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The Effect of Radical-Based Grouping in Character Learning in Chinese as a Foreign Language

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The logographic nature of the Chinese writing system creates a huge hurdle for Chinese as a foreign language (CFL) learners. Existing literature (e.g., Shen, 2010; Taft & Chung, 1999) suggests that radical knowledge facilitates character learning. In this project, we selected 48 compound characters in eight radical groups and examined how grouping characters based on their radicals affected the form, sound, and meaning representations of characters and radical knowledge development. We found that for beginning learners, learning radical-sharing characters in groups consistently led to better recall and better radical generalization than learning in distribution. For intermediate level learners, the grouping factor did not lead to significant differences, while participants in both conditions made improvement in radical perception and radical semantic awareness generalization. We concluded that there is a benefit to presenting learners with recurring radicals in compound characters in groups in character learning and in the autonomous generalization of radical knowledge. We also noted the differences between beginning and intermediate learners in their character perception and learning, and put forward implications for CFL pedagogy.

Keywords: character; Chinese as a foreign language; orthography; proficiency; radical knowledge

PRODUCING CHARACTERS FROM MEMORY and retrieving the form, sound, and meaning of characters are frequently identified as major challenges for students learning Chinese as a foreign language (CFL) (e.g., Shen, 2004). The difficulty comes from the large number of characters, the visual complexity of the graphemes, and the absence of systematic grapheme–phoneme correspondence. Earlier research investigating effective teaching and learning methods to develop second language (L2) reading skills in Chinese confirmed that radical knowledge facilitates character recognition and production (e.g., Shen, 2005, 2010), but researchers have also noted that character teaching in CFL is not systematically guided by the structural

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principles of the characters, making it difficult for learners to extract recurring radicals from compound characters (Taft & Chung, 1999). Wang, Liu, and Perfetti (2004) found that beginning CFL learners cannot infer the meaning of radicals in unknown characters without probing, and hypothesized that the difficulty in extracting radicals' functional regularities may be due to limited exposure. The current research uses compound characters with recurring radicals as learning materials and investigates whether grouping characters based on their shared radical facilitates orthographic knowledge development—such as learning the form, sound, and meaning of new characters and development in knowing radicals' shapes, fixed positions, and semantic functions.

REVIEW OF LITERATURE

Chinese characters correspond to morphemes and are typically monosyllabic, so Chinese has been referred to as a morphosyllabic language (e.g., DeFrancis, 1989). The series of strokes within a character compose recurring subcharacter components, including radicals and chunks. These terms are defined as follows:

1. *Radicals* (*bùshǒu*): the smallest orthographic units within a character that have semantic or phonetic functions. In this article, "radical" refers to semantic radicals and "phonetic component" refers to phonetic radicals.
2. *Chunks* (*bùjiàn*): the smallest visually integrated unit "separated by a visible diminutive space from other units" in a character (Shen & Ke, 2007, p. 99). Unlike radicals, chunks are not consistently associated with a particular function. For instance, 婚 (*hūn*, 'wedding') consists of 女 (*nü*, 'female') as a radical and 昏 (*hūn*, 'dusk') as a phonetic component; but it is also composed of three chunks: 女, coincidentally a radical; and 氏 and 日, which do not serve semantic or phonetic functions in this compound character. Chunks and radicals can overlap when the radical is not further decomposable into smaller chunks; moreover, certain graphic forms, such as 女, may be a radical in some characters (e.g., 婚) but a chunk in others (e.g., 案, *àn*, 'case'). "Chunk" also has a meaning not specific to Chinese characters: In the study of cognition, a chunk is "a meaningful unit of information built from smaller pieces of information" (Gobet & Lane, 2012, p. 541). For example, chunks of information become functional in memory. This definition is used when we refer to "chunking theory."
3. *Subcharacter component*: an orthographic unit internal to a character. This is an umbrella term that can include chunks, radicals, or phonetic components, but does not include strokes, the lowest level component in a character.

Approximately 97% of Chinese characters are semantic–phonetic compounds (*xíngshēng*) with a radical and a phonetic component (DeFrancis, 1989). Commonly-used characters are formed with about 200 semantic radicals (e.g., Feldman & Siok, 1999a). Although the radical does not specify the precise meaning of a compound, the interpretation of the radical is generally consistent with the meaning of the whole character (Feldman & Siok, 1999b).[1] The semantic value of the radical is therefore useful for recognizing the character.

Learning theories and empirical evidence indicate that radical knowledge supports character learning (Shen, 2010; Taft & Chung, 1999). Perceiving characters as organized subunits of radicals and other subcharacter components (e.g., *bùjiàn*) creates units of encoding that are more efficient for processing than perceiving characters as a pile of interwoven strokes. This argument is in line with the cognitive process of chunking that binds lower level elements (e.g., strokes) into larger units (e.g., radicals), reducing memory burden and increasing information capacity (Chase & Simon, 1973). In the application of chunking to language acquisition, Ellis (2003) contends that "[a] chunk that activates some meaning representations makes (...) itself more salient in the input stream" (p. 78). Radicals are examples of such meaning-bearing perceptual units. When a reader develops the awareness that characters are composed of subcharacter components, including some with consistent meaning associations, memorizing a thousand characters as independent units gives way to building interrelated characters connected through a much smaller number of recurring radicals and chunks.

Empirically, the facilitation of radical knowledge is attested among both L1 and L2 speakers. First, L1 speakers' recognition of compound characters involves radical processing (Feldman & Siok, 1999a; Taft, Zhu, & Peng, 1999; among others). Research also shows that radical knowledge is associated with Chinese L1 children's character acquisition and reading performance

(Shu & Anderson, 1997; Tong et al., 2009). In Taft and Chung (1999), the effect of radical instruction was confirmed in an experiment with a group of naïve learners who had no prior experience with Chinese characters. The authors reported that giving radical instruction before teaching characters and in the first presentation of characters both yielded better recall than no radical instruction in character teaching. In the CFL context, Shen and Ke (2007) found that beginning and intermediate students' radical application knowledge (i.e., whether they can make meaning inferences in unknown characters based on radicals) is moderately correlated with their memory retention of vocabulary knowledge. Jackson, Everson, and Ke (2003) and Shen (2005) also reported that learners learn new characters using an assortment of radical knowledge, including locating the radical in unfamiliar characters and making meaning association.

At the same time, the number of radicals that students encounter makes it difficult for students themselves to generate systematic rules to decompose characters (e.g., Everson, 2011), especially because students often do not have enough opportunities to reencounter radicals in different characters after initially learning them (Shen, 2010). An item is better memorized when it repeatedly occurs (Ellis, 2003). Beyond repetition is the question of when to repeat—close together or spaced apart. In many learning situations, widely spaced repetition is effective (Cepeda et al., 2006). However, the effect of spacing depends on the knowledge components involved (Koedinger, Corbett, & Perfetti, 2012), and narrow spacing can be beneficial when what is to be learned—the whole character—changes from trial to trial. Repeating a radical with broad spacing limits the opportunity to make a connection with previously learned characters that contain the same radical. Having radical-sharing characters occur together should help learners make the connection. The present study presents radicals that repeatedly occur in fixed position in different compound characters, varying whether the characters with shared radicals are blocked in groups or distributed over instruction. Close repeated presentation of radicals could potentially bootstrap the learning of radicals and characters. Thus the current study investigates whether classifying characters based on their shared radicals and presenting characters to learners in radical-based groups might raise learners' awareness of these recurring radicals, including the radical's regular positions and semantic functions.

Teaching characters in radical or orthography-based groups has been used in L1 literacy education (Guo & Zhang, 1991; Zhang, 2012). For instance, Chang and Han (2004) reported that, when instructors supplemented the teaching of a key character in text (e.g., 跑 *pǎo*) with the teaching of orthographically similar characters (泡 *paò*, 炮 *paò*, 抱 *bào*), L1 children developed better knowledge regarding the radical and phonetic components than children who learned only the key character 跑. Radical-based grouping was also employed in Chen et al. (2013), in which groups of radical-sharing characters were used as learning material in the experimental group. However, because Chen et al.'s control group did not learn the same set of characters, and explicit orthographic instruction was available only in the experimental group, the beneficial effect associated with their experimental group could be due to the learning of more characters containing target radicals, coupled with instructors' orthographic instruction. Chen et al.'s research did not directly address the role of character grouping, but their study extended radical-based character teaching to adult heritage learners, and their sets of radical recognition and semantic awareness tasks set examples for the current study.

The current project aims to discover whether classifying radical-sharing characters in groups in a learning sequence supports character learning and helps learners extract the visual and functional regularities of radicals. This grouped condition is compared to a distributed condition in which radical-sharing characters are assigned to different learning sessions. The project asks the following questions:

RQ1. Do beginning CFL learners establish better form, sound, and meaning representations of characters learned in the grouped condition or the distributed condition?

RQ2. Do beginning learners in the grouped condition or the distributed condition develop better radical knowledge, including the ability to visually identify the graphic form of a radical in unknown characters and in understanding understanding the radical's semantic function in association with its fixed position?

Existing research is scarce on radical knowledge development and character learning beyond the beginning level (Everson, 2011), so another population of interest is intermediate learners. We asked the same questions for that proficiency group.

RQ3. Do intermediate learners learn characters' form, sound, and meaning better in the grouped condition or the distributed condition?

RQ4. Do intermediate learners develop radical knowledge better in the grouped condition or the distributed condition?

For the more experienced group, it is possible that increased familiarity with the radical based composition of compounds reduces the advantage of closely repeated exposure.

METHOD

Participants

Forty-eight nonheritage adult CFL learners in 1st-year Chinese classes at a northeastern United States university constituted the beginning learners in this research. These learners had learned Chinese in a 7-hour per week program for eight weeks and had acquired approximately 180 characters prior to the experiment. As part of the first week of their regular curriculum, these participants received brief instruction in 40 common radicals introduced in their textbook, with brief exposure to two character examples for each. Forty CFL learners in 2nd-year Chinese classes at the same institution constituted the intermediate learners. These learners had learned Chinese for 36 weeks and had learned approximately 530 total characters. Twenty-four 1st-year participants and 20 2nd-year participants were assigned to the grouped condition, while the remaining participants were assigned to the distributed condition. Participants' overall course grades confirmed that proficiency in the two conditions did not differ (first year: $t(46) = .92$, $p = .36$; second year: $t(38) = .20$, $p = .84$).

Materials

Target radicals in this study are among the 40 radicals introduced in participants' textbook: 贝 ('money'), 火 ('fire'), 钅 ('metal'), 木 ('wood'), 女 ('female'), 日 ('sun'), 饣 ('food'), and 心 ('heart'). Six characters for each radical were selected based on the following criteria: (1) no character was taught to either 1st- or 2nd-year participants in their course curriculum; (2) a radical always appears in the same position for characters in its group; and (3) characters in each radical group are matched by their frequencies in English translations (Brysbaert & New, 2009), their mean number of chunks ($M = 2.98$) (Chen et al., 2011), and their mean number of strokes ($M = 10.11$), with at least one character in each radical group with low (6–8), medium (9–11), and high stroke numbers (12–14). In all cases, radicals contribute to the meaning of the whole character.[2]

The key manipulation was the assignment of those 48 characters into eight character sets. In the grouped condition, each set consisted of six characters from the same radical group; for example, 婚 ('wedding'), 嫁 ('to marry'), 媳 ('daughter-in-law'), 娃 ('baby'), 娇 ('lovely'), and 姑 ('father's sister') all contain the 女 'female' radical. In the distributed condition, characters sharing the same radical are distributed so that each set always contains six characters with different radicals. Appendix A indicates how characters were assigned in the conditions.

Reading texts were created based on each character set, so that learning sessions resembled traditional CFL classroom practices in which character learning is integrated with word-based vocabulary teaching and text comprehension. When the character does not constitute an independent word (e.g., 姑 'father's sister'), the same compound word containing the character (e.g., 姑姑 'father's sister') appears in both conditions. The same texts were used for 1st- and 2nd-year participants. The average length of each text was 46 characters, with no significant length difference between conditions, $t(14) = 1.77$, $p = .10$. The number of unfamiliar words per text (including words containing target characters) in both conditions also matched (1st-year: 10.5 vs. 9.5 unknown words in the distributed and the grouped conditions, $t[14] = 1$, $p = .33$; 2nd-year: 7.5 vs. 7.25 unknown words in the distributed and grouped conditions, $t[14] = .51$, $p = .62$). See Appendix B for sample texts in the conditions.

Procedure

The experiment consisted of the following: a pretest session, four learning sessions each followed by an immediate test session in four consecutive days (with four immediate test sessions in total), a posttest session on the fifth day, and a delayed test session two weeks after the first learning session. Since there were eight sets of characters, participants learned two sets of characters in each learning session. All sessions were conducted in a language lab classroom on the participants' campus.

Pretests. In the pretests, participants were asked to complete a *pinyin* and meaning production test, that is, to write the *pinyin* and meaning for any of the 48 characters that they recognized. Participants also completed a radical recognition (RR) and a semantic awareness (SA) test as generalization tasks. The radicals tested are the aforementioned eight target radicals. These tasks are explained in detail in the *Assessment Instruments* section.

Learning Sessions. In each session, participants learned two sets of characters embedded in two texts. Each class period consisted of two parts. In the first 20 minutes of the class period, participants' regular instructors conducted class using word-based vocabulary teaching and text comprehension questions in both conditions. One instructor taught all 1st-year sessions, while a second instructor taught all 2nd-year sessions. The instructors did not provide etymological or orthographic explanations for the characters.

In the second part of class, participants learned the 12 target characters in that session on individual computers, with approximately 30 seconds per character; that is, participants in the grouped condition learned 12 characters from two radical groups, for example, six with the 女 radical and six with the 钅 radical, and participants in the distributed condition learned 12 characters crossing all eight radical groups. The computer consecutively displayed characters' three lexical constituent information elements: form, sound (*pinyin*, accompanied by a female native speaker's voice pronouncing the character), and meaning. All participants experienced the same variety of encoding methods with a balanced order to establish a robust orthographic representation of each character.[3]

Immediate Tests. Immediately after each learning session, participants completed three tasks on computers: lexical decision, sound matching, and meaning matching. These tasks were enabled by the E-Prime software. Participants also completed a written character production task, in which they were asked to write the 12 characters learned in that session based on a meaning prompt.

Posttests. On the fifth day, participants received a rehearsal for all learned characters. All 48 characters were reviewed one at a time for six seconds each: In the first three seconds, the character form, *pinyin*, and meaning were presented each for one second; in the next three seconds, the character's form, *pinyin*, and meaning remained on the screen. Participants experienced the characters in the same order as they learned them in the learning sessions. After this rehearsal, participants took a *pinyin* and meaning production task, in the same format as the pretest, as well as a form production task with all 48 characters. They also completed a RR and a SA task in the same format as in the pretests.

Delayed Tests. Delayed tests included a *pinyin* and meaning production task, a form production task, a RR task, and a SA task.

Assessment Instruments

The tasks in various testing points and their purposes are summarized in Table 1. Among

TABLE 1
Assessment Measures and Testing Points

	Testing Points				
Measures	Pretest	Immediate test	Posttest	Delayed test	Knowledge/Skill Assessed
Lexical decision		✓			Visual–orthographic form representation (receptive)
Sound matching		✓			Form–sound link
Meaning matching		✓			Form–meaning link
Pinyin production	✓		✓	✓	Sound representation and form–sound link
Meaning production	✓		✓	✓	Meaning representation and form–meaning link
Character production		✓	✓	✓	Visual–orthographic form representation (productive)
Radical recognition	✓		✓	✓	Recognition of the radicals' form in unfamiliar characters
Semantic awareness	✓		✓	✓	Knowledge of the radicals' form, semantic function and fixed position; application of the knowledge in unfamiliar characters

these testing instruments, *pinyin*, meaning, and character production tasks are common in previous CFL character research (e.g., Shen, 2004). We explain other tasks in detail.

Radical Recognition (RR) and Semantic Awareness (SA). The RR task evaluates how well participants visually recognize a radical's graphic form when encountering unfamiliar characters. In this particular task, *radical* refers to general subcharacter components and is not restricted to situations where they serve semantic functions. We accommodate variations in the graphic form's spatial position by including keys such as 案 ('case'), where the target form 女 does not serve semantic functions. The SA task assesses whether learners can identify radicals' shape, meaning and the positional specificity (Taft et al., 1999) of its semantic function in unknown characters. In other words, 案 cannot be a key for a SA task item on the target radical of 女, because 女 does not occur in a character-internal position indicating meaning. These two tasks were designed following Chen et al. (2013). There are 16 items each (2 for each radical) in each version of the test.

Strict procedures were taken in design to ensure the construct validity of those tests. First, we selected options from the Chinese Orthography Database Explorer (CODE) (Chen et al., 2011), with characters from participants' textbooks excluded and low frequency characters given priority. Keys for the SA task are characters defined as compound characters with 贝/火/钅/木/女/日/饣/心 as semantic radicals from the database. Second, the distractors generally have two more or fewer strokes than the key to control for the visual complexity of the options (Liu & Han, 2000). Third, heeding suggestions from King et al. (2004), we created distractors that reflect errors in different natures and at different sophistication levels. For the RR task, we generally supply a Type A distractor that does not contain any component orthographically similar to the radical, and supply two Type B distractors that contain components orthographically similar to the target radical, representing an increasing level of sophistication for participants' perception. For instance, in item (1), 哝 is a Type A distractor while 诙 and 侈 are Type B distractors because the shape of 讠 and 亻 resemble 饣. In item (2), 唧 is a Type A distractor while 絮 and 煲 are Type B distractors because 小 and 火 at the bottom resemble 心. Several other examples follow; the numbers preceding the item stem indicate keys.

EXAMPLE 1. Sample Items From RR Task

(1)	③	Which word has the "饣"radical? ①诙 ②哝 ③饬 ④侈
(2)	②	Which word has the "心" radical? ① 唧 ② 恕 ③ 絮 ④ 煲
(3)	③	Which word has the "钅" radical? ① 荟 ②饵 ③ 铂 ④ 缔
(4)	②	Which word has the "火" radical? ①苎 ②灾 ③汞 ④昊
(5)	②	Which word has the "木" radical? ①筘 ②杳 ③芊 ④卓

The SA task follows the same principles to provide one Type A distractor and two Type B distractors for most items. For instance, in item (6), 町 is a Type A distractor and 恪 and 仗 are Type B distractors. In other cases and when possible, we supply one option each for Type A and Type B distractors, and supply a Type C distractor that contains the radical's form in a position unassociated with semantic functions. In item (7), 佚 is a Type A distractor, 眭 is a Type B distractor (with 目 resembling 日), and 喧 is a Type C distractor (with 日 occurring in a non-meaning indicating position). Items (8–10) each contain these three types of distractors.

EXAMPLE 2. Sample Items From SA Task

(6)	①Which word is related to "female" or "woman"? ①妁 ②恪 ③仗 ④町
(7)	①Which word is related to "sun" or "day"? ①晅 ②佚 ③喧 ④眭
(8)	①Which word is related to "metal" or "gold"? ①针 ② 欲 ③肝 ④淦
(9)	④Which word is related to "wood" or "timber"? ①剁 ②犷 ③积 ④杠
(10)	①Which word is related to "money" or "cash"? ①赎 ②艰 ③殒 ④胺

Additionally, we prevented bias among distractors (Liu & Han, 2000) by avoiding selecting distractors orthographically too close to the key (e.g., 稞 and 棵) and controlled the overall difficulty in the three versions of tests by matching the number of items with distractors at a high sophistication level.

After designing the tests following strict criteria, we consulted three experienced instructors who taught in the program from which participants were recruited. The instructors confirmed that language used in the items' stem was appropriate and understandable to participants (Liu & Han, 2000), and that items were at approximately the same level of difficulty for participants.

We tested the RR and SA tests' reliability by asking a group of 45 CFL students (with no overlap with the participant pool in this study) with one semester's learning to complete all the items included in the tests (48 items each for the RR and the SA tasks). Cronbach's alpha was .71 for the RR task and .83 for the SA task, both higher than the general standard of .70 (Nunnally, 1978), showing good internal consistency.

Lexical Decision and Matching Tasks. The lexical decision task assessed learners' visual–orthographic representation of characters. The stimuli consisted of 24 trials: 12 target characters learned in that particular session, 6 familiar characters not composed of the 8 key radicals, and 6 novel characters containing the 8 key radicals. For each stimuli type, half were real characters and half were noncharacters. For familiar and target characters, noncharacters were created by deleting or adding a stroke. For novel characters, noncharacters were created by moving radicals to illegal positions. Participants were asked to judge whether the stimuli was a real character by pressing one of two keys, and to respond as quickly and as accurately as possible. Each stimulus was presented for 1000 milliseconds (ms) followed by a blank of 3000 ms before the screen moved to the next trial. Participants' accuracy rate and reaction time (RT) on the 12 target characters were analyzed.

The meaning and sound matching tasks assess participants' form–meaning and form–sound mapping. In sound matching, the computer showed a character's form for 1000 ms, and then displayed the character's *pinyin*, accompanied by a female native speaker's voice pronouncing the sound. Participants were instructed to judge whether the *pinyin* and sound represented the correct pronunciation of the character. If no response was made within 3000 ms, the screen proceeded to the next trial. In meaning matching, a character was presented on the screen for 1000 ms, followed by an English translation. Participants were asked to judge whether the translation was the exact meaning of the character. If participants made no response within 3000 ms, the screen moved to the next trial. Both matching tasks had twelve pairs created based on that day's learning session, with six matching pairs and six mismatching pairs. Accuracy and RT for matching pairs were analyzed.

RESULTS AND DISCUSSION

For all tasks, mean accuracies and standard deviations were calculated using the proportion of correct responses. For lexical decision and matching tasks, reaction time (RT) results are reported in milliseconds. Below, means are always reported with the distributed conditions first, followed by the grouped condition. Results for 1st-year participants are discussed first, followed by results for 2nd-year participants. An overall discussion for both proficiency groups is offered afterwards.

Beginning Learners' Form/Sound/Meaning Representation

We report results from the lexical decision and matching tasks before reporting results in *pinyin*, meaning, and character production measures. Pretest results, reported later in the *Pinyin, Meaning, and Character Production* section, verify that participants generally had no knowledge of characters' sound and meaning before learning and that there was no difference between conditions.

Lexical Decision and Matching. Accuracies and RT results are reported in Table 2. A one-way ANOVA with character grouping (distributed vs. grouped) as an independent variable was conducted on each measure. In lexical decision, there were no differences between conditions on accuracy (.75 vs. .72), $F < 1$, or on RT (1291 vs. 1195), $F(1, 46) = 2.30$, $p = .14$. At the same time, participants' accuracy in both conditions was significantly higher than the .50 chance level (distributed: $t[23] = 14.86$, $p < .01$, Cohen's $d = 6.20$; grouped: $t[23] = 8.08$, $p < .01$, Cohen's $d = 3.37$), suggesting that participants developed robust orthographic representation of the target characters and were able to differentiate them from noncharacters.

For sound matching, the distributed condition had a significantly higher accuracy than the grouped condition (.65 vs. .56), $F(1, 46) = 4.26$, $p < .05$, Cohen's $d = .60$, while there was no difference on RT (1225 vs. 1167), $F < 1$, suggesting that grouping characters based on radicals resulted in inhibition of form–sound link activation. Results in the meaning matching task showed a reverse pattern: There was no difference for accuracy (.72 vs. .73), $F < 1$, but the grouped condition had a shorter RT (1131 vs. 1010), $F(1, 46) = 4.32$, $p = .04$, Cohen's $d = .60$, suggesting that grouping strengthened the form–meaning link.

In the grouped condition, the form–sound matching inhibition is likely due to the orthographic similarity in shared radicals among the

TABLE 2
Mean and Standard Deviations (*SD*) of Accuracy and Reaction Time in Lexical Decision and Matching Tasks for 1st-Year Students ($N = 48$)

	Distributed ($n = 24$)		Grouped ($n = 24$)	
	Mean	*SD*	Mean	*SD*
Accuracy				
Lexical decision	.75	.08	.72	.14
Sound matching	.65	.15	.56	.15
Meaning matching	.72	.15	.73	.14
Reaction time				
Lexical decision	1290.63	218.97	1194.83	218.46
Sound matching	1224.78	283.97	1167.32	201.87
Meaning matching	1130.76	235.05	1010.27	159.59

Note. Accuracies were calculated using the proportion of correct responses. Reaction time statistics are in milliseconds.

target characters, which always belonged to two particular radical groups, making the discrimination task more challenging. On the other hand, the faster decision time in form–meaning matching in the grouped condition can be a result of the semantic relatedness of those characters. That is, learning 婚/嫁/媳/娃/娇/姑 in a group made it easier for participants to attend to the related meaning of 'female' in those characters, and such association cued participants' recall of the characters' exact meanings. Previous studies demonstrated that the visual attributes and the semantic transparencies of shared radicals affect character recognition in different ways (e.g., Zhou & Marslen–Wilson, 1999). For instance, Feldman and Siok (1999a) showed that a prime character sharing the same radical as the target character can facilitate recognition, when the meaning of the radical is transparent in both the prime and target, but the prime inhibited recognition when there was semantic inconsistency between the prime and target. These results confirm that radicals can be a psychologically relevant unit of processing in the L2 reading of Chinese (Taft & Zhu, 1997; Wang, Perfetti, & Liu, 2003).

Pinyin, Meaning, and Character Production. Aside from lexical decision and matching tasks, all other testing instruments were applied in three testing points. Those include *pinyin*/meaning/character production and two generalization tests assessing radical knowledge. Table 3 shows descriptive statistics for all these measures in different testing points.

A mixed ANOVA was conducted on these measures with grouping as a between-subjects factor and testing points as a within-subjects factor. When the difference reached significance, pairwise comparisons with Bonferroni adjustments are reported.

Results reveal that the grouped condition led to a posttest advantage in *pinyin* and meaning, but the grouping advantage did not remain in the delayed test. Specifically, in *pinyin* production, the grouping × testing time interaction was significant ($F[2,92] = 5.23$, $p < .01$, $\eta_p^2 = .10$). A simple main effect analysis of grouping did not reveal a pretest difference, where participants all had a .00 accuracy rate ($F < 1$), and did not reveal a difference between conditions in the delayed test (.04 vs. .06), $F < 1$. Meanwhile, the grouped condition showed a posttest advantage (.18 vs. .30), $F(1, 46) = 5.13$, $p = .03$. In meaning production, the interaction was significant, $F(2, 92) = 6.50$, $p < .01$, $\eta_p^2 = .12$. There were no differences in conditions in the pretest (.01 vs. .01, $F < 1$) or the delayed test (.11 vs. .14), $F(1, 46) = 1.29$, $p = .26$, but the grouped condition was more beneficial in the posttest (.27 vs. .40), $F(1, 46) = 6.31$, $p = .02$.

The simple main effect analysis of time revealed that, under both conditions and in both *pinyin* and meaning production, participants' posttest performance was better than their delayed test performance, which in turn was better than their pretest performance (ps $< .05$). Figure 1 illustrates 1st-year participant accuracy in these measures over time.

These results indicate that the grouped condition had a short-term advantage over the distributed condition in sound and meaning representations. The disappearance of the advantage associated with a particular learning condition over an interval beyond 48 hours is consistent with studies on CFL character learning (e.g., Shen, 2004; Wang & Thomas, 1992; Xu et al., 2013). Results also indicate that sound and

TABLE 3
Mean Accuracies and Standard Deviations (*SD*) in Production and Generalization Tasks for 1st-Year Students ($N = 48$)

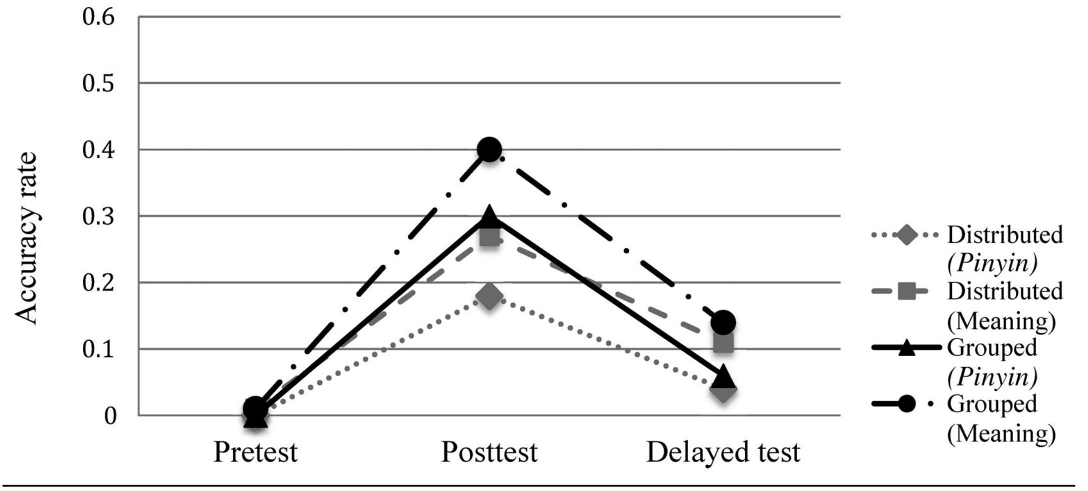
	Distributed *(n = 24)*		Grouped *(n = 24)*	
	Mean	*SD*	Mean	*SD*
Pretest				
Pinyin	.00	.00	.00	.00
Meaning	.01	.04	.01	.02
Radical recognition	.96	.05	.96	.04
Semantic awareness	.65	.20	.62	.28
Immediate test				
Character	.20	.15	.21	.15
Posttest				
Character	.15	.11	.24	.17
Pinyin	.18	.16	.30	.20
Meaning	.27	.19	.40	.17
Radical recognition	.96	.05	.99	.03
Semantic awareness	.72	.26	.87	.16
Delayed test				
Character	.06	.06	.12	.08
Pinyin	.04	.05	.06	.07
Meaning	.11	.12	.14	.07
Radical recognition	.97	.04	.98	.03
Semantic awareness	.78	.24	.91	.12

Note. Accuracies were calculated using the proportion of correct responses.

meaning representation were subject to retention losses without repeated practice, regardless of how characters were sequenced. This suggests the importance of repeated practice to maintain the advantage induced by instructional interventions.

Character production accuracy was assessed in an immediate test, posttest, and delayed test. Results indicate that the grouped condition did not offer an advantage in the immediate test, but led to more beneficial outcomes than the distributed condition in both the posttest and delayed test. Using a mixed ANOVA, the grouping × testing time interaction was significant, $F(2, 92) = 4.34$, $p = .02$, $\eta_p^2 = .08$. The simple main effect analysis of grouping did not reveal a grouping difference in the immediate test

FIGURE 1
1st-Year Participants' *Pinyin* and Meaning Production Accuracies Over Time

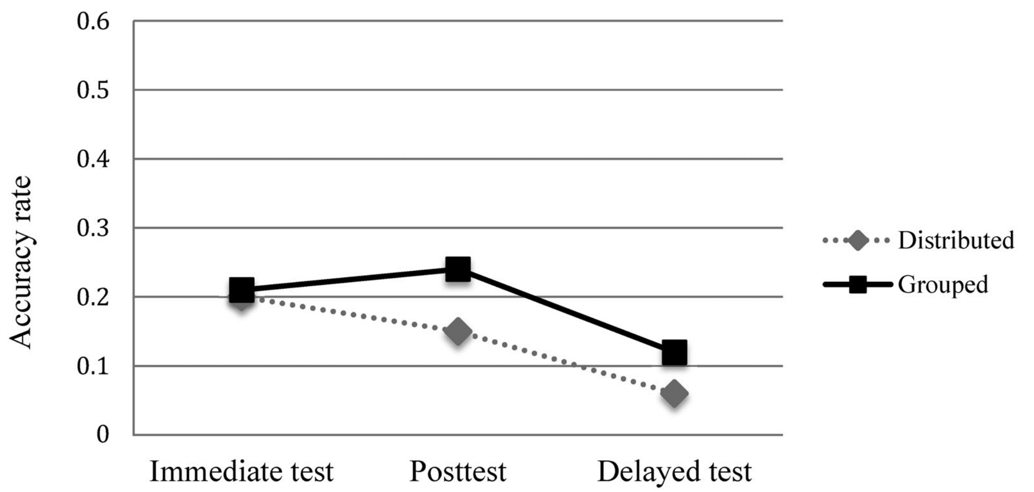


(.20 vs. .21), $F < 1$, but there were significant grouping differences in the posttest (.15 vs. .24), $F(1, 46) = 5.48$, $p = .02$, and in the delayed test (.06 vs. .12), $F(1, 46) = 7.60$, $p < .01$. The simple main effect analysis of time under the distributed condition reached significance, $F(2, 46) = 25.28$, $p < .01$, $\eta_p^2 = .52$. There were retention losses from the immediate test to posttest ($p = .04$), and from posttest to delayed test ($p < .01$). The simple main effect analysis of time under the grouped condition was also significant, $F(2, 46) = 24.02$, $p < .01$, $\eta_p^2 = .51$. Character production accuracy remained from the immediate test to the posttest ($p = .27$), but there was retention loss from the posttest to delayed test ($p < .01$). Figure 2 illustrates the pattern.

Discussion of Beginning Learners' Form/Sound/Meaning Representation. The above results show that presenting radical-sharing characters in groups affected characters' form, sound, and meaning representations. We suggest that beginning learners, depending on their learning conditions, may encode characters in different ways, such as undifferentiated whole characters or with attention to various areas of the visual space. Grouping characters with the same radical helps them by drawing their attention to the radical as a semantic unit across various characters. When the characters with shared radicals are spaced over instruction, this advantage is lost as memory for the radical fades. Spacing radical-sharing characters narrowly (such as in the grouped condition) may require equal or more effort in the learning stage, as shown by the inhibition effect in sound matching in the grouped condition and the lack of difference between the two conditions in character production in the immediate test. But in the posttest, the advantage of radical-based grouping was consistently evident in form, sound, and meaning representations, suggesting that relying on radicals as functional orthographic units in learning is an effective method of memory organization.

The grouping advantage is related to what Craik and Lockhart (1972) refer to as "deeper processing" (p. 679). The depth of processing is the degree of semantic and cognitive analysis involved in learning; deeper processing leads to improvement in memory. Specifically, learning through sheer rote (e.g., copying words) constitutes shallow processing, whereas a deeper level of processing results from associating new information to one's past experience, extracting meaning through pattern recognition, or organizing information into meaningful structures. Taft and Chung (1999) suggest that analyzing characters in terms of radicals constitutes deeper processing. When presenting radical-sharing characters in groups, recurring radicals are likely to draw learners' attention to the shape, position, and consistent semantic function of those characters. Learners have opportunities to realize that target characters can be decomposed into *shared components* and *distinctive components*. For instance, when 嫁 ('to marry') and 姑 ('father's sister') are

FIGURE 2
1st-Year Participants' Character Production Accuracies Over Time



presented together, it is easily observable that 女 is the shared component, contributing to the general concept of 'female' in these characters, while the two characters need to be differentiated from one another by 家 and 古, which, in addition to 女, serve to make their form–sound and form–meaning links distinctive. In making these observations, participants conducted semantic and structural analysis of the characters and made connections between the radical and the whole character, as well as connections among the characters. These elaborations facilitated acquisition.

Previous studies indicate that beginning learners could not automatically use radical knowledge to make meaning inferences in unknown characters without probing (Wang et al., 2004). McGinnis (1999) also reported that beginning learners more frequently used repeated writing and "making up a story" (p. 160) than relying on radicals to learn new characters. In other words, beginning learners might benefit from some type of external aid that would encourage them to apply radical knowledge. Such external aids might be achieved through question probing (Wang et al., 2004) or instructor elaboration (e.g., Shen, 2004). The current study suggests that presenting characters in radical-based groups could be a supportive method that encourages beginning learners to autonomously use radical knowledge in learning new characters.

Thus, to answer our RQ1 regarding beginning learners' character form, sound, and meaning representation in the two conditions, the grouped condition offered a short-term advantage in all these three aspects of character learning. The next section examines results in Radical Recognition and Semantic Awareness tasks.

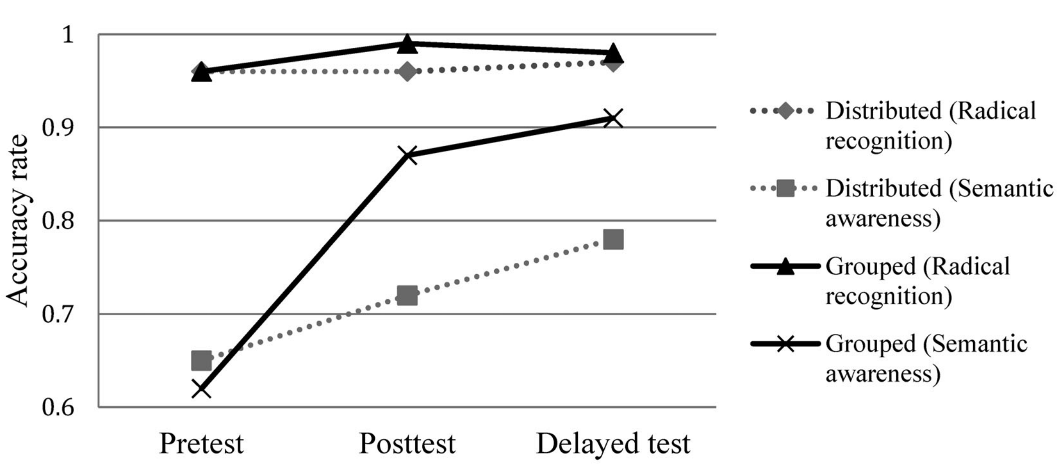
Beginning Learners' Radical Knowledge Application

RR and SA tasks measure how well participants can generalize and apply radical knowledge (including form recognition and meaning association) to unfamiliar characters. Whereas descriptive results were shown in Table 3, Figure 3 below presents 1st-year participants' response accuracies in RR and SA tasks in the pretest, posttest, and delayed test.

In 1st-year participants' performance in RR, there was no evidence of improvement across time and no difference between conditions. The grouping × testing time interaction was not significant, $F(2, 92) = 1.60$, $p = .21$. Mean accuracies in the conditions were .96 vs. .96 in the pretest, .96 vs. .99 in the posttest, and .97 vs. .98 in the delayed test. Neither the main effect of grouping, $F(1, 46) = 1.80$, $p = .19$, nor the main effect of testing time, $F(2, 92) = 2.45$, $p = .09$, was significant.

The above suggests that beginning learners can visually perceive the radical's graphic symbol in compound characters with limited experience in Chinese orthography. Participants' high accuracy rate is consistent with studies reporting early acquisition of character's orthographic structures among alphabetic readers as beginning CFL learners (Shen & Ke, 2007; Wang et al., 2003). Shen and Ke (2007) argued that adult CFL

FIGURE 3
1st-Year Participants' Response Accuracies in RR and SA Tasks Over Time



learners can utilize their cognitive maturity and do not necessarily need to use radical knowledge to accomplish a task asking for visual identification of a radical's graphic form. In this study, the lack of significant results could be explained if beginning learners relied on simple visual skills instead of orthographic structural knowledge to complete the RR task; that is, learners with limited exposure to the graphic components of characters may merely try to identify packs of visual symbols in this perception task, without necessarily understanding these symbols as orthographic units. Since adults' basic visual skill as a cognitive mechanism is unlikely to be affected by a few hours of learning, treatment in the experiment did not impact participants' performance. Later, when analyzing 2nd-year participants' patterns, we suggest that experienced learners handle the RR task differently.

1st-year participants' performance in the SA task showed that the grouped condition led to better outcomes than the distributed condition in the posttest and delayed test. Interaction of the two variables (grouping × testing time) was significant, $F(2, 92) = 3.95$, $p = .02$, $\eta_p^2 = .08$. The simple main effect analysis of grouping did not reveal a pretest difference between conditions (.65 vs. .62), $F < 1$; but the grouped condition was more advantageous in the posttest (.72 vs. .87), $F(1, 46) = 5.78$, $p = .02$, and the grouped condition outperformed the distributed condition in the delayed test (.78 vs. .91), $F(1, 46) = 5.72$, $p = .02$. In the distributed condition, the simple main effect analysis of testing time reached significance, $F(2, 46) = 3.32$, $p < .05$, $\eta_p^2 = .13$; the difference between the delayed test and pretest, but not any other paired comparison between testing points was significant (ps > .05). In the grouped condition, the simple main effect analysis of testing time was significant, $F(2, 46) = 21.16$, $p < .01$, $\eta_p^2 = .48$, and both the posttest and delayed test had higher accuracy than the pretest (ps < .01), with no difference between the posttest and delayed test ($p = .89$).

In addition to showing the advantage of the grouped condition in this measure, improvement in the grouped condition from pretest to posttest and delayed test suggests that radical-based grouping helped participants make associations among the radical's form, position, and semantic function, and to apply such knowledge in unfamiliar characters. Compared to earlier studies demonstrating the role of explicit orthographic instruction in developing learners' semantic awareness (e.g., Chen et al., 2013), these results indicate that radical-based grouping can help beginning learners derive radicals' structural and functional regularity through implicit learning.

Note that under the distributed condition, although gains were observed from pretest to delayed test, this effect might be attributed to participants' learning beyond the experiment, because no improvement in SA from pretest to posttest was evident in the distributed condition, and participants had 14 additional hours of learning in their regular curriculum over the two-week interval between the posttest and delayed test. Thus, it is not clear whether learning in the distributed condition enhanced 1st-year participants' radical semantic awareness development.

In sum, to answer our RQ2 regarding beginning learners' radical knowledge development in the two conditions, we found no difference between the two conditions in radical form recognition, while the grouped condition had an advantage in developing radical semantic awareness.

Intermediate Learners' Form/Sound/Meaning Representation

Pretest results confirmed that 2nd-year participants in both conditions had little knowledge of target characters' sound (.01 accuracy in *pinyin* production in both conditions) and meaning (.00 accuracy in meaning production in both conditions). The same data analysis design for 2nd-year participants indicated that character grouping did not affect 2nd-year participants as it did 1st-year participants. At the same time, the overall learning outcome showed a pattern generally comparable to 1st-year participants in the grouped condition, indicating significant improvement from pretest to posttest in *pinyin* and *meaning* production, and retention loss in these measures after the two-week interval. Meanwhile, form representation measured through character production remained from the immediate test to posttest.

Lexical Decision and Matching. Participants' performance in lexical decision and matching tasks are reported in Table 4. There were no differences between conditions in either accuracy or RT in these tasks: lexical decision accuracy (.79 vs. .76), $F(1, 38) = 1.50$, $p = .23$; lexical decision RT (1105 vs. 1187), $F(1, 38) = 3.32$, $p = .08$; sound matching accuracy (.67 vs. .62), $F(1, 38) = 1.47$, $p = .23$; sound matching RT (1143 vs. 1167), $F < 1$; meaning matching accuracy (.74 vs. .74), $F < 1$; and meaning matching RT (1081 vs.

TABLE 4
Mean and Standard Deviations (*SD*) of Accuracy and Reaction Time in Lexical Decision and Matching Tasks for 2nd-Year Students ($N = 40$)

	Distributed *(n = 20)*		Grouped *(n = 20)*	
	Mean	*SD*	Mean	*SD*
Accuracy rate				
Lexical decision	.79	.05	.76	.12
Sound matching	.67	.15	.62	.11
Meaning matching	.74	.14	.74	.15
Reaction time				
Lexical decision	1105.20	174.02	1187.34	101.67
Sound matching	1143.25	248.93	1167.08	271.96
Meaning matching	1080.97	226.34	1138.39	176.25

Note. Accuracies were calculated using the proportion of correct responses. Reaction time statistics are in milliseconds.

1138), $F < 1$. In lexical decisions, participant response accuracies in both conditions were significantly higher than chance, confirming that participants established visual–orthographic representations of these characters after learning (distributed: $t[19] = 26.10$, $p < .01$, Cohen's $d = 11.97$; grouped: $t[19] = 9.19$, $p < .01$, Cohen's $d = 4.21$).

Pinyin, Meaning, and Character Production. Descriptive statistics in 2nd-year students' *pinyin*, meaning, and character production in different testing points are reported in Table 5. Descriptive results in the two generalization tasks on radical knowledge application are also included in this table.

In *pinyin* production, mean accuracies for the two conditions were .40 vs. .47 in the posttest and .18 vs. .20 in the delayed test. The grouping × testing time (pre, post, delayed) interaction was not significant, $F(2, 76) = 1.01$, $p = .37$. Grouping was not a significant main factor, $F < 1$, but testing time was a significant main factor, $F(2, 76) = 158.52$, $p < .01$, $\eta_p^2 = .81$. Pairwise comparisons with Bonferroni adjustments indicated that the posttest had higher accuracy than the delayed test

TABLE 5
Mean Accuracies and Standard Deviations (*SD*) in Production Task and Generalization Task for 2nd-Year Students ($N = 40$)

	Distributed *(n = 20)*		Grouped *(n = 20)*	
	Mean	*SD*	Mean	*SD*
Pretest				
Pinyin	.01	.02	.01	.01
Meaning	.00	.01	.00	.01
Radical recognition	.95	.04	.97	.04
Semantic awareness	.74	.18	.75	.16
Immediate test				
Character	.39	.16	.38	.21
Posttest				
Character	.39	.19	.43	.18
Pinyin	.40	.20	.47	.22
Meaning	.45	.17	.52	.16
Radical recognition	.99	.03	.99	.03
Semantic awareness	.88	.14	.89	.15
Delayed test				
Character	.22	.15	.25	.17
Pinyin	.18	.11	.20	.14
Meaning	.23	.13	.25	.13
Radical recognition	.99	.01	.99	.03
Semantic awareness	.92	.12	.93	.11

Note. Accuracies were calculated using the proportion of correct responses.

and pretest, and the delayed test had higher accuracy than the pretest (ps < .01).

In meaning production, mean accuracies for the two conditions were .45 vs. .52 in the posttest and .23 vs. .25 in the delayed test. The interaction was not significant, $F(2, 76) = 1.53$, $p = .22$. Grouping was not a significant main factor, $F(1, 38) < 1$, but testing time was a significant main factor, $F(2, 76) = 263.58$, $p < .01$, $\eta_p^2 = .87$. The posttest had higher accuracy than the delayed test and pretest, and the delayed test had higher accuracy than the pretest (ps < .01).

In character production, means for the two conditions at the three testing points were .39 vs. .38 in the immediate test, .39 vs. .43 in the posttest, and .22 vs. .25 in the delayed test. The grouping × testing time (immediate, post, delayed) interaction was not significant, $F(2, 76) = 1.21$, $p = .30$. Grouping as a main factor was not significant, $F < 1$, but testing time was a significant main factor, $F(2, 76) = 58.59$, $p < .01$, $\eta_p^2 = .61$. There was no difference between the immediate test and posttest ($p = .42$), while both had higher accuracy than the delayed test ($ps < .01$). Figures 4 and 5 respectively illustrate 2nd-year participant accuracy in *pinyin*/meaning productions and character production over time, indicating little difference between conditions at all testing points.

Discussion of Intermediate Learners' Form/Sound/Meaning Representation. The above provides an answer to our RQ3 regarding the form, sound, and meaning representation among intermediate learners: There was no advantage associated with a particular condition in any of these measures. The lack of a grouping effect for 2nd-year participants could be due to two factors. First, learning materials in this study included radicals with high combination frequencies: based on Fan (2010), those eight radicals form 6 to 31 characters in textbooks that 2nd-year participants learned from before the experiment. Because instructors regularly decomposed characters and provided explanation of radicals in lectures, 2nd-year participants had considerably more radical knowledge than 1st-year participants, including understanding those radicals' semantic functions and combinability. The second and more important factor is that learners with more than a year's experience in CFL learning develop radical application knowledge and consciously apply this knowledge when learning new characters (Shen & Ke, 2007). Shen's (2005) survey showed that, as learners' proficiency levels increase, learners more strongly perceive the importance of orthographic knowledge-based strategies such as relying on known radicals. Critical learning has occurred between the first and second year, as 2nd-year students have come to perceive characters as the composition of radicals and other subcharacter components and utilize radical knowledge in learning new material. This eliminates the advantage of close spacing of characters with shared radicals, as 2nd-year participants

FIGURE 4
2nd-Year Participants' *Pinyin* and Meaning Production Accuracies Over Time

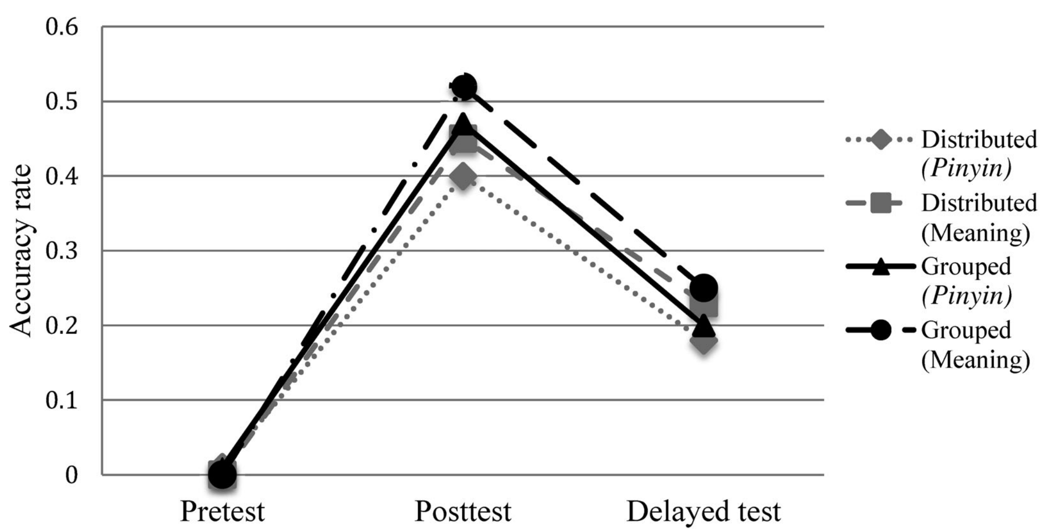
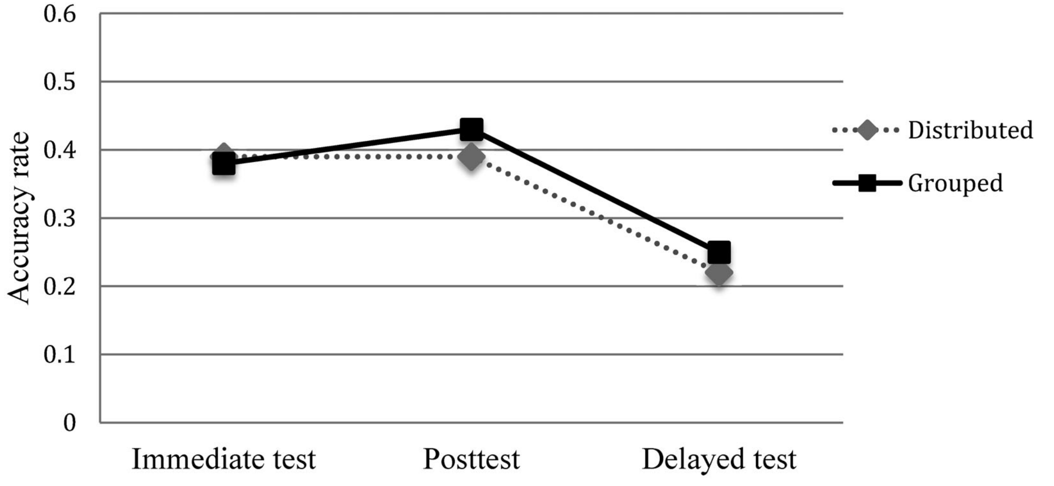


FIGURE 5
2nd-Year Participants' Character Production Accuracies Over Time



more routinely apply radical knowledge when encountering new characters.

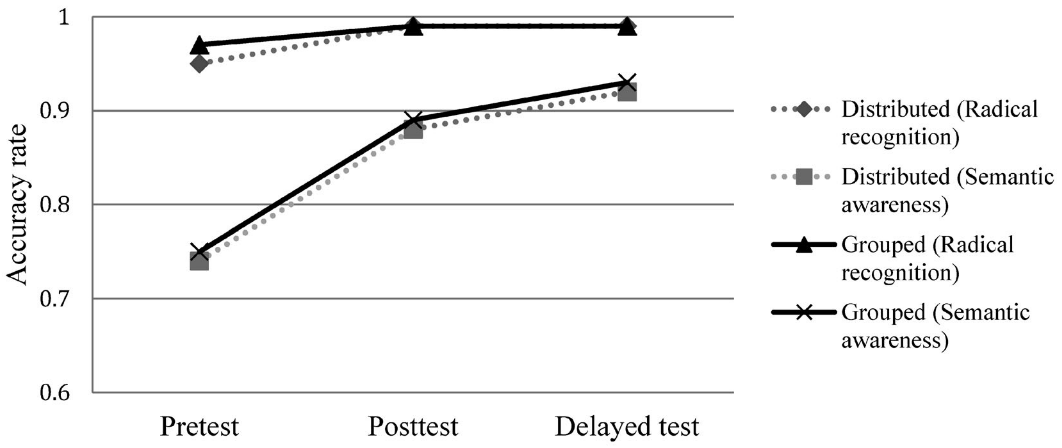
Intermediate Learners' Radical Knowledge Application

Next we examine intermediate learners' results in radical form recognition and semantic awareness. For the RR task, means in conditions at each testing time were .95 vs. .97 in the pretest, .99 vs. .99 in the posttest, and .99 vs. .99 in the delayed test. There was no significant interaction, $F(2, 76) = 2.83$, $p = .07$. Grouping was not a significant main factor, $F < 1$, but testing time was a significant main factor, $F(2, 76) = 10.54$, $p < .01$, $\eta_p^2 = .22$. There was no difference between the posttest and delayed test ($p = .61$), while they both had higher accuracy than the pretest ($p = .01$ and $p < .01$, respectively). For the SA task, means in each condition were .74 vs. .75 in the pretest, .88 vs. .89 in the posttest, and .92 vs. .93 in the delayed test. Interaction of the grouping condition and testing time was not significant, $F < 1$. Grouping was not a significant main factor, $F < 1$, but testing time was a significant main factor, $F(2, 76) = 33.27$, $p < .01$, $\eta_p^2 = .47$. There was no difference between the posttest and delayed test ($p = .19$), while they both had higher accuracy than the pretest ($ps < .01$). Figure 6 illustrates 2nd-year participant response accuracy in the two tasks in each condition across time.

In sum, to answer our RQ4 regarding radical knowledge application including radical form recognition and semantic awareness, neither the grouped condition nor the distributed condition had an advantage over the other. Meanwhile, learning in both conditions resulted in improvement in RR and SA tasks, and this improvement remained in delayed tests.

We discuss results in the semantic awareness task first. As we argued, 2nd-year participants generally applied radical knowledge in learning, regardless of material sequencing. Thus, their improvement from pretest to posttest and to delayed test adhered to the same pattern observed among 1st-year participants in the grouped condition. Results indicate that, for experienced learners who receive explicit orthographic instructions regularly in their curriculum, the ability to infer a radical's semantic functions in unfamiliar characters can be further developed through frequent exposure to radical-sharing compounds. In an early study, Shen and Ke (2007) observed a plateau phenomenon in learners' radical application knowledge development during their second year of study, in which improvement appeared to be less significant than in learners' first or third year of study. Shen and Ke acknowledged that the plateau phenomenon is not necessarily fixed in duration and can possibly be prolonged or shortened depending on practice. Our study indicates that learning a list of radical-containing compound characters in high concentration might be an effective way to overcome the potential plateau period for intermediate learners. In this experiment, participants in both conditions experienced six compound

FIGURE 6
2nd-year Participants' Response Accuracies in RR and SA Tasks Over Time



characters for each radical over four days. This recurrence rate is likely to be more frequent than learning in regular CFL classrooms. Accumulated experience with radicals' structural and functional regularity within a short period of time could enable learners to make rapid improvement in applying radical knowledge in unfamiliar characters.

Next, 2nd-year participants' performance also improved in Radical Recognition. This might seem initially surprising, since no improvement was observed among 1st-year participants in this measure from pretest to posttest. An explanation can be provided if beginning and intermediate learners handle the RR task differently. While we suggested earlier that 1st-year participants relied mostly on visual perception skills to complete this task, existing research indicates that learners finishing one year of study, in comparison with beginners, especially value using subcharacter components including radicals as a method to learn (e.g., Ke, 1998; cf., McGinnis, 1999). Results in this study so far also suggest that experienced learners automatically apply orthographic knowledge to process and learn new characters. That is, 2nd-year participants perceive characters not as a simple visual symbol, but as the combination of radicals and chunks with organization principles. To complete this task, those participants were likely to use strategies such as recognizing familiar radicals/chunks to decompose characters' structures in meaningful ways. Radical knowledge is not necessarily needed to visually perceive a radical in a compound character, but it can facilitate the recognition process (Shen & Ke, 2007). When learners relied on radical knowledge to respond in this perceptual recognition task, as was the case for 2nd-year participants in this study, their performance in identifying radical shape within a compound could improve because of increasing experience with the radicals' form and combinational possibilities.

Overall Discussion of Learners in Different Proficiency Groups

We argued that beginning learners (defined as students with no more than a few weeks of experience in Chinese orthography) might still lack insight into a character's internal structures, whereas intermediate learners may be able to automatically perceive compound characters as the logical composition of radicals and other subcharacter components. This could explain why the grouping manipulation affected 1st-year participants but not 2nd-year participants at a significant level. Evidence for difference between beginning and intermediate learners in character perception and learning is reported in L1 reading acquisition: A meta-analysis by Yang et al. (2013) summarizing 64 Chinese as an L1 studies reported that three visual skills (visual perception, the speed of visual information processing, and pure visual memory) have a medium correlation (.34 to .44) with reading acquisition in lower grades until the 2nd grade, but those visual skills have no significant correlation (.12 to .20) with reading acquisition for 2nd to 6th graders. Note that most L1 children develop an understanding of compound characters' basic configuration in 2nd grade (Shu & Anderson, 1999). Similarly, Lu (2002) showed that beginning and intermediate CFL learners had different levels of sensitivity toward characters' structural configurations. In Chang et al. (2014b), we analyzed the correlation between participants' visual skills and learning outcomes in the current experiment: 1st-year participants' visual skill of pattern discrimination correlated with gains in character form and meaning learning ($r = .33$, $r = .34$, respectively, $ps < .05$), but 2nd-year participants' visual skills did not correlate with their gains (form: $r = .15$, meaning: $r = .12$, $ps > .05$). Such evidence indicates that learners who have not yet developed a full understanding of a Chinese character's orthographic structures may rely on basic visual skills in character perception and learning, whereas those with metalinguistic awareness regarding a character's structures analyze sub-character components as orthographic units and organize them in meaningful ways to learn.

CONCLUSION

For beginning learners, sequencing radical-sharing characters together led to a short-term advantage in the form, sound, and meaning representations of characters. Radical-based grouping can be an instructional method that encourages learners to analyze characters' structures and generalize radicals' structural and functional regularities, thus achieving effective character learning. Intermediate learners routinely rely on radical knowledge to learn, so that radical-based grouping offered no particular advantage. Meanwhile, experiencing recurring radicals in multiple compound characters can facilitate intermediate learners' further development in radical knowledge application.

Radical-based grouping in CFL classrooms is underrepresented in research. While we would not argue for a radical-based approach in sequencing new characters in primary CFL teaching materials, the current research indicates the benefit of frequently presenting recurring radicals to learners. Several implications for teaching are proposed. First, when teaching a target character, instructors could refer to radical-sharing characters in previous and subsequent lessons. For instance, when teaching 时 in 时候 ('time'), it is desirable to review and preview characters such as 晚 ('evening' or 'late'), 明 ('tomorrow'), and 昨 ('yesterday'), which all contain 日 as a radical on the left side, with meaning associations to 'time' or 'day.' Instruction can also extend to characters such as 星 ('star'), 早 ('early'), 是 ('to be'), and 易 ('easy'), with the 日 component in a position different from 时. Whereas students are expected learn these characters in the first semester following text sequences in their theme-based textbooks, instructors can ensure that those characters are presented together in the classroom to achieve a grouping effect to support form, meaning memorization, and radical knowledge development. Second, this study points to the possibility of achieving orthographic knowledge development within meaningful context. Reading passages can be created to contain a range of radical-sharing characters, and such reading texts have been applied in L1 classrooms and as E-learning materials (Chen et al., 2013; Ki et al., 2003). With appropriate character selection, short passages similar to the ones used in this study can be constructed for CFL students as supplementary or extensive reading materials with the primary goal of developing orthographic awareness. Third, many textbook and workbooks provide exercises in which learners must recycle learned characters by grouping them based on shared radicals or by making radical-based meaning inferences in unfamiliar characters. This research provides evidence supporting the validity of these exercises. Finally, we found that intermediate learners' radical knowledge is subject to further development. That is, introducing multiple new characters containing familiar radicals continues to be a meaningful instruction method for second-year CFL students, as it can expedite the further development of their radical application skills.

The beneficial effect of character grouping among beginning learners is likely to depend on some existing orthographic knowledge among learners. Also, since there is variability in how and to what extent radicals contribute to the precise meaning of a character, generalization based on known radicals cannot provide exactly accurate meaning inferences in unknown characters. In these aspects, the implications of the study should be interpreted with caution.

ACKNOWLEDGMENTS

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NOTES

[1] In addition to semantic–phonetic compounds, characters may have internal structures that follow other compounding patterns. For instance, associative compounds (*huìyì*) are characters that consist of two subcharacter components that both contribute to the meaning of the character. Six types of characters following different compounding principles are categorized in the etymological dictionary *Shuōwén Jiězì* (说文解字).

[2] Most of the 48 characters are semantic–phonetic compounds with the eight radicals as semantic radicals based on S*huōwén Jiězì*, with the exception of 蚀, which is categorized as a semantic–phonetic compound with 虫 as the semantic radical and 败 as an associative compound (Gao, 2003). According to *Xīnhuá Dictionary* (新华字典), both characters are associative compounds, and 食(饣) simultaneously acts as a phonetic component for character 蚀. Since associative compounds are characters in which both radicals contribute to the meaning of the whole character (Gao, 2003), the eight radicals for all 48 characters can be considered semantic radicals.

[3] All participants in both conditions experienced reading, writing, character chunk presentation, and stroke counting as encoding methods in different orders. Since this design applies to all participants, it does not affect our analysis of the grouping factor here. Part of the encoding method effect among 1st-year participants is reported in Chang et al. (2014a).

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APPENDIX A
Assignment of the 48 Characters in the Two Conditions

Character sets in the grouped condition			Character sets in the distributed condition		
Set	Code	Character	Set	Code	Character
	A1	贩 'peddler'		G4	饱 'full'
	A2	账 'accounts'		D1	棚 'shack'
1	A3	败 'to be defeated'	1	B5	烟 'smoke'
	A4	赔 'to stand a loss'		H1	忽 'suddenly'
	A5	贼 'thief'		C3	钻 'diamond'
	A6	赚 'to earn'		E1	婚 'wedding'
	B1	炉 'stove'		E4	娃 'baby'
	B2	烘 'to warm by fire'		F2	旷 'spacious'
2	B3	焰 'flame'	2	B6	烛 'candle'
	B4	炮 'firecracker'		A3	败 'to be defeated'
	B5	烟 'smoke'		H5	忍 'to endure'
	B6	烛 'candle'		C5	钥 'key'
	C1	银 'silver'		D2	桶 'pail'
	C2	钞 'bank note'		C6	钓 'to fish'
3	C3	钻 'diamond'	3	F3	晒 'to sun-dry'
	C4	锁 'to lock'		A2	账 'accounts'
	C5	钥 'key'		H2	患 'to contract'
	C6	钓 'to fish'		G6	饶 'to forgive'
	D1	棚 'shack'		E6	姑 'father's sister'
	D2	桶 'pail'		C1	银 'silver'
4	D3	梯 'ladder'	4	D6	概 'approximately'
	D4	板 'board'		F1	晌 'noon'
	D5	材 'material'		G5	蚀 'to lose'
	D6	概 'approximately'		A4	赔 'to stand a loss'
	E1	婚 'wedding'		B4	炮 'firecracker'
	E2	嫁 'to marry'		F6	暗 'dark'
5	E3	媳 'daughter-in-law'	5	C4	锁 'to lock'
	E4	娃 'baby'		D3	梯 'ladder'
	E5	娇 'lovely'		H3	急 'anxious'
	E6	姑 'father's sister'		A5	贼 'thief'
	F1	晌 'noon'		E2	嫁 'to marry'
	F2	旷 'spacious'		A1	贩 'peddler'
6	F3	晒 'to sun-dry'	6	C2	钞 'bank note'
	F4	晾 'to dry in the air'		G2	馅 'stuffing'
	F5	暄 'warm'		F4	晾 'to dry in the air'
	F6	暗 'dark'		B2	烘 'to warm by fire'
	G1	馒 'steamed bun'		E3	媳 'daughter-in-law'
	G2	馅 'stuffing'		G1	馒 'steamed bun'
7	G3	馋 'greedy'	7	B1	炉 'stove'
	G4	饱 'full'		D5	材 'material'
	G5	蚀 'to lose'		F5	暄 'warm'
	G6	饶 'to forgive'		H6	愁 'to worry'
	H1	忽 'suddenly'		E5	娇 'lovely'
	H2	患 'to contract'		G3	馋 'greedy'
8	H3	急 'anxious'	8	H4	忌 'to avoid'
	H4	忌 'to avoid'		A6	赚 'to earn'
	H5	忍 'to endure'		D4	板 'board'
	H6	愁 'to worry'		B3	焰 'flame'

Note. Code is used to illustrate how characters under the same radical group (i.e., marked by a letter) are assigned to the same set in the grouped condition and distributed across different sets in the distributed condition. Letters from A to H are associated with the following radical groups: 贝 ('money'), 火 ('fire'), 钅('metal'), 木 ('wood'), 女 ('female'), 日 ('sun'), 饣 ('food'), and 心 ('heart'), in this sequence.

APPENDIX B

Sample Texts Containing Target Characters in the Two Conditions

Target characters are in block font, while words that they form are underlined. The two texts share the same word 姑姑 (‘father’s sister’).

(1) Text in the grouped condition:

二Ｏ二一年，小爱结婚了，她嫁给了小高，做了高家的儿媳。小爱生了一个娃娃，娇小可爱，现在五岁了。她叫高小音“姑姑”。

‘In 2021, Xiaoai had her wedding. She married Xiaogao and became a daughter-in-law of the Gao family. Xiaoai gave birth to a baby. The baby is dainty and lovely, and is now five years old. She calls Gao Xiaoyin ‘aunt (father’s sister)’.

(2) Text in the distributed condition:

小高的姑姑在银器店里工作，她每天记账，从上午忙到晌午。做生意不蚀本，也不赔钱。她是个很聪明的生意人。

‘Xiaogao’s aunt (father’s sister) works in a silverware shop. She is busy every day, recording transactions from morning till noon. She never loses her capital assets or suffers losses in business. She is a very smart business person.’

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A complete application includes:

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- Brief statement signed by the dissertation advisor/dissertation committee chair stating that the applicant has: successfully defended his/her dissertation proposal; the IRB process has been cleared (if appropriate to the study); the applicant has successfully completed all but the dissertation writing at the time of application for this grant.
- Proposed dissertation title and a description of the proposed research. The description should include: purpose of the study; theoretical framework(s); research questions; methodology; importance of the study; limitations (maximum two pages, Times New Roman 12).

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