Zen Hanzi: A Game for Raising Hanzi Component Awareness

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ABSTRACT

Mastering thousands of logographic characters, such as the Chinese hanzi or Japanese kanji, is a unique and daunting obstacle for many students of those languages. In this paper, we investigate the efficacy of our component-focused hanzi learning game, *Zen Hanzi*, in addressing this issue. *Zen Hanzi* aims to assist Chinese as Foreign Language (CFL) learners in getting over some of the trickier aspects of hanzi, such as differentiating between similar-looking components. We describe our experimental game and provide a comparison study where 63 participants learned 10 complex hanzi using either our game or *Quizlet*, a flashcard app frequently used in Chinese courses. Results found that both groups had similar improvement on the hanzi recognition test, but the treatment group showed significantly better scores on the hanzi composition test ($p<0.004$). Our work extends prior findings on the benefits of component awareness to beginner hanzi learners, as well as contributes a scalable design for component-focused logographic learning tools.

CCS CONCEPTS

• **Applied computing** → **E-learning**.

KEYWORDS

Second-language Acquisition, Chinese as Foreign Language Learning, Educational Game

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1 INTRODUCTION

Millions of people worldwide are taking up languages with logographic writing systems (LWS), such as Chinese or Japanese, as their second languages [18, 19]. However, one of the aspects that presents a unique challenge to students from alphabetic backgrounds is learning to read and write the logographic characters [41]. When it comes to LWS as a foreign language, there is a divide between conversational fluency and functional literacy unlike that in any alphabetic language [40]. In recent years and with some success, many aspiring polyglots are turning to mobile apps to help them overcome this hurdle [4, 30]. The advantages of using such tools are clear: digital media allows for instant feedback, gamification, the inclusion of engaging graphics, audio, video, and even finger-writing practice anytime and anywhere [4, 5, 23, 24, 36].

Surprisingly, despite the potential and wide range of game-based learning approaches, both Chinese language and character (i.e., hanzi) learning apps fall largely into two categories of design [28]. First, purely educational apps with Spaced Repetition System-enabled (SRS) flashcards, stroke order animations, dictionary examples, and so on (see Figure 1 for examples). Notably, SRS stems from the phenomenon that training sessions spaced with irregular intervals can enhance learning compared to consecutive sessions or sessions with very short intervals [46]. Second, game-based approaches with exogenous designs [33, 43] that consist primarily of multiple-choice questions tacked onto another game genre such as a fighting game (see Figure 2 for examples).

Notably, we believe that the second category could be improved upon if one were to consider lessons learned from Chinese language teaching experts and educational game researchers. For instance, studies show that component awareness has a positive impact on a student's ability to memorize characters [10]. However, to our knowledge, none of the commercially available games (with a few exceptions covering only introductory characters) make use of that fact. Similarly, educational game research suggests that endogenous integration of educational content into a game results in better learner engagement [13, 36, 37, 48]. However, in most hanzi learning games today, the learning content is almost entirely separable from the gameplay (e.g., it could be substituted for math questions without changing the gameplay or story in any way).

With this in mind, we set out to create *Zen Hanzi* which would take into account both of these design concepts. Specifically, *Zen Hanzi* is designed to utilize a component-focused hanzi learning mechanic endogenously incorporated into gameplay. We also designed an internal representation system that allows for easy authoring of additional hanzi content and scaling of the game. This scalable design sets us apart from existing beginner-content component-focused apps, where each individual character typically has hand-drawn mnemonic illustrations, and is thus limited by both the authoring burden and increasingly obtuse mnemonics for less representative hanzi components (see Figure 3 for an example). As a result, the core contributions of this work are:

- Design for a scalable component-focused hanzi learning game.
- Quantitative and experiential evaluation of a CFL learning game highlighting the potential benefits of a component-focused design.

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[1] *Skritter* – https://skritter.com/
[2] *Japanese Kanji Tree* – https://play.google.com/store/apps/details?id=com.asji.kanjitree.pro&hl=en_CA&gl=US

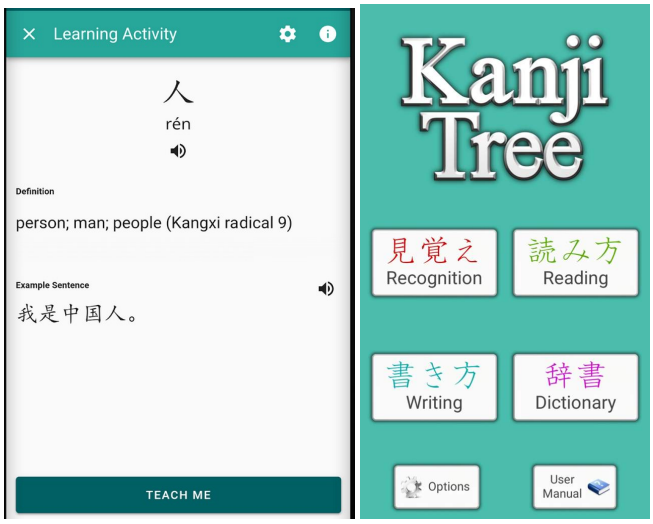

Figure 1: Screenshots of *Skritter*[1] (left) and *Japanese Kanji Tree*[2] (right), two popular feature-rich apps for learning hanzi and kanji respectively.

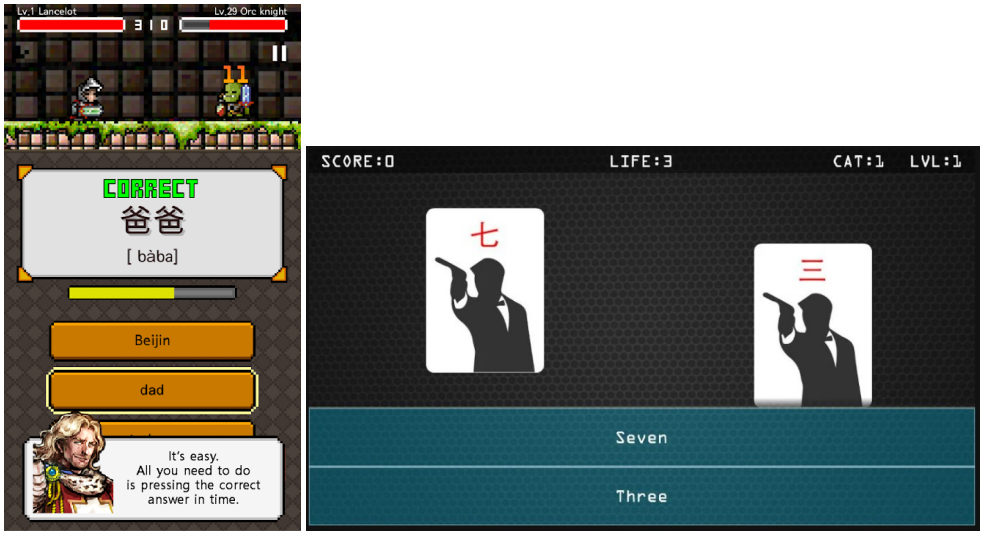

Figure 2: Screenshots of *Chinese Dungeon: Learn C-Word*[3] (left), and *Chinese Spy: Learn Mandarin*[4] (right) hanzi learning games. The gameplay amounts to a series of multiple choice or matching questions.

2 BACKGROUND

2.1 Components and Radicals

In this paper, we use the terms "component" and "radical" nearly interchangeably, however it is important to note that they are not the same. Every radical is a component, but not all components are radicals. Traditionally, a radical is a principal graphic component in a hanzi/kanji, by which one would look up the character in a dictionary. Not counting variants, there are 214 such radicals, each with a name and a meaning of its own (which may or may not relate to the meaning or pronunciation of the character). The definition for 'component' is looser. There is no set list of components. This paper defines 'component' as any part of a hanzi that could be cleanly separated from the rest of the hanzi. We call a component 'basic' if it can't be further broken down. Similarly, a complex component consists of two or more basic components. Figures 4 and 11 provide examples of breaking a hanzi into complex and basic components. We use components rather than radicals in *Zen Hanzi* to take advantage of the flexibility they offer in deconstructing and learning hanzi. Notably, learning the pronunciation of characters is quite different from learning how to write them and is therefore outside the scope of this paper.

[3] *Chinese Dungeon* is currently only available at https://www.99images.com/apps/word/com.terryyoung.chinesedungeon
[4] *Chinese Spy* – https://play.google.com/store/apps/details?id=com.overpass.chinesespy

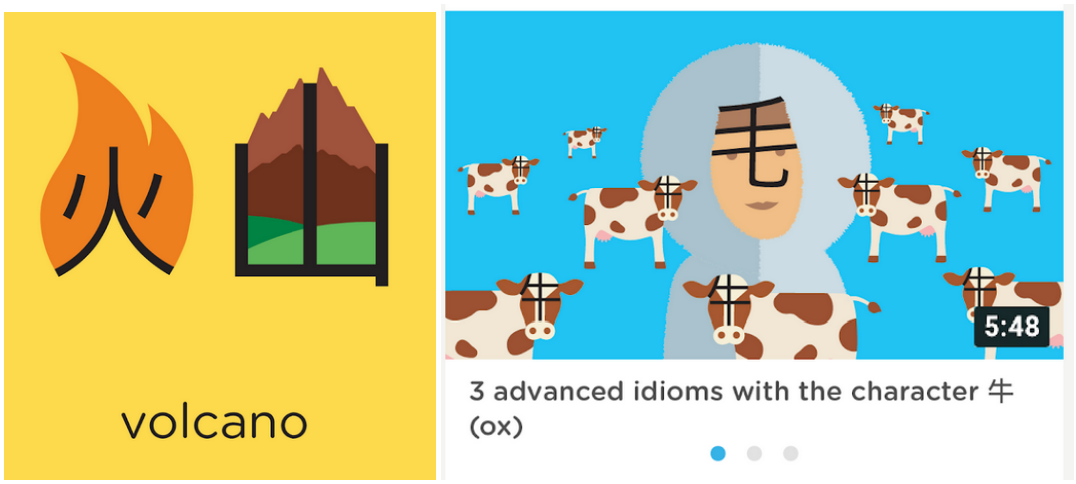

Figure 3: Screenshots of *ChinEasy*[5], a game with visual mnemonics for various hanzi components. As these two illustrations show, some hanzi components lend themselves to visual mnemonics better (left) than others (right).

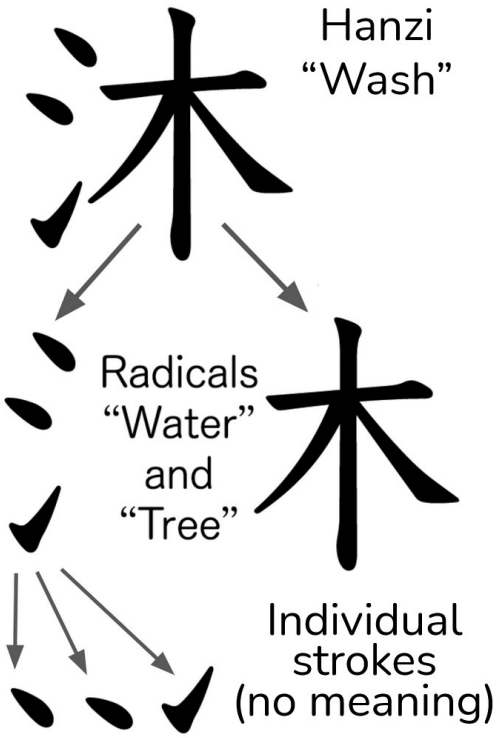

Figure 4: The anatomy of hanzi. A hanzi can consist of one or more radicals, which in turn consist of one or more strokes. While radicals can carry a meaning of their own (which may or may not relate to the meaning of the hanzi), individual strokes are purely graphical elements without inherent meaning.

2.2 Challenges and Methods of Learning Logographic Characters

While we used Chinese characters in *Zen Hanzi* and our study, due to common origin, similarities in structure, and a significant overlap[6] between Chinese hanzi and Japanese kanji, it is fairly safe to say that challenges and methods for learning to write one group of these characters apply to the other as well. Therefore, we draw from literature on learning to write in both Chinese and Japanese languages when motivating and discussing this work.

The traditional and most widely used way of learning logographic characters is rote memorization, requiring students to write the characters over and over [27]. A survey of strategies of successful students of Japanese kanji revealed that they also employ a number of additional learning techniques, one of the prominent ones being component analysis [26, 41]—i.e., breaking up the characters into their components for further analysis and memorization (see Figure 4). Notably, Dr. Heath Rose, a researcher who extensively studied the struggles of mastering writing of Japanese kanji for students from alphabetic background, suggests that developing component awareness at the beginning of a student's kanji learning quest can aid them in developing their writing skills [41]. We posit that our component-focused design can help students both memorize and develop the component awareness Rose talks about, as it has them focus more deeply on the construction of a character.

2.3 Learning Hanzi with Technology

In recent years, computer and mobile apps for learning hanzi and kanji have gained popularity. A study on use of multimedia (including but not limited to apps) for learning kanji, showed that such methods were effective when used strategically (e.g. taking advantage of SRS included in many flashcard apps), and were also perceived as more enjoyable than the pen and paper flashcards and

[5] https://www.chineasy.com
[6] About 60% of the 2000+ most commonly used Chinese and Japanese characters were the same or similar as of 2012 [49]

Figure 5: A partial screenshot from the WaniKani app. *WaniKani*'s 'poop' radical is an excellent example of shock-value driven mnemonics.

writing practice [27]. Apple's *App Store* and Google *Play Store* list hundreds of apps and games developed for that purpose[7], some with millions of downloads. The vast majority of the apps and games focus on flashcard-style recall task, with few offering writing practice or any kind of component emphasis. A notable exception to the latter is *WaniKani*[8], which puts an emphasis on component awareness for introductory characters by assigning unique and often comical meanings to each radical (see Figure 5). The service then uses these meanings to come up with short mnemonic-laden stories for each kanji based on its radical composition. However, many of the mnemonics are stretched and abstract, adding a layer of information for a student to memorise, which has little to do with the kanji (i.e., adding extraneous cognitive load). Rose warns against using such methods, as sometimes a student might remember the story, but not the kanji itself [40]. To our knowledge, there is no commercially available hanzi or kanji learning game that emphasizes component awareness and covers material beyond introductory characters.

Several academic papers describe experimental hanzi and kanji learning apps for non-native learners which make a focus on components at least to some degree. Chen et.al. [16] experimented with a computer application which offered detailed interactive explanations of roles of various components within a hanzi. The app addressed how the position of a component related to the hanzi's meaning or pronunciation. Their experiment showed a dramatic score increase in component awareness in the treatment group. Keehl and Melcer [23] created a musical game for drawing kanji called *Radical Tunes*. In the game, as a way to raise component awareness, each radical was mnemonically connected with a unique melody and instrument, where the pitch of the melody followed the direction of the strokes. They compared the mnemonic musical version of the game with one where writing was accompanied by sounds of chalk on a blackboard. Due to limited educational content of the game (only six simple kanji), they were not able to discern any effects of music on participants' learning. However, they did find that music increased immersion in the treatment group. Follow up work with a larger set of kanji did show that there was a

[7]Estimates obtained by searching for "kanji learning" and "hanzi learning" in the stores' web interfaces and counting the rows of results
[8]https://www.wanikani.com/

Figure 6: *Zen Hanzi* screenshot. The player must drag the components from three rows at the bottom into one of the four structures above to assemble the hanzi indicated by the English translation and pinyin pronunciation at the top of the screen.

significant positive impact of melody presence on retention of character meaning and character production, particularly as characters became more complex [24]. Tsai et.al. [17] used a computer app meant to aid students in learning the proper stroke order and proportions of components within a hanzi. The students would write a character and the app would give them personalized feedback on any mistakes they made. The app would also make the students continue writing a character until they got it right. The researchers found that the treatment group did much better on precise writing and component awareness post-test, as compared to the control group, who studied the hanzi via the traditional pen-and-paper writing following a numbered diagram. However, between the two groups of participants—complete novices and CFL students with 6 months of Chinese experience—while both groups showed improvement with treatment, complete novices preferred using the app, while the advanced students preferred regular writing, saying that the app took more time to get through the same material. Furthermore, in their 2016 review of Information and Communication Technology-supported tools for CFL [50], Čok concludes that "much could still be done" to improve the efficacy of such tools. These studies illustrate that while existing digital tools are already showing some level of efficacy for CFL learning, their is still much room for improvement in their design.

3 *ZEN HANZI*

Zen Hanzi is an experimental component-focused game for learning traditional Chinese characters, i.e., hanzi. The title of the game is a play on the word "Zen", which—in addition to the western adaptation of the Japanese term derived from the Chinese word ch'an (meaning "meditation")—is a homonym of the Chinese word

矢天禾木
正止上土士
夕夕身身

Figure 7: Some examples of look-alike components. Some differ by a single extra stroke, some by comparative length of two strokes, some by whether a stroke crosses another stroke.

for "how," making the title into "how to hanzi". It was inspired by research claiming that component awareness is beneficial to learning hanzi/kanji [10], and the evidence that recognition practice isn't usually sufficient to memorize hanzi well enough to be able to produce them [40]. In *Zen Hanzi*, the player must assemble a given hanzi by selecting correct components and placing them into correct slots in a correct hanzi structure (see Figure 6). In addition to drawing the player's awareness to the component-based nature of the characters, *Zen Hanzi* also makes sure to include look-alike options for each correct component, ensuring the students are aware of some of the possible mistakes they could make when writing (see Figure 7).

In terms of presentation of educational content, *Zen Hanzi* has a "Learn" and a "Review" mode. In "Learn" mode, the player is shown a picture of the hanzi before assembling it (see Figure 8), while in review mode they are guided only by the English meaning and Chinese pronunciation of the hanzi—requiring players to recall the structure of the hanzi without guidance. Additionally, the "Hint" button allows the player to view the hanzi one more time if they are stuck. The game also implements a number of assistance features to help players keep track of options they previously tried, such as by changing the color of the components after each attempt based on their correctness (see Figure 9). Finally, the game has scoring and "lives" mechanics. While those aren't universally effective motivators, they are known to provide motivation for some of the more competitive players [3].

3.1 Rationale

Acquiring and maintaining working knowledge of hundreds of hanzi/kanji needed for LWS literacy requires frequent exposure to the characters, or, barring that, frequent reviews and practice. This

Figure 8: In the learn mode, the player is shown the hanzi before they attempt to assemble it.

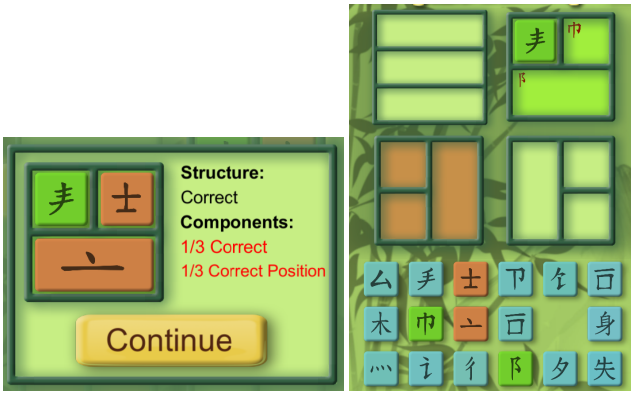

Figure 9: The player receives feedback on their attempt, including whether they used the correct structure, how many components are correct, and whether any of the components were in the correct position. The game helps the player remember which options they tried by coloring incorrect components and structures red, and correct ones green. Once the correct structure is identified, the game also marks which components were incorrectly tried in each slot.

can often be a monotonous, tedious task, and many students rapidly lose their reading and writing proficiency after they are done taking courses [41]. While there are many learning and reviewing apps that offer structure and even written practice, the persisting target language literacy deficiency of LWS students indicates that the current technology isn't quite enough to help them gain and retain hanzi/kanji knowledge [50]. The apps often lack sufficient motivational elements, and the existing games predominantly use exogenous flashcard-style multiple-choice exercises disconnected from the game content and offer no component emphasis. The challenge of designing a good educational game lies in the necessity of three things: effective educational content, an enjoyable/motivating game, and a seamless connection between the two [8, 48]. As a result, we researched methods for learning hanzi, educational game design, and Free-to-Play (F2P) mobile game design. We came up with the following principles, which we applied when designing *Zen Hanzi*.

3.2 *Zen Hanzi* Design Principles

(1) Intrinsic pleasure is a must [29]. This can be aided by appealing graphics/sounds and plentiful feedback to player's actions with visual and audio effects [6, 7, 14, 21, 22, 31, 45], as well as designing the game to be playful overall [36].
(2) The game must have short rounds in order to fit into micro-leisure intervals of contemporary life [25].
(3) The learning content must be endogenously integrated into the game [13, 37, 44, 48]. That is to say, no *Math Blaster*-like "add two numbers to shoot at asteroid" [1]. The core game mechanic must be inseparable from the learning content [34, 35].
(4) The game must avoid orthogonal mechanics [47]. Orthogonal mechanics are those that detract from the primary purpose of a serious game, in this case – learning LWS. An

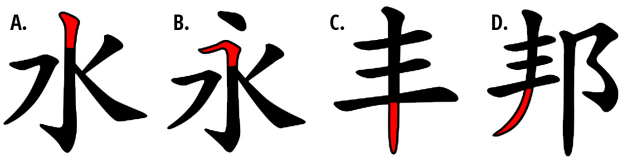

Figure 10: Component variations with differences highlighted in red. The 'water' component (A) is written with a vertical line at the top in some of the hanzi (B). It's still considered the same component according to databases we examined, but it would be incorrect to omit that line or add it where it isn't needed. Similarly, the 'great' component (C) is occasionally written in a slanted form (D). In *Zen Hanzi*, we include both versions of each component to draw the player's attention to the possible mistakes they could make.

example would be requiring the player to become good at aiming and shooting in order to access the learning content. Every action should serve to reinforce or increase knowledge.

(5) The game must be scalable in terms of authoring burden. Hand-authoring separate exercises for thousands of characters to support learners of different skill levels would make the game production logistically infeasible.

(6) The game must raise students' hanzi component awareness as developing component awareness at the beginning of a student's kanji learning quest can aid them in developing their writing skills [41] and has a positive impact on a student's ability to memorize characters [10].

3.3 Designing for Content Scalability

Zen Hanzi's design would be very impractical if one had to hand-author levels for each hanzi, selecting look-alike components, and laying out hanzi structure frames. To get around this, we designed a succinct way to encode all the necessary information about each hanzi, including it's structure and composition. We also created our own mini-database of hanzi components and their look-alikes. This way, the game can randomly include at least one look-alike for each component within the hanzi.

Below is an example of one hanzi encoding:

```
"想":{
"pinyin":"xiǎng",
"hanzi":"想",
"pinyin_sound":"xiang3",
"english":"to want",
"english_sound":"to_want",
"layout":{"type":"s_H","part_1":"s_V",
"part_2":"s_none"},
"components":[
    {"name":"113","position":0},
    {"name":"208","position":1},
    {"name":"115","position":2}]}
```

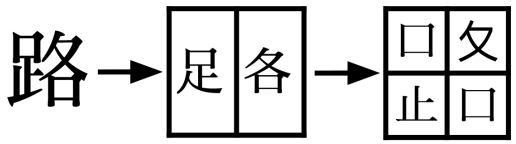

Figure 11: The conventional way of hanzi structure classification would identify this hanzi as a vertically-split two-part hanzi. However, each of those hanzi parts consist of two basic components, each carrying its own potential for a mistake. It's also worth noting that division into two parts in this case results in the transformation of the lower-left component into a different variant of itself, which may confuse the student about the proper shape within the original hanzi. Because of this, *Zen Hanzi* breaks this hanzi into four parts.

Much of the information needed to encode any hanzi can be scraped from free databases online, such as the Chinese Character Decomposition[9]. The sounds can also be obtained from free online datasets, like the Mandarin Voice Soundset[10].

Things get trickier when it comes to the component database. While some lists of look-alike characters and components can be found online, they typically don't address component variations, as in Figure 10, or include incorrect versions of components. The latter ones are useful in highlighting mistakes a novice learner might make.

Two entries from our component database are below:

```
"pie_h_7_7_7r":["7_7_7r","115"],
"113":["211","179"]
```

We used Fordham's list of 800 most common components [11] as a foundation for our own component database. However, we only used the basic components that couldn't be easily broken up into smaller components, and added some of our own, to account both for slight but important variations in some components; and some of the common wrong versions of components.

With all this in mind, the bulk of work in making content scalabe in future games/designs would be in the component database as it has to be assembled largely from scratch—as we had to for *Zen Hanzi*. Notably, the hanzi database would also have to be checked to replace components with their variants where necessary.

3.4 Unconventional Hanzi Component Design

After designing and prototyping *Zen Hanzi*, we showed it to three domain experts (i.e., Chinese language professors) to receive feedback on the design. Notably, all of them expressed their surprise over how we divided hanzi into components (Figure 11). Rather than using the conventional hanzi structure classification methods which split hanzi into 1-3 major parts, we broke them down

[9]https://commons.wikimedia.org/wiki/Commons:Chinese_characters_decomposition
[10]http://www.chinese-lessons.com/

into their more basic components[11]. This was done as each small component holds its own potential for errors and is therefore worthy of attention. Furthermore, if we used complex components, our component database would have to hold exponentially more components in order to achieve the same granularity of possible errors and their combinations. We believe this would both make the design and scaling of the component database logistically infeasible. It would also likely present the student with a less effective learning experience since they would have fewer incorrect options to eliminate at each stage.

3.5 What *Zen Hanzi* is and isn't

Zen Hanzi isn't meant as a stand-alone method of learning Chinese. While it teaches pronunciation and meaning of included hanzi, it is a supplemental activity intended specifically to minimize component substitution mistakes in writing. It is meant to informally supplement formal classroom learning by deepening a student's awareness of the components within each hanzi. Those interested in learning the language as a whole would need to learn sentence structure and nuances of using hanzi in various combinations elsewhere. Furthermore, *Zen Hanzi* is intended to be a supplemental informal learning activity that students might engage in on their own time, thus avoiding the hurdle of classroom integration.

4 METHODOLOGY

For this paper, we wanted to see how the highly granular component-focused design of *Zen Hanzi* compared to the whole-hanzi approach of typical existing CFL learning tools with respect to players' learning of hanzi component composition and hanzi meaning. To this end, we performed a comparative between-subjects study of *Zen Hanzi* and *Quizlet*, a popular flashcard app frequently used in Chinese courses.

4.1 Quizlet

Quizlet is a web-based digital flashcard software. We selected *Quizlet* for our control group because several Chinese professors we spoke to in multiple universities use it to assign hanzi and vocabulary homework for their students. It also takes the whole-hanzi design approach that is common in most CFL learning apps where players are presented with one the entire hanzi all at once to memorize/learn. *Quizlet* offers its users an ability to create their own digital flashcard decks and several ways to study them, including quizzes and two gamified options (Figure 12, bottom). A typical flashcard from a Chinese 1 course includes the hanzi or a multi-hanzi word, its pinyin pronunciation, and an English translation (Figure 12, top). The students can also hear both the English and Chinese words provided via *Quizlet*'s built in sound database.

4.2 Hypotheses

We set out to investigate the educational and experiential aspects of *Zen Hanzi* and took an exploratory approach with the following research question:

[11]There is no one comprehensive list of all hanzi components. We used Fordham's list [11] and our best judgement to identify which parts of the hanzi should be considered as independent components for our purposes.

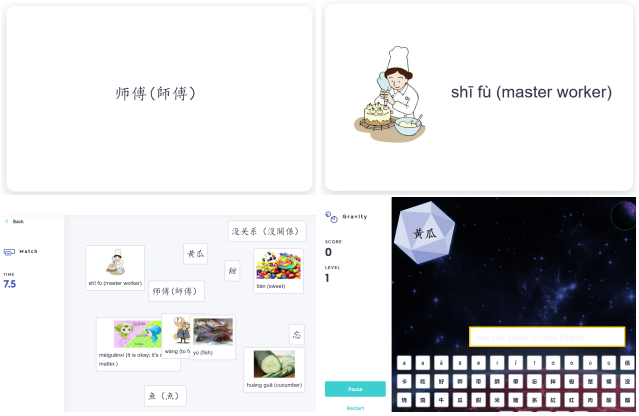

Figure 12: Quizlet screenshots. On the top is a typical two-sided *Quizlet* flashcard from a Chinese 1 course. On the lower left is *Quizlet*'s timed matching game, on the right is their Asteroid game, where entering the corresponding option destroys the asteroids speeding towards Earth.

- **Research Question**: Are there notable differences between user experience perception and learning outcomes for the component-focused design of *Zen Hanzi* and whole-hanzi design of current popular learning apps such as *Quizlet*?

To that end, we identified the following hypotheses:

- **H1.1**: *Zen Hanzi*'s component-focused gameplay will result in higher scores on hanzi component composition post-test, as compared to the whole-hanzi approach of existing hanzi learning tools.

- **H1.2**: since the approach to teaching hanzi meaning is roughly the same between *Zen Hanzi* and *Quizlet* (i.e., both provide written and audio pronunciation of hanzi meaning), they will have comparable effects on the hanzi meaning post-test scores.

4.3 Participants

A convenience sample of participants were recruited for this study by online announcements in large language-learning groups and Chinese drama fan-clubs on *Discord*, *Facebook* and *Tumblr*; as well as by word of mouth. In total, 73 people completed the study. Of those, 10 participants were excluded from the final analysis, as they received 25 or more points out of 29 on the pre-test. This indicated a high level of prior hanzi knowledge, which in turn meant they didn't have much room for improvement. Of the remaining participants, there were 43 female, 13 non-binary, six male and one of undisclosed gender. The ages ranged from 18 to 74, with the average age of 40.2 and median age of 30. The participants were also asked to self-report their reading and writing proficiency in any languages that use hanzi or hanzi-derived written systems.

The participants were randomly distributed into two conditions (i.e., *Zen Hanzi* treatment group or *Quizlet* control condition) with

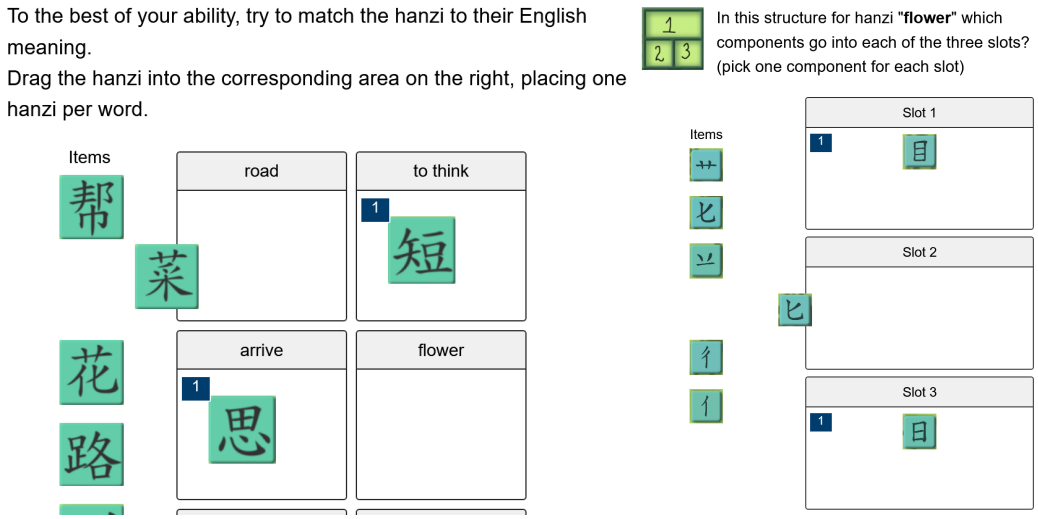

Figure 13: *Qualtrics* pre- and post-test screenshots. On the left is the hanzi meaning test, on the right is the individual hanzi components test.

the final count of 27 people in the control group and 36 in the treatment group[12]. There were no statistically significant differences in age, gender or prior knowledge distribution between the two groups, with the exception of there being 10 non-binary participants in the treatment group vs. only three in the control group. The participants were not paid or compensated for their participation in any way.

4.4 Procedure

The participants were provided with digital instructions and links to the five steps of the experiment. First, they were shown a short video tutorial explaining how to use our chosen survey platform, *Qualtrics*[13], and how the drag-and-drop questions within it work. Second, they were directed to a *Qualtrics* survey where they consented to the study, filled out basic demographic information and took a hanzi pre-test. This test consisted of matching 10 hanzi with their English meaning, and identifying correct individual components and their placement in each of the 10 hanzi (see Figure 13).

For the third step, they were provided a 2-minute YouTube video tutorial of the app they were about to use — *Zen Hanzi* for the treatment group and *Quizlet* for the control group. The participants were then directed to use their assigned app for 10 minutes to study the 10 hanzi. For *Quizlet*, this meant that participants could use either digital flash cards or the two gamified quizzes to study (see Figure 12). As the final step, upon completion of the 10 minute study session, the participants were once again asked to complete a *Qualtrics* survey. This survey consisted of a post-test identical to the pre-test, followed by a 48-question survey consisting of select questions from Player Experience Needs Satisfaction (PENS) [39], Situational Interest (SI) [2], and modified Game Experience Questionnaire (GEQ) [20].

[12]We slightly increased the odds of a participant being assigned to the treatment group, as we wanted to collect as much experiential feedback on *Zen Hanzi* as possible.
[13]https://www.qualtrics.com

Table 1: Questions Used in Experience Analysis

Questionnaire	Subscales Used	Modifications
PENS v1.6	Competence Intuitive Controls	We replaced the word "game" with "app," and "play" with "use," so the questions made sense both in the context of *Zen Hanzi* and *Quizlet*. We chose not to use the Immersion, Relatedness, and Autonomy subscales, because the questions were geared toward story-driven or multi-player games.
GEQ-R	Positive Affect Negative Affect Competence Flow	We chose not to use the Immersion subscale from GEQ-R, because it was geared toward a story-driven game (i.e. "I was interested in the game's story.")
SI	Exploration Intention Instant Enjoyment Attention Quality Challenge Novelty	None

Table 2: Hanzi Test Scores and significance values from ANCOVA with pre-test scores as covariates

Test	Treatment (avg / std)	Control (avg/std)	p	95% CI
Meaning pre-test	3.14 / 3.16	3 / 3.37	0.86	
Component pre-test	8.78 / 6.97	7.19 / 6.39	0.28	
Meaning post-test	4.33 / 3.36	8.48 / 2.72	0.17	-2.64 / 0.06
Component post-test	21.06 / 5.52	15.81 / 5.99	**0.0006**	1.97 / 6.89

Table 3: Experience Evaluation results and significance values from ANCOVA with pre-test scores as covariates

Subcategory	Treatment (avg / std)	Control (avg/std)	p	95% CI
PENS Competence	11.67 / 3.54	13.07 / 2.7	0.08	-3.21 / 0.14
PENS Controls	15.11 / 2.5	14.41 / 2.24	0.25	-0.46 / 2.03
SI Exploration	13.92 / 5.32	13.96 / 5.49	0.97	-3 / 2.66
SI Enjoyment	19.69 / 5.86	20.26 / 5.47	0.7	-3.65 / 2.32
SI Attention	18.28 / 3.57	18.44 / 4.25	0.87	-1.99 / 2.02
SI Challenge	6.94 / 4.16	8.26 / 4.75	0.25	-3.29 / 1.07
SI Novelty	13.14 / 2.92	11.19 / 4.23	**0.03**	0.062 / 3.72
GEQ Positive Aspect	20.97 / 6.02	21.59 / 5.14	0.67	-3.48 / 2.45
GEQ Negative Aspect	12.56 / 7.52	10.89 / 4.71	0.32	-1.26 / 5.22
GEQ Competence	14.44 / 4.38	16.67 / 3.89	**0.04**	-4.53 / 0.53
GEQ Flow	18.44 / 5.59	18.07 / 7.31	0.82	-2.38 / 4.06

4.5 Educational Content

Both *Zen Hanzi* and the *Quizlet* deck provided to the participants included the following ten hanzi: 到, 路, 帮, 菜, 花, 想, 思, 对, 短, 谢. These are all taught in the first year Chinese courses at a large university and were chosen for their multi-component structure.

4.6 Measurements

We scored the participants on the number of hanzi they correctly matched to their English meaning (max score of 10), as well as the total number of components correctly placed into the hanzi structures (max score of 29). We tested them both before and after the treatment, to be able to use pre-test scores as a covariate in our analysis.

To evaluate how *Zen Hanzi* measures up to *Quizlet* experience-wise, we used 48 questions from three game/activity evaluation questionnaires — GEQ-R, SI, and PENS — to assess user experience. The list of subscales used from each of the questionnaires and minor modifications we made (if applicable) are in Table 1.

5 RESULTS

Using the pre-test meaning and component scores as covariates to control for individual differences in prior hanzi knowledge, we ran a series of ANCOVA tests to examine the two post-test knowledge result sets (i.e., hanzi meaning and component composition) and the 11 experience questionnaire subscale result sets.

The hanzi meaning and component test scores are listed in Table 2. The treatment group displayed significantly higher post-tests scores for correct placement of individual components ($p < .001$). Notably, the pre-test component scores were also significant predictors of the post-test component scores with $p = 0.002$. We found no other significant covariate interactions.

The experience evaluation results are listed in Table 3. Notably, we found significantly higher scores with respect to novelty for *Zen Hanzi* ($p = .03$), and significantly higher scores with respect to GEQ competence for *Quizlet* ($p = .04$). Although not quite significant, PENS competency scores trended similarly to the GEQ competence scores ($p = .08$). We discuss these results further in the Discussion.

6 DISCUSSION

6.1 Component-focused vs. Whole-hanzi Design

The treatment group did significantly better on the individual components post-test, thus confirming our first hypothesis **H1.1**. This demonstrates that *Zen Hanzi* was better at helping students recall details of each hanzi, rather than only their approximate shape—at least in the short term and with visual clues. Interestingly, our finding that pre-test component composition scores were a predictor for post-test scores provides further evidence for prior work discussing the importance of hanzi component awareness for new learners developing hanzi writing skills [41] and having a positive impact on ability to memorize characters [10]. Our second hypothesis, **H1.2**, was similarly confirmed as we found no significant difference in post-test meaning scores between the two groups. This indicates that *Zen Hanzi* was not significantly worse or better than current popular hanzi learning apps such as *Quizlet* for teaching hanzi meaning.

On the self-reported experiential side, novelty was significantly higher for *Zen Hanzi* while competence was significantly higher

for *Quizlet*, leaving our exploratory research question about user experience without a definitive answer. With respect to higher perceived novelty scores for situational interest, this is a good sign as situational interest is critical to the design of education tools (and education overall) since it is essential for developing personal interest in learners which can in turn positively impact learning [15, 32, 38]. We hypothesize that the novelty of *Zen Hanzi* may be due to the novelty of the component-focused approach to learning. I.e., many learners study for a variety of topics, including English vocabulary, using flash cards and similar forms of SRS tools. Conversely, the logographic nature of hanzi makes learning a word and meaning more complex as shape becomes a factor of memorization—and area of emphasis in *Zen Hanzi's* design. Therefore, tools that focus on learning components rather than whole words/whole-hanzi are much less commonly encountered by most learners.

It would also be worthwhile to further investigate the users' reported feelings of competence, which trended lower in the treatment group. A person's feeling of competence plays an important part in their motivation to persist with a task [9]. Adopters of our design should be aware of the possible competence penalty that comes with increased awareness of hanzi components, at least at the early stages of learning. We speculate that having to memorize each individual component in a hanzi is more difficult than merely remembering the approximate shape of a hanzi. As a result, it's possible that *Zen Hanzi* players got the answer wrong more frequently than the *Quizlet* users, and therefore felt less competent.

Additionally, in an informal feedback we received from some of the participants, some reported feeling frustrated at having to differentiate between components that differed by a single stroke or even relative length of a single stroke (some examples are in Figure 7). Unfortunately, this frustration is shared by any student tackling an LWS. The lack of any such feedback from *Quizlet* users only highlights the fact that those participants weren't as aware of the shape of components within the hanzi. For example, some explained to us that they would memorize one or two components within the hanzi and then just look for that component to identify the hanzi, without bothering to give any attention to the other components. That is a bad strategy, as there are many hanzi that differ by a single component, or even have the exact same components arranged in a different way. We suggest that hanzi and kanji learning app and game creators could include *Zen Hanzi*'s fairly simple to implement mechanic in their products to help their users learn the characters on a more than just superficial level.

Overall, our results highlight some clear advantages of a component-focused design over traditional whole-hanzi designs, as well as provide some areas that need careful consideration (i.e., improving feelings of competency) in the design of hanzi learning tools.

7 LIMITATIONS AND FUTURE WORK

7.1 Design Limitations

While scalable by design, in its current form *Zen Hanzi* supports only a subset of possible hanzi structures, so it does not include every possible hanzi at this time. Additionally, many Chinese words are composed of multiple hanzi, so *Zen Hanzi* could be further improved by an ability to practice multi-hanzi words. Furthermore, the images for each component currently need to be drawn by hand. However, there are a finite number of basic components, and once the assets for all of them exist, adding new hanzi with the scalable component and hanzi databases is relatively easy. Finally, we were disappointed to see that *Zen Hanzi* players didn't report higher enjoyment than *Quizlet* users. The game would benefit from further user testing and design adjustments to facilitate learner engagement and habit formation. For instance, adding more "juicy" feedback may help to increase player feelings of enjoyment, engagement, and competence [14, 21, 45].

7.2 Evaluation Limitations

There are some notable limitations to the study presented here, i.e., a small sample size that might not be fully representative of CFL learners. However, on a small scale, *Zen Hanzi* demonstrated notable improvement in short-term memorization of hanzi component structure over the widely used *Quizlet* app. These promising results warrant further research with a larger sample size, expanded learning content, longitudinal testing, and testing of participants' ability to produce hanzi unassisted. This will provide a better understanding of the long-term effects that a component-focused design might have in comparison to SRS methods. Future work should also investigate the possibility of lowered feelings of competence and ways to counteract that effect—as feelings of competence have been shown to be important for the efficacy of educational games [12, 42].

8 CONCLUSION

In this paper we described our experimental hanzi learning game, along with evaluations of its educational efficacy and user experience as compared to a popular flashcard app. The game's component-focused design resulted in participants achieving higher scores on the immediate post-test of hanzi component structure. We discussed the possible drawbacks for the beginner students, and other aspects of the game that bear further design improvement and investigation. We shared both our visual design and the underlying data structures. We hope our design has the potential to serve as a useful free resource for students of LWS in any stage of their education, as well as to serve as a reference for the design of future LWS learning tools.

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