Applications of GPC Rules and Character Structures in Games for Learning Chinese Characters

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Abstract

We demonstrate applications of psycholinguistic and sublexical information for learning Chinese characters. The knowledge about the grapheme-phoneme conversion (GPC) rules of languages has been shown to be highly correlated to the ability of reading alphabetic languages and Chinese. We build and will demo a game platform for strengthening the association of phonological components in Chinese characters with the pronunciations of the characters. Results of a preliminary evaluation of our games indicated significant improvement in learners' response times in Chinese naming tasks. In addition, we construct a Web-based open system for teachers to prepare their own games to best meet their teaching goals. Techniques for decomposing Chinese characters and for comparing the similarity between Chinese characters were employed to recommend lists of Chinese characters for authoring the games. Evaluation of the authoring environment with 20 subjects showed that our system made the authoring of games more effective and efficient.

1 Introduction

Learning to read and write Chinese characters is a challenging task for learners of Chinese. To read everyday news articles, one needs to learn thousands of Chinese characters. The official agents in Taiwan and China, respectively, chose 5401 and 3755 characters as important basic characters in national standards. Consequently, the general public has gained the impression that it is not easy to read Chinese articles, because each of these thousands of characters is written in different ways.

Teachers adopt various strategies to help learners to memorize Chinese characters. An instructor at the University of Michigan made up stories based on decomposed characters to help students remember their formations (Tao, 2007). Some take linguistics-based approaches. Pictogram is a major formation of Chinese characters, and radicals carry partial semantic information about Chinese characters. Hence, one may use radicals as hints to link the meanings and writings of Chinese characters. For instance, "河"(he2, river) [Note: Chinese characters will be followed by their pronunciations, denoted in Hanyu pinyin, and, when necessary, an English translation.], "海"(hai3, sea), and "洋"(yang2, ocean) are related to huge water systems, so they share the semantic radical, 氵, which is a pictogram for "water" in Chinese. Applying the concepts of pictograms, researchers designed games, e.g., (Lan et al., 2009) and animations, e.g., (Lu, 2011) for learning Chinese characters.

The aforementioned approaches and designs mainly employ visual stimuli in activities. We report exploration of using the combination of audio and visual stimuli. In addition to pictograms, more than 80% of Chinese characters are phono-semantic characters (**PSCs**, henceforth) (Ho and Bryant, 1997). A PSC consists of a phonological component (**PC**, henceforth) and a semantic component. Typically, the semantic components are the radicals of PSCs. For instance, "讀"(du2), "瀆"(du2), "犢" (du2), "牘"(du2) contain different radicals, but they share the same phonological components, "賣"(mai4), on their right sides. Due to the shared PC, these four characters are pronounced in exactly the same way. If a learner can learn and apply this rule, one may guess and read "黷"(du2) correctly easily.

In the above example, "賣" is a normal Chinese character, but not all Chinese PCs are standalone characters. The characters "檢"(jian3), "撿" (jian3), and "儉"(jian3) share their PCs on their right sides, but that PC is not a standalone Chinese character. In addition, when a PC is a standalone character, it might not indicate its own or similar pronunciation when it serves as a PC in the hosting character, e.g., "賣" and "讀" are pronounced as /mai4/ and /du2/, respectively. In contrast, the pronunciations of "匋", "淘", "陶", and "啕" are /tao2/.

Pronunciations of specific substrings in words of alphabetic languages are governed by grapheme-phoneme conversion (GPC) rules, though not all languages have very strict GPC rules. The GPC rules in English are not as strict as those in Finish

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(Ziegler and Goswami, 2005), for instance. The substring "ean" are pronounced consistently in "bean", "clean", and "dean," but the substring "ch" does not have a consistent pronunciation in "school", "chase", and "machine." PCs in Chinese do not follow strict GPC rules either, but they remain to be good agents for learning to read.

Despite the differences among phoneme systems and among the degrees of strictness of the GPC rules in different languages, ample psycholinguistic evidences have shown that phonological awareness is a crucial factor in predicting students' reading ability, e.g., (Siok and Fletcher, 2001). Moreover, the ability to detect and apply phonological consistency in GPCs, including the roles of PCs in PSCs in Chinese, plays an instrumental role in learners' competence in reading Chinese. Phonological consistency is an important concept for learners of various alphabetic languages (Jared et al., 1990; Ziegler and Goswami, 2005) and of Chinese, e.g., (Lee et al., 2005), and is important for both young readers (Ho and Bryant, 1997; Lee, 2009) and adult readers (Lin and Collins, 2012).

This demonstration is unique on two aspects: (1) students play games that are designed to strengthen the association between Chinese PCs and the pronunciations of hosting characters and (2) teachers compile the games with tools that are supported by sublexical information in Chinese. The games aim at implicitly informing players of the Chinese GPC rules, mimicking the process of how infants would apply statistical learning (Saffran et al., 1996). We evaluated the effectiveness of the game platform with 116 students between grade 1 and grade 6 in Taiwan, and found that the students made progress in the Chinese naming tasks.

As we will show, it is not trivial to author games for learning a GPC rule to meet individualized teaching goals. For this reason, techniques reported in a previous ACL conference for decomposing and comparing Chinese characters were employed to assist the preparation of games (Liu et al., 2011). Results of our evaluation showed that the authoring tool facilitates the authoring process, improving both efficiency and effectiveness.

We describe the learning games in Section 2, and report the evaluation results of the games in Section 3. The authoring tool is presented in Section 4, and its evaluation is discussed in Section 5. We provide some concluding remarks in Section 6.

2 The Learning Games

A game platform should include several functional components such as the management of players' accounts and the maintenance of players' learning profiles. Yet, due to the page limits, we focus on the parts that are most relevant to the demonstration.

Figure 1. The learning game

Figure 1 shows a screenshot when a player is playing the game. This is a game of "whac-a-mole" style. The ***target PC*** appears in the upper middle of the window ("里"(li3) in this example), and a character and an accompanying monster (one at a time) will pop up randomly from any of the six holes on the ground. The player will hear the pronunciation of the character (i.e., "裡"(li3)), such that the player receives both audio and visual stimuli during a game. Players' task is to hit the monsters for the characters that contain the shown PC. The box at the upper left corner shows the current credit (i.e., 3120) of the player. The player's credit will be increased or decreased if s/he hits a correct or an incorrect character, respectively. If the player does not hit, the credit will remain the same. Players are ranked, in the Hall of Fame, according to their total credits to provide an incentive for them to play the game after school.

In Figure 1, the player has to hit the monster before the monster disappears to get the credit. If the player does not act in time, the credit will not change.

On ordinary computers, the player manipulates the mouse to hit the monster. On multi-touch tablet computers, the play can just touch the monsters with fingers. Both systems will be demoed.

2.1 Challenging Levels

At the time of logging into the game, players can choose two parameters: (1) class level: lower class (i.e., grades 1 and 2), middle class (i.e., grades 3 and 4), or upper class (i.e., grades 5 and 6) and (2) speed level: the duration between the monsters' popping up and going down. The characters for lower, middle, and upper classes vary in terms of frequency and complexity of the characters. A student can choose the upper class only if s/he is in the upper class or if s/he has gathered sufficient credits. There are three different speeds for the monsters to appear and hide: 2, 3, and 5 seconds. Choosing different combinations of these two pa-

	Lower	Middle	Upper
5	10	20	30
3	15	25	35
2	20	30	40

Table 1.Credits for challenging levels

rameters affect how the credits are added or deducted when the players hit the monsters correctly or incorrectly, respectively. Table 1 shows the increments of credits for different settings. The numbers on the leftmost column are speed levels.

2.2 Feedback Information

After finishing a game, the player receives feedback about the correct and incorrect actions that were taken during the game. Figure 2 shows such an example.

Figure 2. Feedback information

The feedback informs the players what characters were correctly hit ("埋"(mai2), "理"(li3), "裡"(li3), and "鯉"(li3)), incorrectly hit ("婷"(ting2) and "袖"(show4)), and should have been hit ("狸"(li2)). When the player moves mouse over these characters, a sample Chinese word that shows how the character is used in daily lives will show up in a vertical box near the middle (i.e., "裡面"(li3 mian4)).

The main purpose of providing the feedback information is to allow players a chance to reflect on what s/he had done during the game, thereby strengthening the learning effects.

On the upper right hand side of Figure 2 are four tabs for more functions. Clicking on the top tab (繼續玩) will take the player to the next game. In the next game, the focus will switch to a different PC. The selection of the next PC is random in the current system, but we plan to make the switching from a game to another adaptive to the students' performance in future systems. Clicking on the second tab (看排行) will see the player list in the Hall of Fame, clicking on the third tab (返回主選單) will return to the main menu, and clicking on the fourth (加分題) will lead to games for extra credits. We have extended our games to lead students to learning Chinese words from characters, and details will be illustrated during the demo.

2.3 Behind the Scene

	Lower	Middle	Upper
Experimental	11	23	24
Control	11	23	24

Table 2. Number of participants

The data structure of a game is simple. When compiling a game, a teacher selects the PC for the game, and prepares six characters that contain the PC (to be referred as an **In-list** henceforth) and four characters as distracter characters that do not contain the PC (to be referred as an **Out-list** henceforth). The simplest internal form of a game looks like {target PC= "里", In-list= "裡理鯉浬哩鋰", Out-list= "塊鰓嘿鉀" }. We can convert this structure into a game easily. Through this simple structure, teachers choose the PCs to teach with character combinations of different challenging levels.

During the process of playing, our system randomly selects one character from the list of 10 characters. In a game, 10 characters will be presented to the player.

3 Preliminary Evaluation and Analysis

The game platform was evaluated with 116 students, and was found to shorten students' response times in Chinese naming tasks.

3.1 Procedure and Participants

The evaluation was conducted at an elementary school in Taipei, Taiwan, during the winter break between late January and the end of February 2011. The lunar new year of 2011 happened to be within this period.

Students were divided into an experimental group and a control group. We taught students of the experimental group and showed them how to play the games in class hours before the break began. The experimental group had one month of time to play the games, but there were no rules asking the participants how much time they must spend on the games. Instead, they were told that they would be rewarded if they were ranked high in the Hall of Fame. Table 2 shows the numbers of participants and their actual class levels.

As we explained in Section 2.1, a player could choose the class level before the game begins. Hence, for example, it is possible for a lower class player to play the games designed for middle or even upper class levels to increase their credits faster. However, if the player is not competent, the credits may be deducted faster as well. In the evaluation, 20 PCs were used in the games for each class level in Table 1.

Pretests and posttests were administered with the standardized (1) Chinese Character Recognition

Control Group				
	Class	Pretests	Posttests	p-value
CCRT (characters)	Lower	59	61	.292
	Middle	80	83	.186
	Upper	117	120	.268
RAN Correct Rate	Lower	83%	79%	.341
	Middle	59%	64%	.107
	Upper	89%	89%	1.00
RAN Speed (second)	Lower	23.1	20.6	.149
	Middle	24.3	20.2	.131
	Upper	15.7	14.1	**.026**

Table 3. Results for control group

Experimental Group				
	Class	Pretests	Posttests	p-value
CCRT (characters)	Lower	64	61	.226
	Middle	91	104	**.001**
	Upper	122	124	.52
RAN Correct Rate	Lower	73%	76%	.574
	Middle	70%	75%	.171
	Upper	89%	91%	.279
RAN Speed (second)	Lower	21.5	16.9	**.012**
	Middle	24.6	19.0	**.001**
	Upper	16.9	14.7	**<0.001**

Table 4. Results for experimental group

Test (CCRT) and (2) Rapid Automatized Naming Task (RAN). In CCRT, participants needed to write the pronunciations in Jhuyin, which is a phonetic system used in Taiwan, for 200 Chinese characters. The number of correctly written Jhuyins for the characters was recorded. In RAN, participants read 20 Chinese characters as fast as they could, and their speeds and accuracies were recorded.

3.2 Results and Analysis

Table 3 shows the statistics for the control group. After the one month evaluation period, the performance of the control group did not change significantly, except participants in the upper class. This subgroup improved their speeds in RAN. (Statistically significant numbers are highlighted.)

Table 4 shows the statistics for the experimental group. After the evaluation period, the speeds in RAN of all class levels improved significantly.

The correct rates in RAN of the control group did not improve or fall, though not statistically significant. In contrast, the correct rates in RAN of the experimental group improved, but the improvement was not statistically significant either.

The statistics for the CCRT tests were not statistically significant. The only exception is that the middle class in the experimental group achieved better CCRT results. We were disappointed in the falling of the performance in CCRT of the lower class, though the change was not significant. The lower class students were very young, so we conjectured that it was harder for them to remember the writing of Jhuyin symbols after the winter break. Hence, after the evaluation, we strengthened the feedback by adding Jhuyin information. In Figure 2, the Jhuyin information is now added beside the sample Chinese words, i.e., “裡面” (li3 mian4).

4 An Open Authoring Tool for the Games

Our game platform has attracted the attention of teachers of several elementary schools. To meet the teaching goals of teacher in different areas, we have to allow the teachers to compile their own games for their needs.

The data structure for a game, as we explained in Section 2.3, is not complex. A teacher needs to determine the PC to be taught first, then s/he must choose an In-list and an Out-list. In the current implementation, we choose to have six characters in the In-list and four characters in the Out-list. We allow repeated characters when the qualified characters are not enough.

This authoring process is far less trivial as it might seem to be. In a previous evaluation, even native speakers of Chinese found it challenging to list many qualified characters out of the sky. Because PCs are not radicals, ordinary dictionaries would not help very much. For instance, “埋” (mai2), “狸”(li2), “裡”(li3), and “鯉”(li3) belong to different radicals and have different pronunciations, so there is no simple way to find them at just one place.

Identifying characters for the In-list of a PC is not easy, and finding the characters for the Out-list is even more challenging. In Figure 1, “里” (li3) is the PC to teach in the game. Without considering the characters in In-list for the game, we might believe that “甲” (jia3) and “呈” (cheng2) look equally similar to “里”, so both are good distracters. If, assuming that “理”(li3) is in the In-list, “玾” (jia3) will be a better distracter than “埕” (cheng2) for the Out-list, because “玾” and “理” are more similar in appearance. By contrast, if we have “裡” in the In-list, we may prefer to having “程” (cheng2) than having “玾” in the Out-list.

Namely, given a PC to teach and a selected In-list, the “quality” of the Out-list is dependent on the characters in In-list. Out-lists of high quality influence the challenging levels of the games, and will become a crucial ingredient when we make the games adaptive to players’ competence.

4.1 PC Selection

In a realistic teaching situation, a teacher will be teaching new characters and would like to provide students games that are related to the structures of the new characters. Hence, it is most convenient for the teachers that our tool decomposes a given character and recommends the PC in the character. For instance, given “理”, we show the teacher that we could compile a game for “里”. This is achievable using the techniques that we illustrate in the next subsection.

4.2 Character Recommendation

Given a selected PC, a teacher has to prepare the In-list and Out-list for the game. Extending the techniques we reported in (Liu et al., 2011), we decompose every Chinese character into a sequence of detailed Cangjie codes, which allows us to infer the PC contained in a character and to infer the similarity between two Chinese characters.

For instance, the internal codes for “里”, “理”, “裡”, and “玾” are, respectively, “WG”, “MGWG”, “LWG”, and “MGWL”. The English letters denote the basic elements of Chinese characters. For instance, “WG” stands for “田土”, which are the upper and the lower parts of “里”, “WL” stands for “田中”, which could be used to rebuild “甲” in a sense. By comparing the internal codes of Chinese characters, it is possible to find that (1) “理” and “裡” include “里” and that (2) “理” and “玾” are visually similar based on the overlapping codes.

For the example problem that we showed in Figures 1 and 2, we may apply an extended procedure of (Liu et al., 2011) to find an In-list for “里”: “鋰裡浬狸埋理娌哩俚”. This list includes more characters than most native speakers can produce for “里” within a short period. Similar to what we reported previously, it is not easy to find a perfect list of characters. More specifically, it was relatively easy to achieve high recall rates, but the precision rates varied among different PCs. However, with a good scoring function to rank the characters, it is not hard to achieve quality recommendations by placing the characters that actually contain the target PCs on top of the recommendation.

Given that “里” is the target PC and the above In-list, we can recommend characters that look like the correct characters, e.g., “鈿鉀鍾” for “鋰”, “裸袖嘿” for “裡”, “湮湩渭” for “浬”, “狎猥狠狙” for “狸”, and “黒墨” for “里”.

We employed similar techniques to recommend characters for In-lists and Out-lists. The database that contains information about the decomposed Chinese characters was the same, but we utilized different object functions in selecting and ranking the characters. We considered all elements in a character to recommend characters for In-lists, but focused on the inclusion of target PCs in the decomposed characters to recommend characters for Out-lists. Again our recommendations for the Out-lists were not perfect, and different ranking functions affect the perceived usefulness of the authoring tools.

Figure 3. Selecting a character for an Out-list

Figure 3 shows the step to choose characters in the Out-list for characters in the In-list. In this example, six characters for the In-list for the PC “䍃” had been chosen, and were listed near the top: “搖遙謠瑤鷂搖”. Teachers can find characters that are similar to these six correct characters in separate pull-down lists. The screenshot shows the operation to choose a character that is similar to “遙” (yao2) from the pull-down list. The selected character would be added into the Out-list.

4.3 Game Management

We allow teachers to apply for accounts and prepare the games based on their own teaching goals. However, we cannot describe this management subsystem for page limits.

5 Evaluation of the Authoring Tool

We evaluated how well our tools can help teachers with 20 native speakers.

5.1 Participants and Procedure

We recruited 20 native speakers of Chinese: nine of them are undergraduates, and the rest are graduate students. Eight are studying some engineering fields, and the rest are in liberal arts or business.

The subjects were equally split into two groups. The control group used only paper and pens to author the games, and the experimental group would use our authoring tools. We informed and showed the experimental group how to use our tool, and members of the experimental group must follow an illustration to create a sample game before the evaluation began.

Every subject must author 5 games, each for a

	Avg. scores (In-list and Out-list)	Avg. time
Control	16.8	15 min
Experimental	52.8	7.1 min
p-value	< 0.0001	< 0.0001

Table 5. Improved effectiveness and efficiency

	Avg. scores	
	In-list	Out-list
Control	15.9	1
Experimental	29.9	22.9

Table 6. Detailed scores for the average scores

different PC. A game needed 6 characters in the In-list and 4 characters in the Out-list. Every evaluator had up to 15 minutes to finish all tasks.

The games authored by the evaluators were judged by psycholinguists who have experience in teaching. The highest possible scores for the In-list and the Out-list were both 30 for a game.

5.2 Gains in Efficiency and Effectiveness

Table 5 shows the results of the evaluation. The experimental group outperformed the control group in both the quality of the games and in the time spent on the authoring task. The differences are clearly statistically significant.

Table 6 shows the scores for the In-list and Out-list achieved by the control and the experimental groups. Using the authoring tools helped the evaluators to achieved significantly higher scores for the Out-list. Indeed, it is not easy to find characters that (1) are similar to the characters in the In-list and (2) cannot contain the target PC.

Due to the page limits, we could not present the complete authoring system, but hope to have the chance to show it during the demonstration.

6 Concluding Remarks

We reported a game for strengthening the association of the phonetic components and the pronunciations of Chinese characters. Experimental results indicated that playing the games helped students shorten the response times in naming tasks. To make our platform more useable, we built an authoring tool so that teachers could prepare games that meet specific teaching goals. Evaluation of the tool with college and graduate students showed that our system offered an efficient and effective environment for this authoring task.

Currently, players of our games still have to choose challenge levels. In the near future, we wish to make the game adaptive to players' competence by adopting more advanced techniques, including the introduction of "consistency values" (Jared et al., 1990). Evidence shows that foreign students did not take advantage of the GPC rules in Chinese to learn Chinese characters (Shen, 2005). Hence, it should be interesting to evaluate our system with foreign students to see whether our approach remains effective.

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