11.47.
- Set 2: Students with SLDs' average solving time is 17 seconds with a standard deviation of 15.19, while general education students' solving time is 15 seconds with a standard deviation of 13.57.
- Set 3: Students with SLDs' average solving time is 30 seconds with a standard deviation of 23.26, while general education students' average solving time is 25 seconds with a standard deviation of 21.17.
- Set 4: Students with SLDs' average solving time is 16 seconds with a standard deviation of 12.81, while general education students' average solving time is 15 seconds with a standard deviation of 12.47.

5 CONCLUSION AND FUTURE WORK

We present an SLDs pre-screening game and verify whether it can accurately and efficiently pre-screen students with SLDs. Our system design can significantly distinguish two groups of students. Also, students with SLDs spent more time answering questions than those without SLDs. After our in-depth observation, all participants can use the system without technology literacy problems. Moreover, we can see that our instructional design, game activity design, application operation, and game interface design are suitable for our participants. In the future, we will invite students with different demographic backgrounds to use our application.

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