Project Title : Improving children's Chinese literacy performance by developing an educational computer game for training morphological skills

Grantee : The Education University of Hong Kong

Principal Investigator : LIU Duo
Department of Special Education and Counselling
The Education University of Hong Kong

Co-investigators : CHEN Xi
Applied Psychology and Human Development
University of Toronto

LI Hong
School of Psychology
Beijing Normal University

LIU Sisi
Department of Applied Psychology
Lingnan University

POON Kei-yan
Department of Special Education and Counselling
The Education University of Hong Kong

WANG Li-Chih
Department of Special Education
National Tsing Hua University

Final Report

by

Principal Investigator

Improving Children's Chinese Literacy Performance by Developing an Educational Computer Game for Training Morphological Skills

Abstract

Morphological awareness is critical for learning Chinese, however, few studies focused on developing the training regarding morphological awareness. Consider the prevalence of using digital tools in children, the current project developed a computer game for training morphological awareness, i.e., MorphorGame. An intervention study, including pre-test, training, and post-test, was conducted for the effectiveness of the game. In total, 163 children in Grades 1 and 2 participated, and 77 of them completed the intervention study. In the pre-test and post-test, tasks were administrated for the participants' morphological awareness, literacy abilities, cognitive skills. Between the pre-test and post-test, the participants were assigned to one of four training conditions: (a) computer game training, (b) dialogic reading with morphological training, (c) dialogic reading, and (d) control group for a three-month training. The participants in condition (a) were asked to play the MorphorGame during the training. In conditions (b) and (c), the participants were asked to read selected storybooks; the participants in the training (b) were asked to read with the morphological training handbooks, whereas in the training (c) a parent-child dialogue was conducted during reading. The results showed that compared to the control group, the three trainings led to extra improvements of the children's morphological awareness, and the game training had the largest improvement. Moreover, the training, especially these relating to morphological awareness, improved children's reading abilities, e.g., Chinese character reading, reading comprehension, dictation, and vocabulary. The current findings suggest that with high-quality content, using digital tools can facilitate children's reading development.

Keywords: morphological training, educational game, reading intervention, metalinguistic skills, Chinese word reading

Introduction

Literacy abilities are crucial for information acquisition and effective communication; thus, early education mainly focuses on teaching children how to read and write. Given the particular importance of morphological awareness in learning the Chinese language (Liu & McBride-Chang, 2010; McBride-Chang et al., 2003), the present project aims to develop a computer-assisted intervention method for training morphological awareness and evaluate its effectiveness in early-grade primary school children in Hong Kong.

Review of Literature of the Project

Reading and writing involve complex processes as they require not only connecting spoken sound units with written forms but also associating the oral and written language to semantic meanings. Therefore, knowledge of the morphology of a language is crucial for literacy development (Ku & Anderson, 2003; Liu & McBride-Chang, 2010). Morphological awareness is the awareness of and ability to manipulate the meaning structure of a language (Carlisle, 2000). This ability includes the understanding of basic meaning units (i.e., morphemes) and the rules of structuring multiple morphemes to form complex words. The unique importance of morphological awareness for reading and writing success has been supported by a large number of studies on various orthographies, in concurrent and longitudinal research (e.g., Deacon & Kirby, 2004; Mahony et al., 2000; Nagy et al., 2006).

In the Chinese language, in which the phoneme-to-grapheme mapping rule is rarely applied (Kuo & Anderson, 2006), the role of morphological awareness in literacy development has been reported in a body of studies (e.g., McBride-Chang et al., 2003; Li, Anderson, Nagy, & Zhang, 2002). For example, McBride-Chang and colleagues (2003) found that morphological awareness predicts Chinese character reading ability in kindergarten and second grade students. Similarly, Li et al., (2002) showed that phonological

awareness is important for Chinese reading in first and fourth grade students, but morphological awareness is more important at both grade levels. Morphological awareness is a marker for identifying children with reading difficulties (Shu et al., 2006). The research of the PI and collaborators (e.g., Hao et al., 2013; Li et al., 2016; Liu et al., 2017; Liu & McBride-Chang, 2010) also suggested that specific aspects of morphological awareness are unique predictors of Chinese children's reading acquisition.

Morphological awareness in Chinese is generally understood at two levels: morpheme and morphological structure (Liu & McBride-Chang, 2010). At the morpheme level, children need to link morphemes to corresponding syllables in oral language and characters in print and be aware that a particular syllable or Chinese character can represent multiple morphemes. For example, the character 商 (/soeng1/) means "business" in the word 商店 (/soeng1 dim3/; shop) but means "negotiate" in the word 商討 (/soeng1 tou2/; discuss). At the morphological structure level, children must understand how morphemes are structured to form the compound words as most Chinese words comprise two or more morphemes. For example, the word 認知 (/jan6 zi1/, cognition) can mean "know and understand" if the word follows a coordinative structure, or "know the knowledge" if the first morpheme is a verb and the second a noun, following a verb + object structure (Liu & McBride-Chang, 2010).

Compared with alphabetic orthographies, morphological awareness is more crucial for reading and writing in Chinese, because of the features of Chinese orthography (Shu & Anderson, 1999). Specifically, a Chinese character can represent different meanings within different contexts (words). Morphological awareness at the morpheme level is expected to facilitate the acquisition of new words through the component character that children already know (Nagy & Anderson, 1984). For example, a character appears in different complex words with related meanings. The morpheme 火 (/fo2/; fire) appears in the word 火把

(/fo2 baa2/; torch) and the word 火柴 (/fo2 caai4/; match). Children's knowledge of the morpheme "fire" serves as a cue to understand and memorize these semantically related words, thereby facilitating vocabulary growth and character reading. Thus, children need to be sensitive to the different morphemes associated with a character.

Another feature of the Chinese orthography is a large number of homophones. Approximately 4,500 characters (morphemes) are regularly used, but they map onto only 1,700 syllables in the Cantonese dialect (Qian et al., 2004). Therefore, three distinct morphemes share one syllable on average. Chinese children who are morphologically aware understand that different morphemes can share an identical pronunciation and habitually search for information to distinguish these morphemes (Anderson & Li, 2005). Morphological awareness is thus especially important for avoiding misunderstandings of ambiguous meanings expressed in spoken Chinese. At the word level, lexical compounding is the primary method to form Chinese words. Over 75% of the words in modern Chinese are compound words including two or more constituent morphemes, and Chinese words are semantically transparent. In the case of 電視 (/din6 si6/; television), the morphemes 電 (/din6/; electric) and 視 (/si6/; vision) contribute to the word meaning straightforwardly. Thus, morphological structure awareness is helpful for learning Chinese words. Several different compounding structures exist in Chinese, including coordinative, subordinate, verb–object, subject–predicate, and verb–adjective complement (e.g., Yuan & Huang, 1998). No explicit cues are available for judging these structures, thereby emphasizing the importance of morphological awareness at the structure level for learning Chinese compounds.

Given the crucial role of morphological awareness in literacy development, intervention studies have been conducted to examine the causal impact of this ability on children's reading and writing acquisition. Morphological awareness-based intervention is an

effective approach to literacy education in alphabetic orthographies (Lyster, 2002; Nunes et al., 2003). Although only a few studies have examined morphological interventions in Chinese children, the findings similarly support the effectiveness of such interventions (e.g., Packard et al., 2006; Chow et al., 2008). In a study of Chinese first graders, those who received a one-year instruction on morphemic and orthographic structure of Chinese words show an increase in ability to write characters in comparison with those in the control group (Packard et al., 2006). The part of the instruction on morphological awareness focused on analyzing how a particular morpheme contributed to the meaning of a compound word comprising it, instead of requiring children to simply memorize the word as a whole. In a similar study, Wu and colleagues (2009) examined the effect of a two-year morphological instruction on first graders. The data collected in beginning of the second and third grade revealed benefits in development of various reading and writing skills, as well as morphological awareness itself, in comparison with the control group.

Most existing intervention studies were conducted at school where teachers were trained by the research teams to deliver the intervention. In the aforementioned studies, the interventions were comprehensive as they incorporate orthographic and morphological training, and were integrated into regular classroom instruction. The teachers attended training before the intervention and weekly seminars throughout the study. They also received reference materials and guidance based on observations of their lessons. The school-based intervention approach presents beneficial results but requires close cooperation among the school, teachers, and researchers, and investment of considerable amount of resource. This need imposes difficulties in expanding and sustaining such interventions. Therefore, the present project will focus on parental instruction at home.

Home literacy experiences play a unique role in children's early literacy development. Young children whose parents are engaged in reading and writing with them have advantages

in learning oral and written languages (Payne et al., 1994; Sénéchal & LeFevre, 2002; for reviews see Bus et al., 1995; Reese et al., 2010). Moreover, home-based interventions may enhance parents' self-efficacy through helping children in learning, and then boost children's self-efficacy and reading achievement (Lam et al., 2013; Lynch, 2002). In Hong Kong, parents tend to have positive attitudes toward home literacy activities. According to Li and Rao (2000), over 80% of Hong Kong parents believe that parent-child reading is helpful for developing children's literacy skills, and 73% of them teach their children to read characters at home. As parents are willing to invest in home literacy activities and parental instruction exerts a positive impact on early literacy acquisition, evidence-based educational tools should be developed to effectively assist parents in teaching Chinese literacy.

To the best of our knowledge, only one study has developed a morphological-based intervention for Hong Kong families. Chow and colleagues (2008) created an intervention that integrates morphological instruction with parent–child shared book reading, and they discovered that kindergartners who received the 12–week intervention show improved character reading, morphological awareness, and reading interest. Specifically, the parents in the experimental group were trained to read one book a week with their child. They first read the book using dialectic reading techniques and then taught morphological awareness on the basis of the content of the books. The intervention focused on lexical compounding and homophone identification. For example, after reading a story of a farmer pulling a "carrot king" (蘿蔔王 /lo4 baak6 wong4/) from the ground in the lexical compounding training, the parent explained to the child that a "carrot king" meant a large carrot. With the aid of the pictures of a large watermelon and a large ice cream, the parent then explained that a "watermelon king" (西瓜王 /sai1 gwaa1 wong4/) represented a large watermelon. The child's task was to construct a word or phrase meaning a large ice cream (i.e., "ice cream king" 雪糕王 /syut3 gou1 wong4/). Therefore, children were explicitly taught the different

morphemic structures of Chinese words, and practiced to generate new words following those structures.

Another aspect of the morphological intervention was homophone training, which raised the children's awareness that the same syllable may represent different morphemes. After reading a story of a little sheep looking for its mother, the parent labelled in the storybook and the training book the pictures of the little sheep (小羊/siu2 joeng4/), the sun (太陽 /taai3 joeng4/), and the sea (海洋 /hoi2 joeng4/), which share the syllable joeng4. The child was then required to identify the pictures corresponding to the meanings of the wool (羊毛 /joeng4 mou4/) and the sunlight (陽光 /joeng4 gwong1/). The said storybook reading intervention and our game intervention are based on morphological training and are implemented at home; thus, we will use the above-mentioned method in one of our comparison groups to examine whether computer game has advantages as a home literacy education tool.

Parent–child shared book reading is a conventional home literacy instruction method and presents a few limitations. The selection of appropriate books and parents' skills to interact with children during shared book reading are keys to maximize the benefit of this method. Moreover, children should have at least some interest in reading for them to sit down and read books with their parents; however, some children, especially those who are poor readers, may not be willing to read books in the first place. The present project aims to develop and evaluate an educational computer game, which serves as a home-based literacy instruction tool. The computer game will provide learning materials and tasks for parents and thus attract children's interest.

Theoretical and/or Conceptual Framework of the Project

Playing computer games is popular among children and teenagers, and the video game industry is one of the largest creative industries in Hong Kong (Hong Kong Monthly Digest of Statistics, March 2014). Around 50% of Hong Kong children play video games daily, and one-third of children spend up to three hours per day playing games on weekdays. In addition, the number of young game players is growing, with approximately 19% of preschool students playing games for 27 min on average daily (Wang et al., 2014). Computer-assisted interventions are considered an individualized and viable method for training literacy skills given children's interest in computer games. Computer-assisted reading interventions are generally effective in training children with difficulties in learning alphabetical orthographies (Saine et al., 2011; Torgesen et al., 2010; for reviews see Blok et al., 2002; Cheung & Slavin, 2013), and Chinese-speaking children (for a review see Liao, 2007).

Although reading intervention studies adopting digital games are still sparse, the value of games as an instructional tool is supported by the findings that digital games are more effective in terms of learning and retention than conventional instructions (Wouters et al., 2013). This result may be partly due to the fact that children enjoy computer-based learning tasks more than conventional learning tasks (Rosas et al., 2003), and are concentrated in computer-based tasks (Clarfield & Stoner, 2005). Digital games have potential in beginning and remedial reading instruction. Thus, we aim to develop an educational game for helping Hong Kong Chinese children improve their morphological awareness and literacy performance.

A successful precedent of educational game for learning to read is GraphoGame, which was originally developed by a Finnish research team (Richardson & Lyytinen, 2014). GraphoGame was initially developed to provide training for Finnish-speaking children who show early signs of reading difficulty before entering the first grade. The game was built on

the basis of the research findings that the key to learning to read an alphabetic orthography is to learn how letters and speech sounds correspond to each other, and reading difficulties lie in problems in differentiating and manipulating speech sounds and thus in connecting sound units to their matching letters. Accordingly, the tasks in the game were designed to train children's ability to connect written language units (e.g., a grapheme or long text segment) with the corresponding speech sound units (e.g., phoneme, syllable, and word). Specifically, some multiple-choice tasks required the player to match a speech segment presented via headphones to its written representation, and other tasks were to construct written words from small components to match the spoken words the player heard. The essence of the game is training the mappings of a specific orthography to its spoken language form by focusing on most frequently used connections between the smallest distinguishable units of the written and spoken language.

Over the years, controlled experimental intervention studies on different versions of GraphoGame suggested that playing the game improves performance in reading various alphabetic languages, including Finnish (e.g., Heikkila et al., 2013), English (Kyle et al., 2013), and German (Brem et al., 2010), as well as the alphabetic languages used in Zambia and other African countries. Long-term effects of the game training have been documented by Saine et al.'s study (2010), which indicated that poor readers who played GraphoGame in the first grade improve their reading skills to the level of typically developing peers and outperform the children who received traditional remedial intervention in the beginning of third grade.

The present project aims to develop an educational game called MorphorGame, which is based on the extensive research on morphological awareness in Chinese language and its role in literacy development in Chinese-speaking children. To further explore whether the MorphorGame can benefit children's literacy abilities, in particular morphological awareness,

the present study conducted a controlled intervention study. Children in Grades 1 and 2, who are at the beginning stage of literacy acquisition, were recruited. The children were assigned into one of four conditions: (a) computer game training, (b) dialogic reading with morphological training, (c) dialogic reading, and (d) no-treatment condition. The major features and contents of the game were designed based on existing research, especially the GraphoGame method. The dialogic reading with and without morphological training were referred to these in Chow et al. (2008).

The first objective was to investigate the impact of the game training by comparing the changes in morphological awareness and literacy achievement of the four participant groups. We anticipated that the children who receive the morphological game training and who receive the storybook reading with morphological training would outperform the two comparison groups in morphological awareness and literacy tasks after the intervention and in the follow-up testing. Given that educational games stimulate children's interest in learning, the computer game group was expected to show higher levels of interest and motivation in reading than the other groups and outperform the dialogic reading group.

Methodology

The project consisted of two major phases. One focused on game development, and the other comprised an intervention study to evaluate the effectiveness of the game on children's literacy skills.

Participants

In total, 163 children from a primary school in Hong Kong were recruited for the intervention study. All the participants were native speakers of Cantonese and written informed parental consent was obtained for them. However, due to several reasons, in particular, the outbreak of COVID-19 led to dramatic changes regarding children's daily

routines. Finally, only 77 of the participants completed the intervention. Their mean age was 7.18 (*SD* = .74) at the pre-test and 8.71 (*SD* = .52) at the post-test.

Procedure

The present study had two components: game development and an intervention study. The game development was completed before the intervention study. A professional company was hired for developing the game according to the requirements of the project team. Then, the game was utilized in the intervention study, as the training method of the computer game training condition. The intervention study had three stages: pre-test, training, and post-test. In the pre-test and post-test, the participants were asked to complete a series of tasks for morphological awareness, literacy abilities, and cognitive skills. Between the pre-test and post-test, the participants were assigned to one of four training conditions for a three-month training. The four conditions were (a) computer game training (N = 22), (b) dialogic reading with morphological training (N = 19), (c) dialogic reading (N = 17), and (d) no-treatment condition (N = 19).

Measures

The measures that were involved in the pre-test and post-test were described below.

Core Measures

1. *Morphological Awareness*. The homophone identification task (McBride-Chang et al., 2013) and morphological production task (Liu & McBride-Chang, 2010) were administered with reading materials different from those used in the training by the online game.

2. *Chinese Character Reading*. This task required children to read aloud 100 Chinese characters at an increasing level of difficulty (Ho et al., 2000).

3. *Reading Fluency*. The children were asked to read 104 Chinese words within 45 s in this task (Pasquarella et al., 2015).

4. *Reading Comprehension*. A task (Leong et al., 2007) includes three short passages with no more than 15 sentences each was adopted. The children were asked to read the passages and answer 10 multiple-choice questions to 13 multiple-choice questions and three short-answer questions about each passage.

5. *Word Dictation*. This task (Lam & McBride-Chang, 2013) required children to write 20 two-character Chinese words read by the tester or by the audio presenting by the testing application.

6. *Motivation for Reading*. Children completed the motivation for the reading questionnaire (Lin et al., 2012), which taps on eight possible motivations for reading, including self-efficacy belief, curiosity, enjoyment, and social purposes. Meanwhile, parents respond to a three-item scale on child motivation and another three-item scale on child competence (Lam et al., 2013).

Control measures

7. *Phonological Awareness*. Children completed 29 syllable and 22 onset deletion items in this test (McBride-Chang et al., 2008).

8. *Vocabulary Knowledge*. The vocabulary definition task (McBride-Chang et al., 2008) required children to explain the 30 words presented to them orally.

9. *Rapid Automatized Naming*. This task (McBride-Chang et al., 2008) presented a 5×5 array of single-digit numbers and asked the children to read aloud the numbers as rapidly as possible.

10. *Working Memory*. The backward digit recall test was adopted to test children's working memory. The children were asked to recall a sequence of spoken digits in the reverse order. The number of digits in each list increases across trials.

11. *Nonverbal IQ test*. The Sets A and B of Raven's Standard Progressive Matrices (Raven, 2003) will be administered.

12. *Demographic Questionnaire*. A demographic questionnaire was completed by the parents before the intervention study. The questionnaire included questions about the date of birth, gender, school, and a class of children, the educational levels and occupations of the mother and father, family income, and reading resources and activities at home.

Training Groups

There were three training groups, i.e., (a) computer game training, (b) dialogic reading with morphological training, and (c) dialogic reading. The children in these three groups were asked to do the assigned training at least three times per week, and 20 minutes per time. A control group was adopted to investigating the training effects.

(a) Computer game training. An application, i.e., MorphorGame, which was developed by the current project team, was utilized in this training.

(b) Dialogic reading with morphological training. The children in this group were asked to read one storybook per week, in total, 12 storybooks. Meanwhile, their parents were asked to use the morphological training handbooks, which were developed by the current project team, to help the children to learn morpheme-related knowledge.

(c) Dialogic reading. The children in this group were asked to read one storybook per week, in total, 12 storybooks. The 12 storybooks were the same as those used in the dialogic reading with morphological training. At the same time, the parents of the children in this group were asked to according to the corresponding handbook, conducting a parent-child dialogue according to the storybook during the training.

Data Collection and Analysis

For the game development, to improve the quality of the game, the project team consulted frontline teachers, educational psychologists, experts in primary education, and parents before developing the game. The project team hired a professional company to

develop the game with the suggestions from them. More features of the game will be introduced in the results and discussion section. Then, the intervention was conducted to examine the effectiveness of the game.

The intervention study, as mentioned before, consisted of three stages: pre-test, training, and post-test. In total, 85 students completed the pre-test during two 1-h sessions at the primary school. However, due to the outbreak of the pandemic and school closure, we had to pause the pre-test and adjust the procedure. Consider that the face-to-face testing approach was not appropriate in the pandemic period, the project team developed a testing application including the measures for the pre-test after working for months. By doing so, in total, 163 students completed the pre-test. Then, the participants were assigned into one of four training conditions: (a) computer game training, (b) dialogic reading with morphological training, (c) dialogic reading, and (d) no-treatment condition. The participants started a three-month training from October 2020 successively. At last, 77 participants completed the core measures through the testing application. Only 65 of these 77 participants received book coupons as compensation as the others did not complete the measures or we lost contact with them. At the same time, because of using the testing application for the data collection, less manpower (e.g., student helpers) than proposed was required. Therefore, about 30% of the fund were not used. Nevertheless, the major objectives of the project have been fulfilled well, including the development of the game package and the evaluation of it using the intervention study. Below please find the relevant details.

Results and Discussion

There were four training conditions in the intervention study, i.e., (a) computer game training, (b) dialogic reading with morphological training, (c) dialogic reading, and (d) no-treatment condition. For the (a) computer game training condition, the project developed a computer game, i.e., MorphorGame. For the (b) dialogic reading with morphological training

and (c) dialogic reading, the project selected 12 storybooks that are good for improving children's reading. In addition, two morphological training handbooks were developed by the project team for dialogic reading with morphological training. Although the game and morphological training handbooks were only provided to the participants in conditions (a) and (b), respectively, these materials were open to all participants for 6 months after they completed the intervention study.

MorphorGame

A main result of the current project is the computer game, i.e., MorphorGame, which has been released on Google Play (https://play.google.com/store/apps/details?id=com.eduhk.MorphoGameFull) and Apple Store (https://apps.apple.com/hk/app/morphorgame/id1533275754). The game presents morphological training for 16 weeks, relating to homophones, homographs, and morphological structures. The training content was developed by the project team, referring to Chinese textbooks for primary students in Grades 1 to 3. Through interesting games, children can acquire knowledge regarding morphemes and morphological structures of most frequency Chinese words.

To improve children's interests, the full version of the game has a storyline regarding the advantage of the main character, i.e., Morphor (毛福). The project team created stories with regard to the history and culture of 17 countries, e.g., China, America, France, and Canada. The story of each country would last for seven days. Accordingly, more than one thousand pictures and audio of the stories were completed. Thus, in addition to the morphological training, children also can gain knowledge about these countries during gaming. Meanwhile, considering the comments from the parents of the participants, we made a time limit of the game to prevent addiction. That is, the game would be locked when a daily game time reaches 20 minutes.

There are three main game scenes, i.e., look for the same, look for the difference, and judge. In the scene of look for the same, a target word will be presented, and the player will be asked to find the item that includes the same morpheme or structure as the target, from three to five options. In the scene of look for the difference, the player will be asked to find the item that has a different morpheme or structure from others. In the scene of the judge, the player will be asked to judge if the masked items or structure of the items are the same or not. Moreover, the game involves more features to improve children's interests in learning. Specifically, the games are integrated into the storyline. The players need to play more games if they want to know more about the story. The difficulty level of the games will be adjusted according to the performance of each player. The game has two reward systems, including a reward mechanism for finishing the assigned games and a reward mechanism for having a good performance.

Dialogic Reading with Morphological Training Handbooks

As mentioned before, the current project selected 12 storybooks for the participants in the two dialogic reading conditions. The project introduced how to use effective dialogues during reading to improve children's literacy abilities to the parents and children in the corresponding group. In addition, two handbooks of morphological training were developed. To develop the handbooks, all words of the 12 storybooks were selected and sorted by the per book. Then, according to the morphemes and morphological structures of the words that were selected from the storybooks, two more examples of each word were given. Moreover, after the daily training, the children would answer related questions to enforce the words that they learned through the training. These handbooks also contain most words for primary schools students in Grades 1-3, in addition, these words were systematically presented according to their morphemes and morphological structures.

Results of the Intervention Study

Preliminary Analyses

The descriptive statistics of homophone awareness, morphological awareness, Chinese character reading, reading fluency, reading comprehension, dictation, motivation of reading, phonological awareness, vocabulary, rapid automatized naming, working memory, and non-verbal IQ of the pre-test and post-test are summarized in Table 1.

Table 1

Means and SDs of All Measures of the Pre-test and Post-test

	Pre-test				Post-test				[*]Results
	M (SD)				M (SD)				
	Game	MA	Dialogic	Control	Game	MA	Dialogic	Control	
	(N = 22)	(N = 19)	(N = 17)	(N = 19)	(N = 22)	(N = 19)	(N = 17)	(N = 19)	
HA	20.47	19.80	20.21	20.75	24.56	23.47	25.40	23.46	Game ≈ MA ≈ Dialogic ≈ Control
	(3.47)	(3.27)	(3.63)	(6.23)	(4.71)	(5.07)	(3.36)	(3.17)	
MP	60.24	59.25	62.38	60.33	99.11	88.44	81.44	76.60	Game > MA > Dialogic > Control
	(24.55)	(17.50)	(15.99)	(24.26)	(6.71)	(7.99)	(6.30)	(9.88)	
CCR	34.65	30.46	31.73	36.53	74.84	56.88	67.60	57.64	Game > MA ≈ Dialogic ≈ Control
	(23.23)	(11.55)	(19.02)	(20.68)	(18.50)	(21.23)	(12.96)	(15.53)	& Game ≈ Dialogic ≈ Control
RF	31.92	35.77	36.33	38.94	40.65	38.07	49.89	46.58	Game ≈ MA > Dialogic ≈ Control
	(9.16)	(14.35)	(15.42)	(13.06)	(11.33)	(11.92)	(11.68)	(8.00)	
RC	5.90	6.69	7.82	7.231	11.50	10.56	11.09	11.00	Game ≈ MA ≈ Dialogic ≈ Control
	(2.67)	(2.84)	(2.12)	(3.43)	(3.95)	(4.78)	(3.44)	(3.51)	

	Pre-test M (SD)				Post-test M (SD)				*Results
	Game (N = 22)	MA (N = 19)	Dialogic (N = 17)	Control (N = 19)	Game (N = 22)	MA (N = 19)	Dialogic (N = 17)	Control (N = 19)	
Dictation	13.72 (6.01)	10.21 (6.20)	11.33 (5.86)	12.06 (8.68)	23.81 (11.27)	24.58 (9.43)	21.36 (7.03)	16.78 (9.89)	Game ≈ MA ≈ Dialogic ≈ Control
MR	38.52 (14.20)	40.27 (10.01)	35.18 (12.19)	39.17 (14.28)	37.78 (14.50)	40.44 (10.80)	41.64 (9.32)	33.40 (8.65)	Game ≈ MA ≈ Dialogic ≈ Control
PA	19.56 (7.56)	18.07 (6.79)	15.83 (6.05)	17.07 (8.02)	27.11 (4.32)	26.81 (4.09)	26.56 (3.69)	25.08 (4.47)	Game ≈ MA ≈ Dialogic ≈ Control
Vocabulary	16.43 (8.50)	17.36 (6.86)	18.12 (2.26)	18.54 (4.71)	26.90 (8.27)	25.69 (8.09)	31.13 (7.95)	23.00 (5.73)	Dialogic > Control ≈ Game ≈ MA
RAN	28.48 (9.45)	28.22 (8.70)	24.09 (8.63)	26.92 (4.95)	28.66 (10.00)	29.22 (8.29)	32.08 (12.39)	28.00 (4.75)	
WM	4.41 (3.94)	3.68 (4.24)	4.24 (3.07)	3.26 (2.83)	10.45 (3.48)	9.06 (3.54)	8.78 (2.37)	8.33 (3.04)	

	Pre-test				Post-test				[*]Results
	M (SD)				M (SD)				
	Game	MA	Dialogic	Control	Game	MA	Dialogic	Control	
	(N = 22)	(N = 19)	(N = 17)	(N = 19)	(N = 22)	(N = 19)	(N = 17)	(N = 19)	
Nonverbal IQ	17.00	15.72	15.94	14.56	20.85	20.11	21.00	21.13	
	(4.46)	(3.80)	(5.01)	(4.86)	(3.54)	(2.64)	(2.65)	(1.85)	

Note. Game = computer game training; MA = dialogic reading with morphological training; Dialogic = dialogic reading; Control = no-treatment condition. HA = homophone awareness; MP = morphological production; CCR = Chinese character reading; RF = reading fluency; RC = reading comprehension; MR = motivation for reading; PA = phonological awareness; RAN = rapid automatized naming; WM = Working memory.

[*] Results are the analyses of the post-test, with control of age and nonverbal IQ. The score of each task of the four groups was similar in the pre-test.

To have an overview of the training effects of each group, we compared the participants' performance in all measures between the pre-test and post-test. The results showed that for (a) the game group (N =22), 77.3 %, 100%, 100%, 77.3%, 90.9%, 86.4%, 54.5%, 72.7%, and 90.9% of the participants improved their performances in homophone awareness, morphological awareness, Chinese character reading, reading fluency, reading comprehension, dictation, motivation of reading, phonological awareness, and vocabulary, respectively. For (b) the morphological training group (N = 19), 78.9%, 94.7%, 89.5%, 57.9%, 78.9%, 94.7%, 57.9%, 89.5%, and 84.2% of the participants improved their performances in homophone awareness, morphological awareness, Chinese character reading, reading fluency, reading comprehension, dictation, motivation of reading, phonological awareness, and vocabulary, respectively. For (c) the dialogic reading group (N = 17), 88.2%, 88.2%, 88.2%, 82.4%, 76.5%, 88.2%, 76.5%, 94.1%, and 100% of the participants improved their performances in homophone awareness, morphological awareness, Chinese character reading, reading fluency, reading comprehension, dictation, motivation of reading, phonological awareness, and vocabulary, respectively. For the control group, 73.7%, 68.4%, 78.9%, 68.4%, 63.2%, 42.1%, 89.5%, and 78.9% of the participants improved their performances in homophone awareness, morphological awareness, Chinese character reading, reading fluency, reading comprehension, dictation, motivation of reading, phonological awareness, and vocabulary, respectively.

To examine whether there was a group difference in the numbers of participants that improved performance in the post-test, further analyses was conducted. The results of the Jonckheere-Terpstra test showed that the group difference was (marginally) significant in morphological production ($p = .002$), Chinese character reading ($p = .03$), reading comprehension ($p = .08$), and dictation ($p = .06$). Further comparison between groups showed that the game group had marginally significant differences in reading comprehension with the

morphological training group ($p = .08$) and dictation with the dialogic reading group ($p = .06$). The game group and the control groups had significant differences in morphological production ($p = .01$) and Chinese character reading ($p = .03$). The morphological training group and the dialogic reading group had a significant difference in Chinese character reading ($p = .04$). Also, the morphological training group and the control group had significant differences in morphological production ($p = .04$) and dictation ($p = .02$). In addition, the dialogic reading group and the control group differ in the motivation of reading ($p = .04$).

Analyses of Measures

To further examine whether there were differences among these four groups, 2 (Test: Pre-test/Post-test) × 4 (Group: Game/MA training/Dialogic reading/Control) ANCOVAs, with control of age and non-verbal IQ (that was measured in the pre-test), were conducted for analyzing homophone awareness, morphological awareness, Chinese character reading, reading fluency, reading comprehension, dictation, motivation of reading, phonological awareness, vocabulary. The results are summarized in Table 2.

The results showed that for the homophone awareness (see Figure 1), the main effect of the Test was significant. The participants had higher scores on the homophone awareness in the post-test than in the pre-test (mean difference = 3.91). The main effect of Group and the interaction effect between Test and Group were not significant. For the morphological production task (see Figure 1), the main effects of Test and Group were (marginally) significant. All the participants had better performance in the post-test than in the pre-test (mean difference = 25.81). Overall, the participants in the game condition had better performance than the control group (mean difference = 8.79). The interaction effect of Test and Group was significant. Simple main effects showed that in the post-test, the participants in these four groups had similar performance. However, in the post-test, the participants in

the game group had higher scores on the morphological production task than those in the morphological training (mean difference = 10.36, $p < .001$), in the dialogic (mean difference = 17.32, $p < .001$), and control (mean difference = 22.61, $p < .001$) groups. Also, the children in the morphological training group had (marginally) significant higher scores than those in the dialogic reading group (mean difference = 6.96, $p = .05$) and in the control (mean difference = 12.26, $p < .001$) group. However, the children in the dialogic reading group had similar performance with those in the control (mean difference = 5.30, $p = .27$) group. On the other hand, the difference between the pre-test and post-test was significant in all the four groups.

For Chinese character reading (see Figure 2), the main effects of Group and Test, and the interaction effect of them were not significant. The main effect of the Test was significant. The participants had higher scores on the homophone awareness in the post-test than in the pre-test (mean difference = 30.90). The main effect of the Group was not significant. Overall, the participants in the four groups had similar performances in the Chinese character reading task. However, the interaction effect between Test and Group was significant. Simple main effects showed that in the post-test, the participants in these four groups had similar performance. In the post-test, the participants in the game group had higher scores than those in the morphological training (mean difference = 16.30, $p = .01$). However, the participants in the game group had similar scores to those in the dialogic reading (mean difference = 6.00, $p = .84$) and control (mean difference = 12.81, $p = .11$) groups.

For the reading fluency, reading comprehension, and motivation for reading, the main effects of Test and Group, and the interaction effect between them were not significant (see Figure 2). For the dictation task, the main effect of the Test was significant, the scores in the post-test were higher than in the pre-test (mean difference = 9.79). The main effect of the

Group was not significant. Overall, the participants in the four groups had similar performances. The interaction between Test and Group was significant. Simple main effects showed that the group difference was not significant neither in the pre-test nor in the post-test. However, the difference between the pre-test and post-test was significant in the game (mean difference = 10.61, $p < .001$), morphological training (mean difference = 14.68, $p < .001$), and dialogic reading (mean difference = 10.55, $p < .001$) groups, but not in the control group (mean difference = 3.33, $p = .20$).

For the phonological awareness task (see Figure 3), the main effect of the Test was significant; the participants had higher scores on the task in the post-test than in the pre-test (mean difference = 8.76). However, the main effect of Group and the interaction effect of Test and Group were not significant. For the vocabulary task (see Figure 3), the main effects of Test and Group were not significant. Overall, the participants had similar performance in the task on the two testing points. The participants in the four groups had similar performance in general. However, the interaction between Test and Group was significant. Simple main effects showed that the participants in these four groups did not have significant differences in the pre-test. In the post-test, the participants in the control group had lower scores than those in the dialogic reading group (mean difference = -7.66, $p = .03$) but had similar scores to the participants in the game (mean difference = - 3.48, $p = .66$) and morphological training (mean difference = - 2.28, $p = .94$) groups.

Table 2

Results of ANCOVAs for Homophone Awareness, Morphological Production, Chinese Character Reading, Reading Fluency, Reading

Comprehension, Dictation, Motivation of Reading, Phonological Awareness, Vocabulary

	F_{Test}	p	η^2	F_{Group}	p	η^2	$F_{(\text{Test} \times \text{Group})}$	p	η^2
Homophone awareness	5.03	**.03**	.07	.40	.76	.02	.99	.40	.04
Morphological production	9.37	**.003**	.12	2.39	**.08**	.09	5.88	**.001**	.20
Chinese character reading	4.03	**.05**	.05	1.55	.21	.06	4.30	**.01**	.15
Reading fluency	1.76	.19	.02	1.76	.19	.02	2.19	.10	.09
Reading comprehension	0.73	.40	.01	.87	.46	.04	.89	.45	.04
Dictation	7.58	**.01**	.10	.88	.45	.04	3.34	**.02**	.12
Motivation for reading	0.76	.39	.01	.36	.78	.02	2.15	.10	.08
Phonological awareness	28.60	**< .001**	.29	.71	.55	.03	1.83	.15	.07
Vocabulary	0.02	.89	.001	1.64	.19	.07	2.42	**.07**	.09

Figure 1

Scores on Homophone Awareness and Morphological Production Tasks of the Pre-test and Post-test
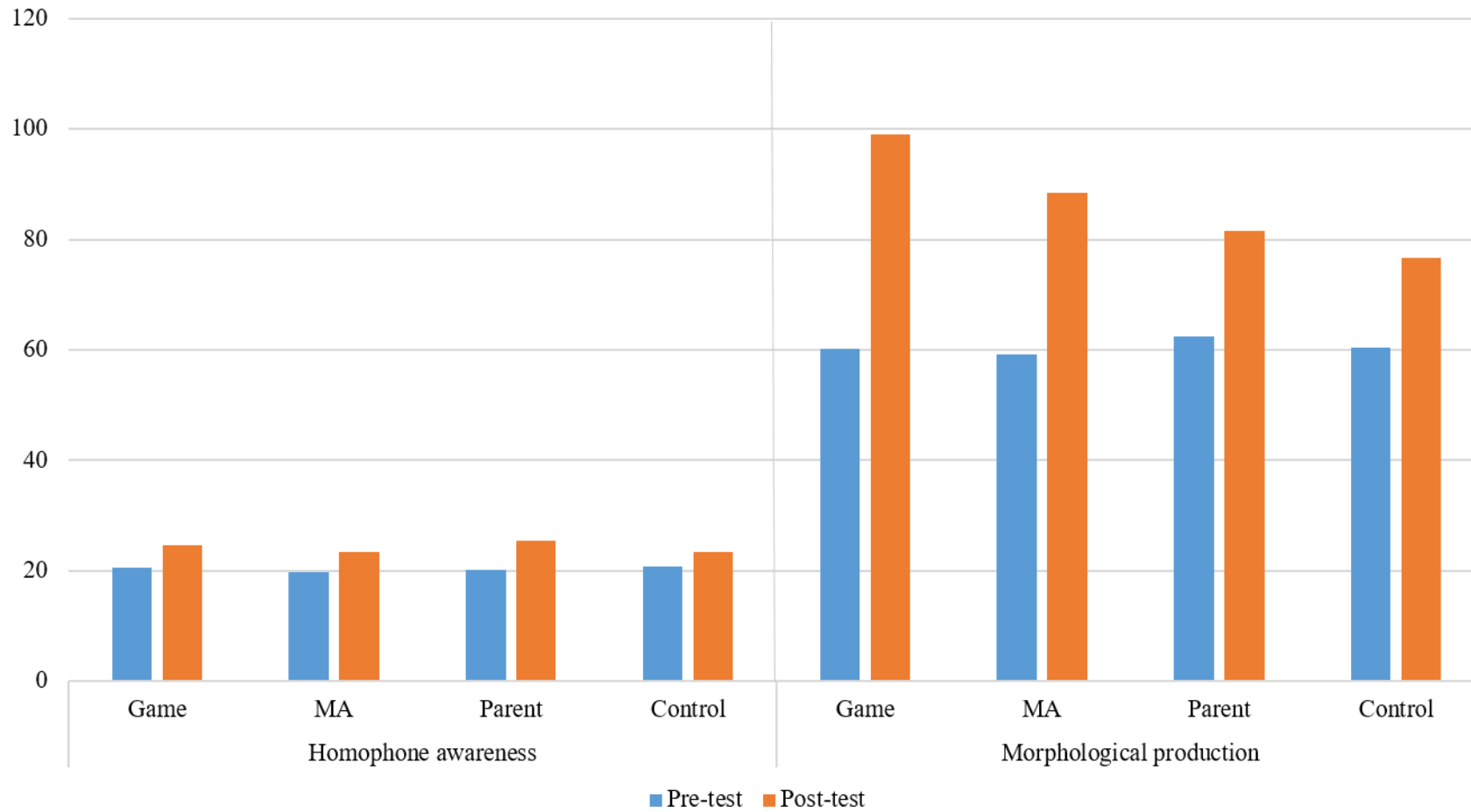
Figure 2

Scores on Chinese Character Reading, Reading Fluency, Reading Comprehension, Dictation, and Motivation for Reading of the Pre-test and
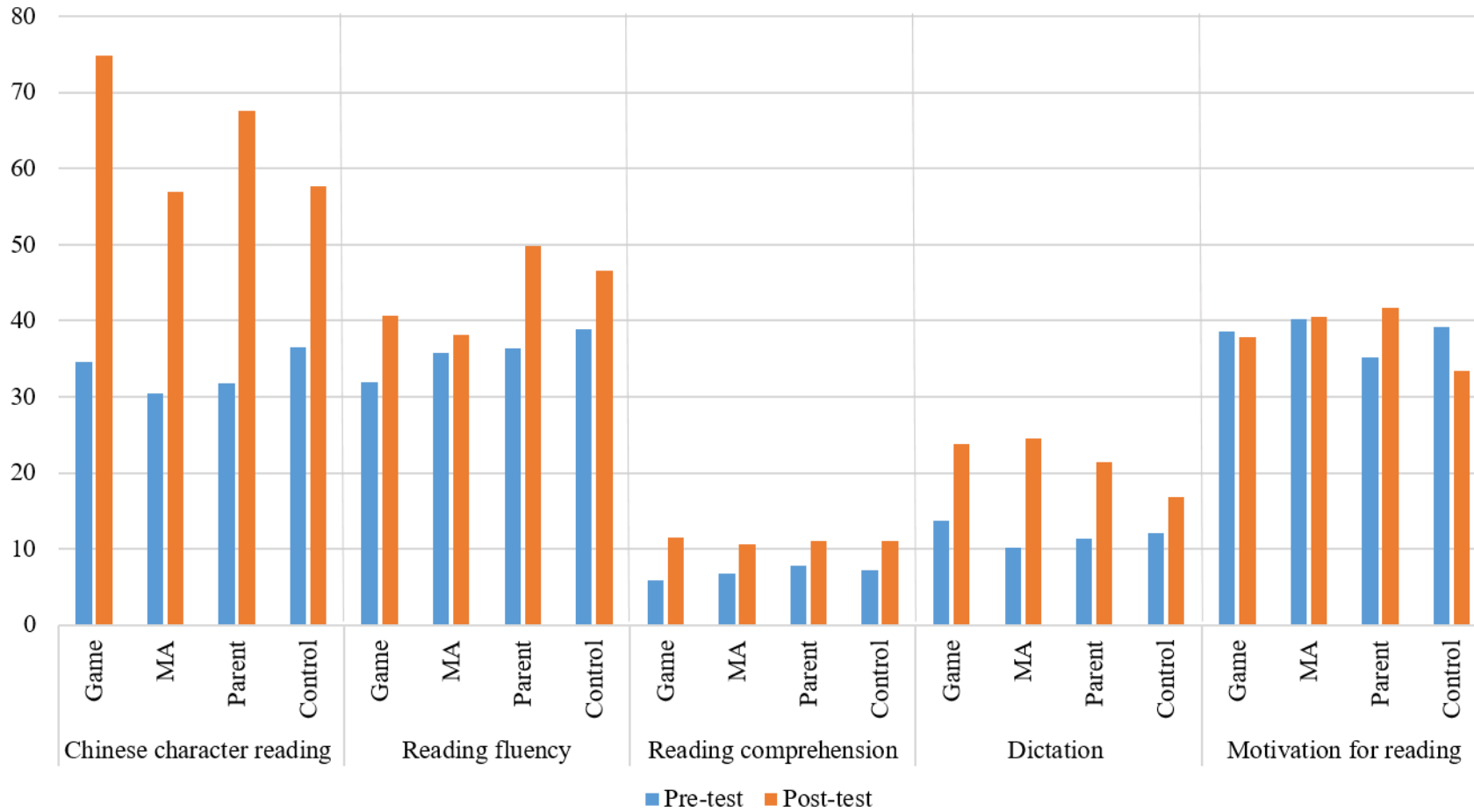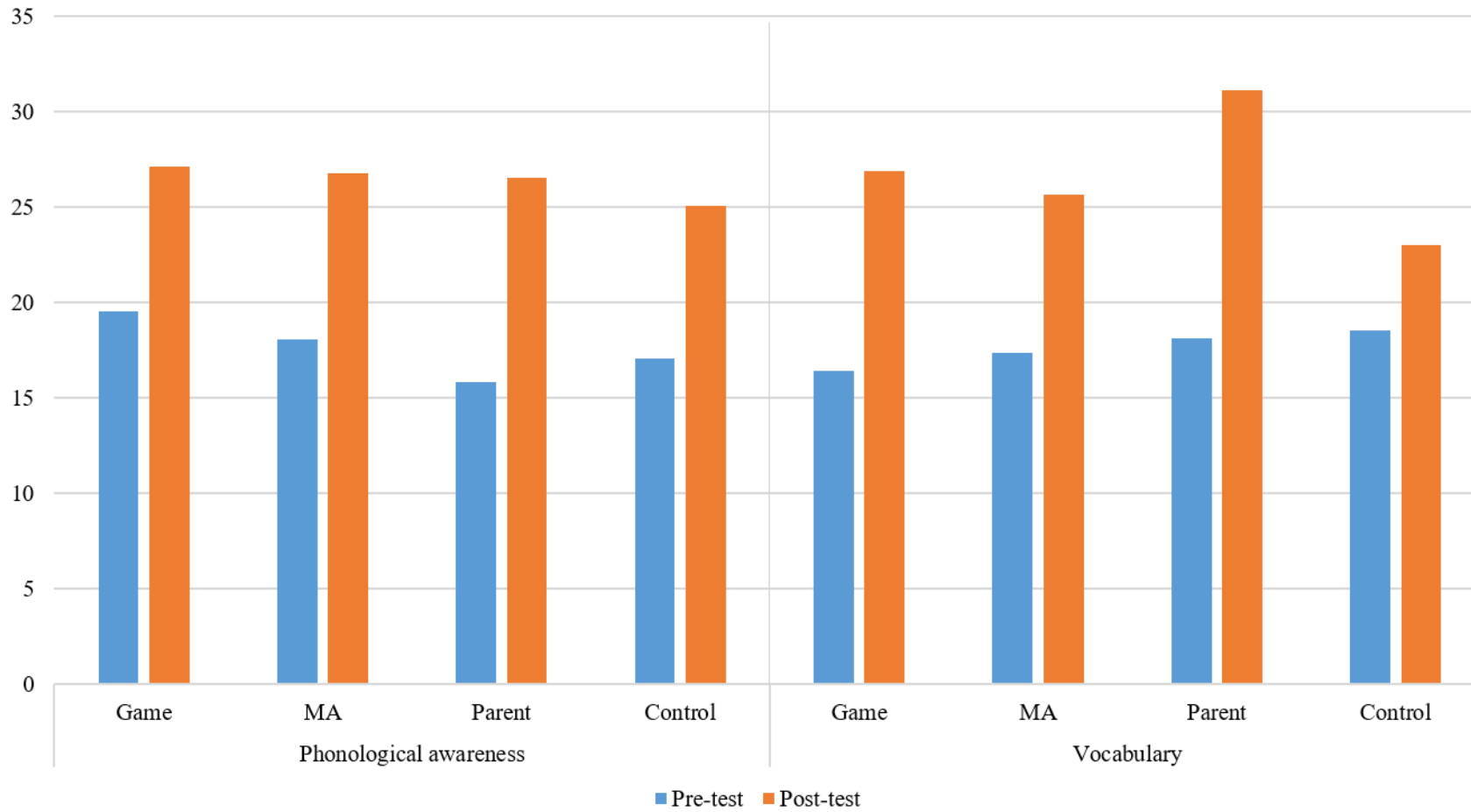
Post-test

Figure 3

Scores on Phonological Awareness and Vocabulary of the Pre-test and Post-test

Analyses of the Game Group

To further study the relationship between the game training and the improvements of literacy skills, the results of the game group were further analyzed. Two indicators regarding the game training were selected. One was the game time in minutes ($M = 920.69$; $SD = 674.78$), that is, the total time that spending on the game training. Another one was the game score ($M = 816.55$; $SD = 603.73$), that is, the total score that the children gained through responding correctly to the questions in the game. A correlation analysis showed that the game time had a positive correlation with the improvement (i.e., the difference between the post-test and the pre-test) of Chinese character reading ($r = .40$, $p = .03$). The game score had positive correlations with the improvement of reading comprehension ($r = .38$, $p = .04$) and vocabulary ($r = .37$, $p = .05$).

Discussion

The results of the intervention study reflected that the children had improvements in different literacy aspects after the training. The comparisons between the three training groups and the control group reflected the training effects of each group. Specifically, consistent with our assumption, the current findings indicated that compared to the other groups, game training can benefit children's morphological awareness more. However, such extra benefit of the game training on morphological awareness only was observed in the morphological production task, but not in the homophone awareness task. One possible interpretation is that the homophone awareness task was relatively easy for the children in the current sample. The scores of the homophone awareness task (Maximum = 31) were relatively high in the pre-test (Mean = 20.32) and the post-test (Mean = 24.20). It is possible that the group difference would be observed in a homophone awareness task with a higher difficulty. Also, the morphological training improved the children's performance in morphological production, whereas the dialogic reading elicited improvements similar to the

control group. Together, these findings demonstrated that training including morphological information can improve children's morphological awareness.

Another interesting finding is that the game training also led to a larger enhancement in Chinese character reading than the morphological training. This finding implied a possibility that the computer game can facilitate the reading ability at the word level. Consistent with this finding, previous studies also found that playing games with high-quality content through digital tools can improve children's academic achievements, including literacy abilities (Neumann, 2014; Shamir & Korat, 2007). In line with the current findings, previous studies found that even after controlling for children's performance on homophone sensitivity along with other measures, the morphological production task still explained unique variance in character reading (Shu et al., 2006).

It should be noted that in the morphological production task, both sensitivities to specific morphemes and knowledge of morphological structure were required. Thus, the morphological production task is particularly comprehensive as a measure of morphological awareness. The morphological production task first requires that children correctly identify critical morphemes. For example, in the question 我們把小馬在跳舞叫什麼？ ("What do we call a scenario in which a horse is dancing?"), the critical morpheme in the word 跳舞 (tiu3-mou5, jump-dance) is 舞 (dance), because 舞 (dance), but not 跳 (jump), most precisely represents the meaning of the word 跳舞. In addition, children must use the correct word structure to combine the two critical morphemes to produce a novel word 馬舞 (maa5-mou5, horse-dancing), reflecting children's awareness of Chinese compounding structure, and the subject-predicate structure in this case. Some children gave variable incorrect answers, including 舞馬 (mou5-maa5, dancing-horse) or 跳馬 (tiu3-maa5, jumping-horse), the structures of which are incorrect in expressing the exact meaning of the question. This task appears to directly tap children's ability to use both the morpheme and morphological

structure knowledge. Therefore, group differences in this task demonstrated that the game and the morphological training were beneficial for the morpheme and morphological structure knowledge.

An alternative interpretation is that playing the game, which presents interesting stories and challenges, enhanced the children's interests in reading. Literature demonstrated that interest in reading can assist reading development (Wigfield et al., 2004), however, this interpretation should be further explored with empirical evidence. Meanwhile, the data of the game group showed positive correlations of playing the game with literacy abilities, i.e., Chinese character reading, reading comprehension, and vocabulary. These results lent support for the effectiveness of the game. It can not only improve children's morphological awareness but also improve their general literacy abilities (Li et al., 2002; Liu & McBride-Chang, 2010; McBride-Chang et al., 2003).

As well, we found a group difference in dictation. That is, the children in the three training groups had significant improvements after the training session, but not the control group. These results demonstrated that reading-related training can not only benefit the ability relating to the training content but also assist children's general reading ability. Also, the improvements in the game and morphological training groups might be led by the improvements of morphological awareness, which has correlated with literacy abilities, including dictation (Kalindi & Chung, 2018; Shu et al., 2006).

At the same time, the current findings showed that dialogic reading leads to the largest improvement in vocabulary. This finding reflected an advantage of parent-child dialogic reading in improving vocabulary. A possible reason is that the content of the parent-child dialogue was not limited. The parents were asked to lead dialogues during reading storybooks. The dialogues even can beyond the content of the storybook. The training aimed to encourage children to think about the story and to express their ideas. The children may be

acquired more words through the dialogues, resulting in an improvement of vocabulary (Teepe et al., 2017). However, as the current project did not record the parent-child dialogues, it is hard to provide empirical evidence for this interpretation. Future studies could explore it by analyzing more details of the dialogic reading training.

On the other hand, we received some feedback about the MorpheGame and the morphological training handbooks, which were developed by the project team. According to the feedback from the participated children and parents, both of these two training materials improved children's learning interests. More importantly, these two materials make the knowledge relating to morpheme and morphological structure explicitly, which is rarely been taught directly in traditional teaching materials. At the same time, we also acquired many valuable comments to improve the quality of the two materials. These comments can help us make a better interface of the game, which makes the game more child friendly. Also, during the training, the children found the morphological structures are relatively hard to acquire. To make the content of the game and handbooks consistent, we used the same template for training the morphemic knowledge (i.e., homophones and homographs) and the morphological structure. However, indeed, compared to the homophones and homographs, which can be seen directly, the invisible morphological structure is harder to acquire. Thus, to improve their effectiveness, it would be better to revise the design of the game and the handbooks to make the content, in particular the one regarding morphological structure, easier for children to obtain. If it is possible, we hope to discuss with SCOLAR to upgrade the MorpheGame and the morphological training handbooks and promote them to the community in the future.

Conclusions and Recommendations

The current project developed a computer game and two handbooks to improve children's morphological awareness, and their effectiveness was examined through an

intervention study. The results showed that the training that was utilized in the current project, i.e., the game, the dialogic reading with morphological training, and the dialogic reading, can benefit children's reading development. In particular, the game and the dialogic reading with morphological training can facilitate children's morphological awareness. In addition, these three trainings, especially these relating to morphological awareness, could improve children's reading abilities at multiple levels, such as Chinese character reading, reading comprehension, dictation, and vocabulary. The current findings provide insights into using digital tools to facilitate children's reading development. Notably, the prevalence of using digital tools in children is increasing. Although using digital tools may lead to some negative results (Dias et al., 2016; Madigan et al., 2019; McManis & Gunnewig, 2012; van der Kooy-Hofland et al., 2012), it also could result in benefits. We should utilize these convenient digital tools to develop more interesting and efficient educational games or learning materials.

Bibliography

Anderson, R. C., & Li, W. (2006). A cross-language perspective on learning to read. In Geekie, P.,

Cambourne, B., & Fitzsimmons, P. (Eds), *Understanding literacy development* (pp. 77-104).

Routledge.

Blok, H., Oostdam, R., Otter, M. E., & Overmaat, M. (2002). Computer-assisted instruction in support of

beginning reading instruction: A review. *Review of Educational Research*, *72*(1), 101-130.

https://doi.org/10.3102/00346543072001101

Brem, S., Bach, S., Kucian, K., Kujala, J. V., Guttorm, T. K., Martin, E., Lyytinen, H., Brandeis D., &

Richardson, U. (2010). Brain sensitivity to print emerges when children learn letter–speech sound

correspondences. *Proceedings of the National Academy of Sciences*, *107*(17), 7939-7944.

https://doi.org/10.1073/pnas.0904402107

Bus, A. G., Van Ijzendoorn, M. H., & Pellegrini, A. D. (1995). Joint book reading makes for success in

learning to read: A meta-analysis on intergenerational transmission of literacy. *Review of*

Educational Research, *65*(1), 1-21. https://doi.org/10.3102/00346543065001001

Carlisle, J. F. (2000). Awareness of the structure and meaning of morphologically complex words: Impact

on reading. *Reading and Writing*, *12*(3), 169-190. https://doi.org/10.1023/A:1008131926604

Cheung, A. C., & Slavin, R. E. (2013). The effectiveness of educational technology applications for

enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research*

Review, *9*, 88-113. https://doi.org/10.1016/j.edurev.2013.01.001

Chow, B. W. Y., McBride-Chang, C., Cheung, H., & Chow, C. S. L. (2008). Dialogic reading and

morphology training in Chinese children: Effects on language and literacy. *Developmental*

Psychology, *44*(1), 233–244. https://doi.org/10.1037/0012-1649.44.1.233

Clarfield, J., & Stoner, G. (2005). The effects of computerized reading instruction on the academic

performance of students identified with ADHD. *School Psychology Review*, *34*(2), 246-254.

https://doi.org/10.1080/02796015.2005.12086286

Deacon, S. H., & Kirby, J. R. (2004). Morphological awareness: Just "more phonological"? The roles of

morphological and phonological awareness in reading development. *Applied*

Psycholinguistics, *25*(2), 223-238. https://doi.org/10.1017/S0142716404001110

Dias, P., Brito, R., Ribbens, W., Daniela, L., Rubene, Z., Dreier, M., Gemo, M., Gioia, R., & Chaudron,

S. (2016). The role of parents in the engagement of young children with digital technologies:

Exploring tensions between rights of access and protection, from 'Gatekeepers' to

'Scaffolders'. *Global Studies of Childhood*, *6*(4), 414-427.

https://doi.org/10.1177/2043610616676024

Teepe, R. C., Molenaar, I., & Verhoeven, L. (2017). Technology-enhanced storytelling stimulating

parent–child interaction and preschool children's vocabulary knowledge. *Journal of Computer*

Assisted Learning, *33*(2), 123-136. https://doi.org/10.1111/jcal.12169

Hao, M., Chen, X., Dronjic, V., Shu, H., & Anderson, R. C. (2013). The development of young Chinese

children's morphological awareness: The role of semantic relatedness and morpheme

type. *Applied Psycholinguistics*, *34*(1), 45-67. https://doi.org/10.1017/S0142716411000609

Heikkilä, R., Aro, M., Närhi, V., Westerholm, J., & Ahonen, T. (2013). Does training in syllable

recognition improve reading speed? A computer-based trial with poor readers from second and

third grade. *Scientific Studies of Reading*, *17*(6), 398-414.

https://doi.org/10.1080/10888438.2012.753452

HKSAR government (2012). Hong Kong poverty situation report 2012. Retrieved from:

http://www.povertyrelief.gov.hk/pdf/2012_Poverty_Situation_Eng.pdf

HKSAR government (2014). 2014 policy address. Retrieved from:

http://www.policyaddress.gov.hk/2014/eng/p46.html

Ho, C. S. H., Chan, D. W., Chung, K. K., Lee, S. H., & Tsang, S. M. (2007). In search of subtypes of

Chinese developmental dyslexia. *Journal of Experimental Child Psychology*, *97*(1), 61-83.

https://doi.org/10.1016/j.jecp.2007.01.002

Kalindi, S. C., & Chung, K. K. H. (2018). The impact of morphological awareness on word reading and

dictation in Chinese early adolescent readers with and without dyslexia. *Frontiers in

Psychology*, *9*, Article 511. https://doi.org/10.3389/fpsyg.2018.00511

Ku, Y. M., & Anderson, R. C. (2003). Development of morphological awareness in Chinese and

English. *Reading and Writing*, *16*(5), 399-422. https://doi.org/10.1023/A:1024227231216

Kuo, L. J., & Anderson, R. C. (2006). Morphological awareness and learning to read: A cross-language

perspective. *Educational Psychologist*, *41*(3), 161-180.

https://doi.org/10.1207/s15326985ep4103_3

Kyle, F., Kujala, J., Richardson, U., Lyytinen, H., & Goswami, U. (2013). Assessing the effectiveness of

two theoretically motivated computer-assisted reading interventions in the United Kingdom: GG

Rime and GG Phoneme. *Reading Research Quarterly*, *48*(1), 61-76.

https://doi.org/10.1002/rrq.038

Lam, S. F., Chow-Yeung, K., Wong, B. P., Lau, K. K., & Tse, S. I. (2013). Involving parents in paired

reading with preschoolers: Results from a randomized controlled trial. *Contemporary Educational*

Psychology, *38*(2), 126-135. https://doi.org/10.1016/j.cedpsych.2012.12.003

Lam, S. S. Y., & McBride-Chang, C. (2013). Parent-child joint writing in Chinese kindergarteners:

Explicit instruction in radical knowledge and stroke writing skills. *Writing Systems*

Research, *5*(1), 88-109. https://doi.org/10.1080/17586801.2013.812532

Leong, C. K., Hau, K. T., Tse, S. K., & Loh, K. Y. (2007). Component skills of text comprehension in

less competent Chinese comprehenders. *Annals of Dyslexia*, *57*(1), 75-97.

https://doi.org/10.1007/s11881-007-0004-z

Li, H., & Rao, N. (2000). Parental influences on Chinese literacy development: A comparison of

preschoolers in Beijing, Hong Kong, and Singapore. *International Journal of Behavioral*

Development, *24*(1), 82-90. http://www.tandf.co.uk/journals/pp/01650254.html

Li, H., Dronjic, V., Chen, X. I., Li, Y., Cheng, Y., & Wu, X. (2017). Morphological awareness as a

function of semantics, phonology, and orthography and as a predictor of reading comprehension in

Chinese. *Journal of Child Language*, *44*(5), 1218-1247.

https://doi.org/10.1017/S0305000916000477

Li, W., Anderson, R. C., Nagy, W., & Houcan, Z. (2002). Facets of metalinguistic awareness that

contribute to Chinese literacy. In W., Li, Gaffney, J., & Packard, J. (Eds), *Chinese children's*

reading acquisition (pp. 87-106). Springer.

Liao, Y. K. C. (2007). Effects of computer-assisted instruction on students' achievement in Taiwan: A

meta-analysis. *Computers & Education*, *48*(2), 216-233.

https://doi.org/10.1016/j.compedu.2004.12.005

Lin, D., Wong, K. K., & McBride-Chang, C. (2012). Reading motivation and reading comprehension in

Chinese and English among bilingual students. *Reading and Writing*, *25*(3), 717-737.

https://doi.org/10.1007/s11145-011-9297-8

Liu, P. D., & McBride-Chang, C. (2010). What is morphological awareness? Tapping lexical

compounding awareness in Chinese third graders. *Journal of Educational Psychology, 102*(1), 62–

73. https://doi.org/10.1037/a0016933

Liu, P. D., McBride-Chang, C., Wong, T. T. Y., Shu, H. U. A., & Wong, A. M. Y. (2013). Morphological

awareness in Chinese: Unique associations of homophone awareness and lexical compounding to

word reading and vocabulary knowledge in Chinese children. *Applied Psycholinguistics*, *34*(4),

755-775. https://doi.org/10.1017/S014271641200001X

Lynch, J. (2002). Parents' self-efficacy beliefs, parents' gender, children's reader self-perceptions,

reading achievement and gender. *Journal of Research in reading*, *25*(1), 54-67.

https://doi.org/10.1111/1467-9817.00158

Lyster, S. A. H. (2002). The effects of morphological versus phonological awareness training in

kindergarten on reading development. *Reading and Writing*, *15*(3), 261-294.

https://doi.org/10.1023/A:1015272516220

Madigan, S., Browne, D., Racine, N., Mori, C., & Tough, S. (2019). Association between screen time and

children's performance on a developmental screening test. *JAMA Pediatrics*, *173*(3), 244-250.

https://doi.org/10.1001/jamapediatrics.2018.5056

Mahony, D., Singson, M., & Mann, V. (2000). Reading ability and sensitivity to morphological

relations. *Reading and Writing*, *12*(3), 191-218. https://doi.org/10.1023/A:1008136012492

McBride-Chang, C., Shu, H., Zhou, A., Wat, C. P., & Wagner, R. K. (2003). Morphological awareness

uniquely predicts young children's Chinese character recognition. *Journal of Educational*

Psychology, 95(4), 743–751. https://doi.org/10.1037/0022-0663.95.4.743

McBride-Chang, C., Tardif, T., Cho, J. R., Shu, H. U. A., Fletcher, P., Stokes, S. F., ... & Leung, K.

(2008). What's in a word? Morphological awareness and vocabulary knowledge in three

languages. *Applied Psycholinguistics*, *29*(3), 437-462.

https://doi.org/10.1017/S014271640808020X

McManis, L. D., & Gunnewig, S. B. (2012). Finding the education in educational technology with early

learners. *Young Children*, *67*(3), 14-24.

https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.388.2016&rep=rep1&type=pdf

Nagy, W. E., & Anderson, R. C. (1984). How many words are there in printed school English? *Reading*

Research Quarterly, 19(3), 304-330. https://doi.org/10.2307/747823

Nagy, W., Berninger, V. W., & Abbott, R. D. (2006). Contributions of morphology beyond phonology to

literacy outcomes of upper elementary and middle-school students. *Journal of Educational*

Psychology, 98(1), 134–147. https://doi.org/10.1037/0022-0663.98.1.134

Neumann, M. M. (2014). An examination of touch screen tablets and emergent literacy in Australian pre-

school children. *Australian Journal of Education*, *58*(2), 109-122.

https://doi.org/10.1177/0004944114523368

Nunes, T., Bryant, P., & Olsson, J. (2003). Learning morphological and phonological spelling rules: An

intervention study. *Scientific Studies of Reading*, *7*(3), 289-307.

https://doi.org/10.1207/S1532799XSSR0703_6

Packard, J. L., Chen, X., Li, W., Wu, X., Gaffney, J. S., Li, H., & Anderson, R. C. (2006). Explicit

instruction in orthographic structure and word morphology helps Chinese children learn to write

characters. *Reading and Writing*, *19*(5), 457-487. https://doi.org/10.1007/s11145-006-9003-4

Pasquarella, A., Chen, X., Gottardo, A., & Geva, E. (2015). Cross-language transfer of word reading

accuracy and word reading fluency in Spanish-English and Chinese-English bilinguals: Script-

universal and script-specific processes. *Journal of Educational Psychology*, *107*(1), 96–

110. https://doi.org/10.1037/a0036966.

Payne, A. C., Whitehurst, G. J., & Angell, A. L. (1994). The role of home literacy environment in the

development of language ability in preschool children from low-income families. *Early Childhood

Research Quarterly*, *9*(3-4), 427-440. https://doi.org/10.1016/0885-2006(94)90018-3

Qian, Y., Lee, T., & Soong, F. K. (2004). Use of tone information in continuous Cantonese speech

recognition. In *Speech Prosody 2004, International Conference*.

Raven, J. (2003). Raven progressive matrices. In *Handbook of nonverbal assessment* (pp. 223-237).

Springer.

Reese, E., Sparks, A., & Leyva, D. (2010). A review of parent interventions for preschool children's

    language and emergent literacy. *Journal of Early Childhood Literacy*, *10*(1), 97-117.

    https://doi.org/10.1177/1468798409356987

Richardson, U., & Lyytinen, H. (2014). The GraphoGame method: The theoretical and methodological

    background of the technology-enhanced learning environment for learning to read. *Human*

    Technology, *10*(1), 39-60. https://doi.org/10.17011/ht/urn.201405281859

Rosas, R., Nussbaum, M., Cumsille, P., Marianov, V., Correa, M., Flores, P., Grau, V., Lagos, F., López,

    X., López, V., Rodriguez, P., & Salinas, M. (2003). Beyond Nintendo: Design and assessment of

    educational video games for first and second grade students. *Computers & Education*, *40*(1), 71-

    94. https://doi.org/10.1016/S0360-1315(02)00099-4

Saine, N. L., Lerkkanen, M. K., Ahonen, T., Tolvanen, A., & Lyytinen, H. (2011). Computer-assisted

    remedial reading intervention for school beginners at risk for reading disability. *Child*

    Development, *82*(3), 1013-1028. https://doi.org/10.1111/j.1467-8624.2011.01580.x

Sénéchal, M., & LeFevre, J. A. (2002). Parental involvement in the development of children's reading

    skill: A five-year longitudinal study. *Child Development*, *73*(2), 445-460.

    https://doi.org/10.1111/1467-8624.00417

Shamir, A., & Korat, O. (2007). Developing an educational e-book for fostering kindergarten children's

    emergent literacy. *Computers in the Schools*, *24*(1-2), 125-143.

    https://doi.org/10.1300/J025v24n01_09

Shu, H., & Anderson, R. C. (1999). Learning to read Chinese: The development of metalinguistic

    awareness. *Reading Chinese script: A cognitive analysis* (pp. 1-18). Psychology Press.

Shu, H., McBride-Chang, C., Wu, S., & Liu, H. (2006). Understanding Chinese developmental dyslexia: Morphological awareness as a core cognitive construct. *Journal of Educational Psychology, 98*(1), 122–133. https://doi.org/10.1037/0022-0663.98.1.122

Tong, X., McBride-Chang, C., Shu, H., & Wong, A. M. (2009). Morphological awareness, orthographic knowledge, and spelling errors: Keys to understanding early Chinese literacy acquisition. *Scientific Studies of Reading*, *13*(5), 426-452. https://doi.org/10.1080/10888430903162910

Torgesen, J. K., Wagner, R. K., Rashotte, C. A., Herron, J., & Lindamood, P. (2010). Computer-assisted instruction to prevent early reading difficulties in students at risk for dyslexia: Outcomes from two instructional approaches. *Annals of Dyslexia*, *60*(1), 40-56. https://doi.org/10.1007/s11881-009-0032-y

Van der Kooy-Hofland, V. A., Van der Kooy, J., Bus, A. G., van IJzendoorn, M. H., & Bonsel, G. J. (2012). Differential susceptibility to early literacy intervention in children with mild perinatal adversities: Short-and long-term effects of a randomized control trial. *Journal of Educational Psychology*, *104*(2), 337. https://doi.org/10.1037/a0026984

Wang, C. W., Chan, C. L., Mak, K. K., Ho, S. Y., Wong, P. W., & Ho, R. T. (2014). Prevalence and correlates of video and Internet gaming addiction among Hong Kong adolescents: A pilot study. *The Scientific World Journal*, Article 874648. https://doi.org/10.1155/2014/874648

Wigfield, A., Guthrie, J. T., Tonks, S., & Perencevich, K. C. (2004). Children's motivation for reading: Domain specificity and instructional influences. *The Journal of Educational Research*, *97*(6), 299-310. https://doi.org/10.3200/JOER.97.6.299-310

Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van Der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology*, *105*(2), 249 –265. https://doi.org/10.1037/a0031311

Wu, X., Anderson, R. C., Li, W., Wu, X., Li, H., Zhang, J., Zheng, Q., Zhu, J., Shu, H., Jiang, W., Chen, X., Wang, Q., Yin, L., He, Y., Packard, J., & Gaffney, J. S. (2009). Morphological awareness and Chinese children's literacy development: An intervention study. *Scientific Studies of Reading*, *13*(1), 26-52. https://doi.org/10.1080/10888430802631734

Yuan, C., & Huang, C. (1998). The study of Chinese morphemes and word formation based on the morpheme data bank. *Applied Linguistics*, *3*, 83-88.