A "Radical" Approach to Reading Development in Chinese: The Role of Semantic Radicals and Phonetic Radicals

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Two studies investigating the significance of radical knowledge in Chinese reading development are reported in this paper. Study 1 examined the semantic radical knowledge of 20 Grade 1, 20 Grade 3, and 20 Grade 5 Chinese children in Hong Kong. It was found that various types of semantic radical knowledge, including the position and semantic category of semantic radicals, correlated significantly with Chinese word reading and sentence comprehension. Study 2 examined phonetic radical knowledge with another three groups of 20 Chinese children in Grades 1, 3, and 5 respectively. It was found that various measures of phonetic radical knowledge, including the function and sound value of phonetic radicals, correlated significantly with Chinese word reading. These studies found that, developmentally, the children started acquiring the knowledge of character structure, position, semantic category, and sound value of radicals from about Grade 1. However, they did not understand that the function of semantic radicals is to provide meaning cues in reading until Grade 3. The authors concluded that the radical is an important orthographic processing unit in reading development in Chinese.

JLR
V. 35 No. 3
2003
PP. 849-878

Reading is an important means of acquiring knowledge in today's literature world. However, not all children master this important skill without difficulty. It may be difficult for a child to learn to read if he or she treats every new word as a new visual configuration without discovering the underlying regularities of the script. Researchers like Ehri (1991, 1992) and Frith (1985) propose that children initially learn to read holistically at the logographic stage by associating some visual features of a word with its sound. Later, when children discover the

"cipher" of the language system at the alphabetic stage, they solve the problem of having to memorize many different words and are able to read new words (Gough, Juel, & Griffith, 1992). What Gough et al. (1992) mean by "cipher" is the phonological regularity of a writing system (e.g., letter-sound correspondence rules in an alphabetic language). At the third and orthographic stage, letter strings and whole words are processed as whole units and this allows efficient and automatic word recognition.

In the opinion of Nagy and Anderson (1999), learning to read is "fundamentally metalinguistic." Metalinguistic awareness is the ability to reflect on and manipulate the structural features of language. Past research has shown a strong association between metalinguistic awareness and reading development. For instance, awareness of phonemes has been found to be important in learning to read alphabetic languages. However, many studies have shown that apart from awareness of the phonological regularity of a writing system, awareness of the orthographic regularity (i.e., the spatial and sequential redundancy of orthographic units) (e.g., Berninger, 1987, 1990, 1994; Corcos & Willows, 1993) and morphological regularity (i.e., the correspondence between morphological units and meaning) (e.g., Anderson & Nagy, 1992; Anshen & Aronoff, 1988; Freyd & Baron, 1982; Nagy, Anderson, Schommer, Scott & Stallman, 1989; Tyler & Nagy, 1989; Wysocki & Jenkins, 1987) is also important in reading. Since most of these studies have been conducted with alphabetic languages, one may ask whether the same findings apply to learning to read Chinese, a non-alphabetic script. The present studies were conducted with the aim of providing an answer to this question. Before we proceed to review related literature in Chinese, we will first describe the main characteristics of the Chinese orthography.

The Main Characteristics of the Chinese Orthography

The basic graphic unit in Chinese is a character. Almost all Chinese characters represent morphemes, and all characters are monosyllabic. That is why Chinese script is often described as morphosyllabic. There are about 3,000 Chinese characters in daily use in Mainland China (Foreign Languages Press Beijing, 1989) and about 4,500 frequently used characters in Taiwan (Liu, Chuang, & Wang, 1975).

Chinese characters are made up of different strokes. Strokes are combined to form stroke-patterns (e.g.,  ,  , and ). Chen, Allport, and Marshall (1996) reported that the number of stroke-patterns in a character is a better indicator of character complexity than the number of strokes in a character.

The Chinese language is often described as "logographic." For a logographic writing system, the script maps onto the meaning rather than the sound of words. In fact, Chinese is not as logographic as people expect because only a small percentage (about 10%) of Chinese characters convey meaning by pictographic or ideographic representation. Pictographic characters are those like drawings of objects (e.g., 山 for "hill" and 日 for "sun"). Ideographic characters symbolically represent concepts that cannot be easily depicted by pictures (e.g., 上 for "above" and 下 for "below"). Most pictographic and ideographic characters are simple characters. According to Kang (1993) and Zhu (1987), about 80% to 90% of Chinese characters are ideophonetic compound characters, each comprising a semantic component (the semantic radical) and a phonological component (the phonetic radical). For instance, in the character 燈 [dang]1[1] "lamp," 火 [fo]2 "fire" is the semantic radical which gives a cue to the meaning of the character (as one needed fire to light an oil lamp in the olden days), and 登 [dang]1 "climb" is the phonetic radical that gives a cue to the pronunciation of the compound. There are about 200 semantic radicals and 800 phonetic radicals in Chinese (Hoosain, 1991). Semantic radicals mostly occupy a habitual position in a Chinese character—left or top. Many radicals are themselves simple characters with independent meanings and pronunciations (e.g., the semantic radical of "fire" 火). Some radicals are bound forms that never appear alone, but only as components of compound characters (e.g., the semantic radical of "water" 氵).

In general, the semantic radical in a Chinese character signifies the semantic category of the character. There are different degrees of transparency for the semantic implication of different semantic radicals. A transparent semantic radical gives a reliable cue for the meaning of a character (e.g., the semantic radical 女 "female" in the character 媽 "mother"), but an opaque semantic radical does not (e.g., the semantic radical 土 "soil" in the character 增 "increase").

Unlike the case of an English word in which the sound is encoded in all letters, only one part of a Chinese character (i.e., the phonetic radical, encodes or specifies the sound of the character). This part-to-whole conversion rule is called the orthography-phonology correspondence rule (Ho & Bryant, 1997a) or phonetic principle (Anderson, Li, Ku, Shu, & Wu, 2003). The phonetic radical provides the sound cue of an ideophonetic compound character either by "direct derivation" or by "analogy." If the phonetic radical itself is a simple character and a reader knows its pronunciation, he/she may derive the sound of the character directly from the sound of the phonetic radical (e.g., deriving the sound of the character 碼 [ma]5 "yard" from the sound of its phonetic radical 馬 [ma]5). On the other hand, if the phonetic radical is a bound form or the reader does not know its pronunciation, he/she may derive the sound of the character by making an analogy to the sound of other

characters having the same phonetic radical (e.g., deriving the sound of the character 碼 [ma]5 "yard" from other characters having the same phonetic radical, such as 螞 [ma]5 "ant" and 瑪 [ma]5 "agate"). The direct derivation method is similar to deriving the pronunciation of an English word "fat" by assembling the sound of the letters in the word (/f/-/a/-/t/). With the analogy method, the sound of the word "fat" would be arrived at by making an analogy to similar words like "cat."

Based on some linguistic analyses, Shu, Chen, Anderson, Wu, and Xuan (2003) and Zhu (1987) have suggested that the semantic cueing function of the semantic radical in a Chinese character is stronger than the phonological cueing function of the phonetic radical. For instance, in the 3,756 frequently used Chinese characters, there are 184 characters with the semantic radical "扌." In these 184 characters, most of them are related to the meaning of "hand" or "motion," e.g., 打 "hit," 抱 "embrace," and 搖 "shake" (Zhu, 1987). On the other hand, the predictive accuracy of the pronunciation of an ideophonetic compound character from its phonetic radical is about 40% (Shu et al., 2003; Zhou, 1980; Zhu, 1987). This drops to 23% to 26% if tone is taken into consideration (Shu et al., 2003; Zhou, 1980).

According to Shu et al. (2003), the average rate of phonological consistency for phonetic radicals in elementary grades is 64%, which is higher than that of phonological regularity for phonetic radicals. However, since the size of phonetic families (i.e., number of characters with the same phonetic radical) is small, it takes a long time for children to develop phonetic consistency awareness. There are 563 phonetic families in Shu et al.'s corpus and the average family size is 3.23. Children's awareness of both phonetic regularity and consistency (as reflected in the use of direct derivation and analogy strategies respectively) was examined in the present studies.

Shu et al. (2003) have also suggested that children develop semantic radical awareness at an early age because of the high transparency, high frequency and large family size of semantic radicals. There are 124 semantic families in their corpus and the average family size is 14.99. One of the objectives of the present studies was to examine whether children develop the awareness of semantic radicals earlier than phonetic radicals.

The Radical as an Important Orthographic Unit in Chinese Character Recognition

A number of recent studies have shown that the radical is an important processing unit for adult skilled readers in the recognition of Chinese characters (e.g., Chen et al., 1996; Feldman & Siok, 1997, 1999a, 1999b; Li, 1997; Taft & Zhu, 1997).

However, few studies have been conducted to examine systematically the role of radicals in Chinese reading development. The aim of this paper is to fill this gap.

Some researchers have reported that the position and function of radicals are the main factors that determine how a radical affects character recognition in Chinese skilled readers (e.g., Feldman & Siok, 1999a; Li, 1997; Li & Chen, 1997). We inquired whether the same types of radical knowledge are important in learning to read Chinese.

The Positional Regularity of Radicals

Many researchers have proposed that automatic word recognition in English depends on a reader having knowledge of the orthographic regularity of a script (e.g., Barker, Torgesen, & Wagner, 1992; Berninger, 1994; Corcos & Willows, 1993; Venezky & Massaro, 1979). The orthographic knowledge is based on statistical probability or rules (e.g., letter probabilities, positional frequencies, and sequential redundancy patterns). This knowledge is acquired through repeated exposure to the orthographic structure of words in text.

In the case of Chinese, the positional regularity of radicals is the crux of a character's orthographic structure. Like the frequency effect of letter sequences in English, the positions of all the radicals in a Chinese character mostly determine whether the character is legal or not. If all the radicals in a Chinese character are in their legal positions (i.e., in positions where the radical may appear in real characters), that character may either be a real character or a pseudocharacter. If any of the radicals is not positioned legally, the character is a noncharacter. The most common way of testing Chinese readers' knowledge of radical position or character structure is by a character decision task (e.g., Cheng & Huang, 1995; Feldman & Siok, 1997; Peng, Li, & Yang, 1997; Taft & Zhu, 1997). For instance, Cheng and Huang (1995) asked 71 children in grades 2 through 6 in Taiwan to judge whether an item had been learned before as a legal character, and, if not, to judge whether it looked like a legal character. The stimuli were frequently used characters, rare characters, pseudocharacters and noncharacters. They found that most children judged frequently used characters as real characters and noncharacters as illegal characters. The second and third graders judged rare characters and pseudocharacters as character-like at chance level. From fourth grade onward, more children judged the two types of characters as looking like characters. It appears that even second graders have some rudimentary knowledge of the orthographic structure, and this knowledge grows with age. The children have gained more accurate positional knowledge of radicals by the time they reach Grade 4.

In two other studies, one conducted by Chan and Nunes (1998) on 60 preschoolers and primary school children in Hong Kong and the other by Shu and Anderson (1999) on 143 primary school children in Beijing, it was found that even first graders could use the positional rule to reject noncharacters and judge pseudocharacters as orthographically acceptable. This suggests that basic character structure or radical position knowledge develops quite early in Chinese children.

However, it is noteworthy that the character decision tasks described above are considered as tests of knowledge of character structure and implicit knowledge of radical positions. The above findings therefore did not show anything about explicit knowledge of radical positions or specific knowledge regarding semantic radical position and phonetic radical position. The present studies examine such explicit positional knowledge and whether the knowledge of orthographic structure in Chinese, as represented in the positional regularity of radicals, is related to a child's reading development.

The Functional Regularity of Radicals

As pointed out by Feldman and Siok (1997), the position of radicals is often confounded with its function. Feldman and Siok (1999a) reported that about 75% of Chinese ideophonetic compound characters have their semantic radicals on the left. In other words, in characters of left-right structure, most left radicals serve the semantic function and right radicals serve the phonological function. Therefore, a reader's knowledge of the position of radicals to some extent helps him/her determine the semantic radical and the phonetic radical that is in a Chinese character.

The Phonological Function. The impact of phonological regularity in learning to read alphabetic languages has been the focus of many researchers for years. Goswami (1986) has proposed that beginning readers read words by analogy, even before they are able to decode words phonologically. Ehri and Robbins (1992) have further demonstrated that some decoding skills are needed in order to read words by analogy. Similarly, both direct derivation and analogy strategies are used in reading by Chinese beginning readers (Ho & Bryant, 1997a; Ho, Wong, & Chan, 1999).

Similar to beginning readers of English, 90 Chinese first and second graders were found to name phonologically regular Chinese characters better than irregular ones (Ho & Bryant, 1997a), and 30 Chinese third and sixth graders were found to name consistent Chinese characters better than inconsistent ones (Yang & Peng, 1997). Phonetic-related errors were also found to be the most dominant type in reading Chinese characters and words among Chinese first and second graders (Ho & Bryant, 1997a). Chan and Siegel (2001) tested 94 primary school children in Hong

Kong and found that older and normally achieving students made more phonetic-related errors, whereas younger normal and poor readers made more semantic and visual errors. These findings suggest that even Chinese first-graders start to make use of the phonetic radical for sound cues, and the reliance on the phonetic principle seems to be related to reading proficiency. However, the development of phonetic knowledge and its relationship to reading development has not been studied systematically.

The Semantic Function. Shu and Anderson (1999) have suggested that morphological awareness (i.e., the awareness of the morphemic structure of words and the ability to reflect on and manipulate the structure) is an important aspect of metalinguistic awareness that is closely related to literacy in both alphabetic and non-alphabetic scripts. The semantic radical is the orthographic unit in Chinese that encodes or specifies the meaning of a character. Similar to the findings on phonological consistency, significant semantic consistency effects were reported with adult skilled readers in performing a semantic categorization/decision task (Chen & Weekes, 1997; Leck, Weekes, & Chen, 1995; Miao & Sang, 1991; Zhang, Zhang, & Peng, 1990), a lexical decision task, and a priming task (Feldman & Siok, 1997). Only a limited number of studies have examined the awareness of the function of semantic radicals. One was conducted by Cheng and Huang (1995), who used a semantic-relatedness judgment (SRJ) task to assess Taiwan children's knowledge of the function of semantic radicals. The task required participants to identify among three choices the character that was semantically related to the target character. The correct choice was the one that shared the same semantic radical as the target. They tested 71 Chinese children in grades 2-6 and reported that only the sixth graders used the radical as a reference for getting at the meaning of characters in the SRJ task.

Shu and Anderson (1997) assessed 220 Beijing children's semantic radical awareness by presenting them with two-syllable words familiar from oral language. One syllable was written in character and the other was written in Pinyin (an alphabetic system used to write the sounds of Putonghua, the national spoken language in Mainland China). The children were asked to circle a character to replace the Pinyin in each word. The correct character contained a semantic radical consistent with the meaning of the two-syllable word. This task appeared to provide more contextual cues to the participants than Cheng and Huang's (1995) SRJ task. Shu and Anderson found that both third and fifth graders used the semantic radicals to derive meaning of unfamiliar characters and recently learned characters, but the first graders did not. As compared with the findings in Cheng and Huang's study, younger children displayed some awareness of the function of semantic radicals

when given more contextual cues. Shu and Anderson also found that children who were rated as good readers by their teachers displayed more awareness of radicals than children rated as poor readers. However, they based this finding solely on teachers' ratings without actually measuring the children's reading performance.

The age when children appear to have acquired the knowledge of the function of semantic radicals depends very much on how the knowledge is assessed. In a creative writing task, Chan and Nunes (1998) presented six pictures of objects to 60 children. The children were asked to make up a name for each object by creating a new character with two radicals. Six familiar semantic and six familiar phonetic radicals were provided as choices for the six pictures. They found that from age six, some of the children were able to use semantic radicals to represent the meaning of a pseudocharacter. It is noteworthy that the radicals in their study were of very high frequencies. Therefore, some children seem to have acquired the function and meaning of familiar semantic radicals quite early.

Nevertheless, most of the studies cited above did not separate a reader's awareness of the function of radicals from his/her knowledge of the specific sound value or semantic category of radicals. For instance, a child may know by its appearance or position that 成 [sing]4 is the phonetic radical of the character 城 [sing]4. However, this knowledge alone does not help a reader to name the character. Knowledge of the sound value of the phonetic radical is also essential.

In summary, the orthographic, phonological, and morphological regularities of the Chinese writing system are mainly represented in the positional frequencies, functional regularities, and consistencies of radicals in Chinese characters. Some past studies have examined the implicit knowledge of positional regularities of radicals, but explicit or specific knowledge regarding semantic radical position and phonetic radical position is seldom examined. Previous researchers have also failed to examine separately a reader's awareness of the function of radicals and his/her knowledge of the specific sound value or semantic category of the radicals. The development of these various aspects of radical awareness and how they relate to reading development has also yet to be studied systematically. The authors addressed all these issues.

Aims of the Present Studies

Since the radical is an important unit in processing Chinese characters that relates to orthographic, phonological, and morphological regularities, the present studies were designed to examine systematically and comprehensively Chinese children's development of radical knowledge. The aims of the studies were to investigate

(1) whether Chinese children's radical knowledge (both positional and functional) was related to their reading performance, and (2) when children acquired different aspects of radical knowledge. Two studies were conducted in Hong Kong to examine these issues: Study 1 on semantic radical knowledge and Study 2 on phonetic radical knowledge. Although a sentence comprehension test was included in Study 1, these studies focused more on word-level than text-level processing because individual differences in word-level processing skills are a major source of individual differences in text-level processing skills (e.g., Jackson & Coltheart, 2001; Perfetti, 1985; Shankweiler et al., 1999). Hong Kong children, including the participants in the present studies, are taught to read Chinese characters by the whole word approach without much emphasis on the use of the knowledge of radicals. Teachers may teach the meaning of some semantic radicals explicitly but not the sound of phonetic radicals. Students also learn to use semantic radicals to look up characters in a Chinese dictionary from about Grade 3 onwards. However, the role or function of semantic and phonetic radicals is not taught systematically.

Study 1

As reviewed above, Chan and Nunes (1998) and Shu and Anderson (1999) have shown that the knowledge of basic character structure develops quite early in Chinese children. Young children seem to have a rudimentary understanding of the function and meaning of highly familiar semantic radicals as well, especially with contextual cues. However, these studies did not examine explicit knowledge of semantic radical positions, or separate a reader's awareness of the function of radicals from his/her knowledge of the specific semantic category of radicals.

Study 1, therefore, was designed to examine comprehensively Chinese children's development of semantic radical knowledge. Specifically, we looked at when children acquired three aspects of semantic radical knowledge: namely the position (both implicit and explicit knowledge) and function of semantic radicals and the specific semantic categories of different radicals. We also looked at the relationship between the children's semantic radical knowledge and their reading development.

Method

Participants. A total of 60 Chinese children, 20 each in Grade 1 (mean age = 7 years, 2 months, mean IQ = 112), Grade 3 (mean age = 9 years, 2 months, mean IQ = 115), and Grade 5 (mean age = 11 years, mean IQ = 122), were recruited from one government-subsidized ordinary primary school in Hong Kong. Parents of these children responded positively to our invitation letter and consented to allow their children to participate in the study. The kind of reading instruction

they received was typical of that which we described in the last section. There were 10 boys and 10 girls at each grade and all spoke Cantonese. The average IQ of the fifth graders was significantly higher than that of the first graders ($p < .05$ for Tukey HSD).

Materials and Procedures. An IQ test (the *Raven's Standard Progressive Matrices*), two reading tests, and five tasks of semantic radical knowledge (see Appendix A for sample items) were administered to the children. The IQ test was included because IQ was found to correlate significantly with Chinese word reading in previous studies (e.g., Ho & Bryant, 1997b; Huang & Hanley, 1997). We developed all the test materials except for the Raven's test and the Chinese word reading test, which were standardized test materials. Pilot studies were conducted to ensure that the test materials and procedures were appropriate. Apart from the Chinese word reading test that was administered individually, all others were group tests.

The *Raven's Standard Progressive Matrices* (with local norms developed by the Hong Kong Education Department in 1986) was adopted to measure the children's nonverbal reasoning ability and hence to estimate their intelligence. The first graders were given the short form (Sets A to C) and the third and fifth graders were given the full version (Sets A to E). In each item of the test, there was a target visual matrix with one missing part. The children were required to select, from six or eight alternatives, the one that best completed the matrix.

The *Chinese Word Reading Test* (developed and standardized by the Hong Kong Education Department in 1988) was used to measure the children's word reading skills. Materials consisted of 65 Chinese two-character words of primary school levels arranged in ascending order of difficulty. The children were asked to read the words aloud one by one. The task was discontinued when the child failed to read 10 consecutive words.

Three versions, of different difficulty levels, of a Chinese sentence comprehension test of 30 sentences each were constructed. The children at each grade received a version of appropriate difficulty according to their grade level. In each sentence of the task, the children chose, from four alternatives, a character that best completed the sentence. Half of the correct characters had semantically transparent semantic radicals (e.g., the character 吃 "eat" with the semantic radical 口 "mouth") and half had opaque semantic radicals (e.g., the character 增 "increase" with the semantic radical 土 "soil"). Twenty-five Chinese skilled readers judged the degree of semantic transparency of these radicals on a 5-point scale. A score of 1 stood for a radical being totally unable to cue the meaning of a character while a score of 5 meant that the radical was very informative in providing semantic cues of a character. The mean

semantic transparency scores for the transparent and opaque semantic radicals used in this task were 4.2 and 1.9, respectively.

The character decision task measured the children's knowledge of character structure. Test materials included 16 familiar characters, 16 rare characters, 16 pseudo-characters, and 16 noncharacters. Familiar and rare characters were real Chinese compound characters while pseudo and noncharacters were not real characters. Pseudo-characters, which had no real meaning, were novel combinations of semantic and phonetic radicals in their legal positions (e.g, 戳). Noncharacters were created by combining semantic and phonetic radicals in their illegal positions (e.g., 呀). Half of the characters had semantic radicals of high frequencies and the other half had radicals with low frequencies. The children were asked to judge whether a stimulus looked like a real Chinese character.

The radical position judgment task measured the children's explicit knowledge of the position of semantic radicals. Forty semantic radicals, 20 of high frequency and 20 of low frequency, were chosen as stimuli. Of these, half were left-radicals, 20% were right-radicals, 20% were top-radicals, and 10% were bottom-radicals, which approximated the distribution frequency of radical positions. In each item, the children were visually presented with two square boxes, of which one was divided into two halves horizontally and the other vertically (see Appendix A). These boxes represented left-right character structure and top-bottom character structure respectively. The children were asked to indicate the legal position of each semantic radical by pointing to the appropriate half in the boxes (left, right, top, or bottom).

The semantic-relatedness judgment task measured the children's knowledge of the function of semantic radicals that provided semantic cues for a character. Thirty pseudocharacters were constructed as targets to avoid the children knowing the meaning of real characters. Again, the pseudocharacters were novel combinations of semantic and phonetic radicals in their legal positions. Like the procedures in Cheng and Huang's (1995) study, in each item the children selected, from three alternatives, a character that might relate semantically to the target "funny" character. The three choice-characters were: common semantic radical character (sharing same semantic radical as the target), common phonetic radical character (sharing same phonetic radical as the target), and control character (having nothing in common with the target). The common semantic radical character was the correct answer. For instance, if the target pseudocharacter was 猶, the three choice-characters might be 狗 (common semantic radical character), 植 (common phonetic radical character), and 功 (control character). 狗 was considered semantically related to the target pseudocharacter.

The semantic category judgment task measured how well the children knew the semantic category conveyed by specific semantic radicals. Forty semantic radicals, 20 lexical (radicals themselves were simple characters) and 20 non lexical (radicals of bound forms) were chosen as stimuli. In each item, the children were asked to select, from four picture alternatives, the one that represented the meaning or semantic category of the radical. For instance, when given the semantic radical "clothing" 衤 (an example of a bound form radical), the children should choose the picture of clothes to indicate the meaning of the target radical.

The Chinese pseudocharacter meaning judgment task measured the children's overall knowledge of the position, function, and semantic category of semantic radicals. Forty pseudocharacters with lexical or nonlexical semantic radicals were presented to the children. They needed to select, from four alternatives, a picture that might represent the meaning of these "funny" characters.

Results and Discussion

Table 1 presents the mean scores and standard deviations of the tasks given in Study 1. All the tasks had good internal reliability (all reliability coefficients > .80). Figure 1 shows the percentages of character-like responses for the four types of characters in the Character decision task. A two-way (grade x type of character) analysis of variance (ANOVA) was conducted. The two main effects and the interaction effect were all significant (all $Fs > 2.6$, all $ps < .05$). Post-hoc comparisons by the Tukey HSD showed that children at the three grade levels did not differ significantly among themselves in their judgement of frequent characters as character-like or noncharacters as not character-like. Significantly more fifth graders judged rare characters and pseudocharacters as character-like than the first graders. More fifth graders also judged pseudocharacters as character-like than the third graders but the difference was only marginally significant. Similar to Cheng and Huang's (1995) findings, majority of the first graders judged frequent characters as character-like (97%) and noncharacters as illegal (94%) like the third and fifth graders. The first and third graders judged pseudocharacters as real characters at about chance level (54% and 57% respectively) and the percentage increased to 72% at Grade 5 which was significantly different from chance level [$t(19) = 3.88$, $p = .001$]. Judgment of the rare characters also improved with grade level. These findings suggest that even first graders had gained some knowledge of character structure and the children's knowledge improved as they advanced in grades.

Apart from the first-graders' score on semantic-relatedness judgment, scores on all other tasks that involved force-choice responses were significantly different from chance (all $ts > 5.2$, all $ps < .001$). In other words, it was not until Grade 3 that the children began to understand that the semantic radical was for semantic function.

The children seemed to acquire semantic radical positional knowledge earlier than its function.

Table 1. Mean Scores, Standard Deviations, and Spearman-Brown Reliability Coefficients of the Tasks Given in Study 1

Task	Max. possible score	Mean	*SD*	Reliability coefficient
Chinese word reading	65			.97
Grade 1		45.9	8.3	
Grade 3		63.2	2.0	
Grade 5		64.1	1.0	
Chinese sentence comprehension	30			.90
Grade 1		21.2	5.8	
Grade 3		28.0	2.1	
Grade 5		28.6	0.8	
Character decision	64			.89
Grade 1		49.5	2.8	
Grade 3		52.2	3.7	
Grade 5		51.0	3.4	
Radical position judgment	40			.95
Grade 1		29.9	10.9	
Grade 3		38.7	1.5	
Grade 5		38.9	1.1	
Semantic-relatedness judgment	30			.95
Grade 1		12.6	5.8	
Grade 3		17.4	6.3	
Grade 5		20.1	6.4	
Semantic category judgment	40			.81
Grade 1		34.0	2.5	
Grade 3		37.5	1.7	
Grade 5		39.3	1.0	
Chinese pseudocharacter meaning judgment	40			.95
Grade 1		27.9	6.5	
Grade 3		36.8	3.3	
Grade 5		39.4	0.8	

In both the semantic category judgment task and the pseudocharacter meaning judgment task the children at all the grade levels judged the semantic category of the lexical radicals better than the nonlexical ones (all $ts > 3.23$; all $ps < .01$).

In other words, when the semantic radicals were also standalone characters, the children might have relied on the meaning of the character to infer the semantic category of the radical, and hence lexical radicals produced better semantic cues than non-lexical ones.

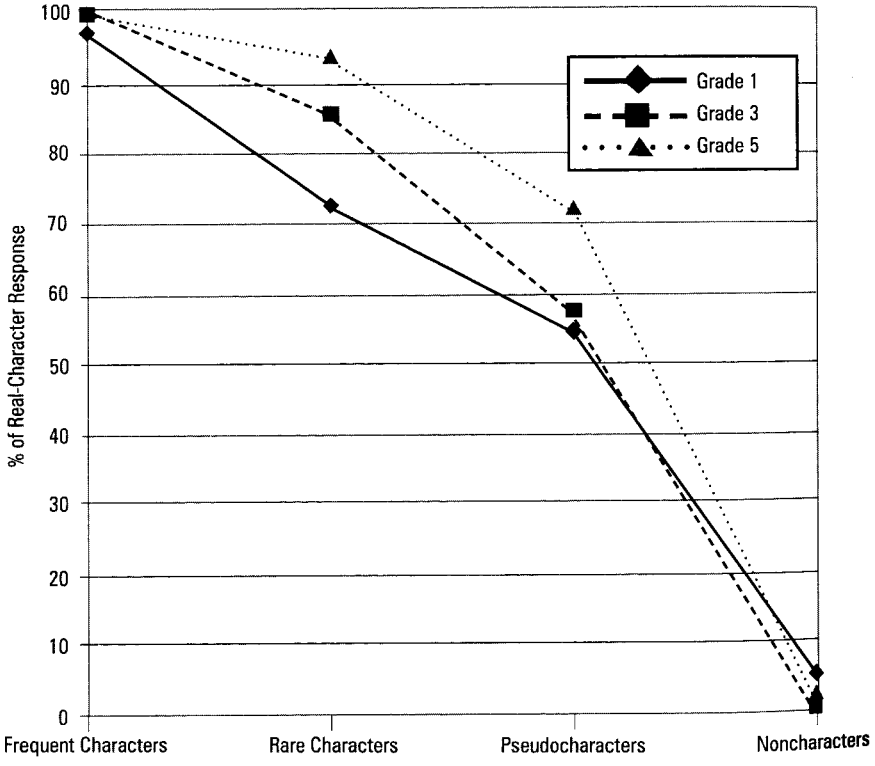

Figure 1. Percentages of character-like responses for the four types of characters in the character decision task in Study 1.

Regarding the semantic transparency of the choice characters' semantic radicals in the Chinese sentence comprehension task, first graders (transparent: 10.5, opaque: 10.8) and third graders (transparent: 14.2, opaque: 13.8) performed similarly on the transparent radical items and the opaque radical items. However, the fifth graders performed significantly better on the transparent items than the opaque ones [transparent: 14.7, opaque: 13.9, $t\,(19) = 3.56, p < .01$]. This suggests that the fifth graders relied on the semantic radicals of target characters for meaning cues in processing a sentence.

Correlation coefficients were calculated to examine the importance of various types of semantic radical knowledge for Chinese word reading and sentence

comprehension. Table 2 presents a matrix of partial correlation coefficients among the various measures after controlling for the effects of age and IQ. It was found that character decision, semantic category judgment, and pseudocharacter meaning judgment correlated significantly with both Chinese word reading and sentence comprehension (all $rs > .25$, all $ps < .05$). Radical position judgment correlated significantly with Chinese word reading only ($r = .43, p < .01$). These findings suggest that semantic radical knowledge, including character structure, radical position and semantic category, is important in reading Chinese. The semantic radical knowledge is more important for reading at word level than sentential level even when the word level reading task does not explicitly require semantic processing. Comprehending sentences may require some general and linguistic knowledge other than character-level knowledge.

Table 2. Matrix of Partial Correlation Coefficients between Reading Tasks, Pseudocharacter Meaning Judgment and Various Radical Knowledge Tasks after Controlling for the Effects of Age and IQ (Study 1)

	Word reading	Sentence comprehension	Pseudocharacter meaning judgment
Character decision	.37**	.26*	.14
Radical position judgment	.43**	.15	.09
Semantic-relatedness judgment	10	-.05	.07
Semantic category judgment	.41**	31*	.42***
Pseudo-character meaning judgment	.54***	.37**	—

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

Pseudo-character meaning judgment was found to correlate significantly only with Semantic category judgment ($r = .42, p < .001$). Hence, it appears to be largely a measure of the knowledge of the semantic category of radicals. It associated more strongly with the reading measures than all other radical knowledge tasks did.

The semantic-relatedness judgement failed to correlate significantly with any of the reading or meaning judgment measures. This finding might be partly due to the fact that the first graders did not score significantly above chance level in this task. In addition, the finding may also suggest that knowledge of the function of semantic radicals may be less important than knowledge of their semantic categories in reading Chinese words and sentences.

Study 2

Study 2 was designed to examine Chinese children's development of phonetic radical knowledge. Although information about pronunciation is represented less

systematically in Chinese than in other orthographies, various studies have shown that children do rely on phonetic radicals for sound cues, even sometimes when phonetic radicals only provide partial information to pronunciation (e.g., Anderson et al., 2003). As in Study 1, we looked at when children acquired three aspects of the phonetic radical knowledge (the position, function and sound value of phonetic radicals) and the relationship between phonetic radical knowledge and children's reading development.

Method

Participants. A total of 60 Chinese children, 20 each in Grade 1 (mean age = 7 years, 2 months, mean IQ = 106), Grade 3 (mean age = 9 years, mean IQ = 114), and Grade 5 (mean age = 11 years, 2 months, mean IQ = 111), were recruited from another government-subsidized ordinary primary school in Hong Kong. Again parents of these children consented to allow their children to participate in the study. The kind of reading instruction they received was similar to that which we described in the introduction of this paper. There were 10 boys and 10 girls at each grade and all were Cantonese-speaking. They were not required to have participated in Study 1 because it would have taken them too long to go through both studies.

Materials and Procedures. An IQ test (*Raven's Standard Progressive Matrices*), a *Chinese Word Reading Test*, and five phonetic radical knowledge tasks (see Appendix B for some sample items) were administered to the children. Apart from the IQ test which was a group test, all other tests were administered to the children individually. The IQ test and the word reading test were the same as those used in Study 1. Again all the test materials were developed by the authors except for the Raven's test and the *Chinese Word Reading Test*. Pilot studies were conducted to ensure that the test materials and procedures were appropriately developed and designed.

The character decision task was similar to the character decision task in Study 1. It measured the children's knowledge of character structure. Test materials included 24 familiar characters, 24 rare characters, 24 pseudocharacters, and 24 nonchar-acters. Half of the characters had phonetic radicals with high frequencies and the other half had radicals with low frequencies. Again, the children were asked to judge whether a stimulus looked like a real Chinese character.

The radical position judgment task, as in Study 1, measured the children's explicit knowledge of the position of phonetic radicals. Twenty phonetic radicals, 10 of

high frequency and the other 10 of low frequency, were chosen as stimuli. For each item, the children were visually presented with two square boxes, of which one was divided into two halves horizontally and the other vertically. These boxes represented left-right character structure and top-bottom character structure respectively. The children were asked to indicate the legal position of each phonetic radical by pointing to the appropriate half in the boxes (left, right, top, or bottom).

The phonological-relatedness judgment task measured the children's knowledge of the function of phonetic radicals and the use of analogy strategy. Twenty pseudocharacters were constructed as targets to avoid the children knowing the sound of the characters. Again, each pseudocharacter was created by combining a semantic and a phonetic radical in their legal positions. Like the procedures of semantic-relatedness judgment task in Study 1, in each item the child was asked to select from three alternatives a character that might have the same pronunciation as the target "funny" character. The three choice characters were common phonetic radical character, common semantic radical character, and control character. The common phonetic radical character was the correct answer.

The Chinese phonetic radical naming task measured how well the children knew the sound value of common phonetic radicals. Twenty-two phonetic radicals, half lexical and half nonlexical, were chosen as stimuli. Lexical radicals were themselves simple characters (e.g., the phonetic radical of [fan]1 分) and nonlexical radicals were bound forms (e.g., the phonetic radical of 艮). For each item, the children were asked to name the phonetic radical. The correct response was either the name of the radical as a standalone character or the pronunciation of a character containing the radical.

The Chinese pseudocharacter naming task measured the children's overall knowledge of the position, function, and sound value of phonetic radicals, and the use of both direct derivation and analogy strategies. Twenty-five pseudocharacters were presented to the children. They were asked to guess the pronunciation of these "funny" characters. The phonetic radicals of these pseudo-characters were selected from some phonologically regular and consistent characters that were within the children's reading vocabulary. A pseudocharacter was considered to be correctly read if it was pronounced by the name of its phonetic radical or a character having the same phonetic radical as the pseudocharacter.

Results and Discussion

Table 3 presents the mean scores and standard deviations of the tasks given in Study 2. The internal reliability of the various tasks ranged from satisfactory (Chinese phonetic radical naming, reliability coefficient = .69) to very good (Chinese word reading, reliability coefficient = .99). The first and third graders in this study performed somewhat less well than those in Study 1 in the same Chinese word reading test. This difference in performance may be due to the fact that the first graders in the study had lower average IQ than those in Study 1 (106 vs. 112), and the third graders in this study were on average younger than those in Study 1 (9 years vs. 9 years 2 months).

Scores on all tasks that involved force-choice responses (i.e., character decision, radical position judgment, and phonological-relatedness judgment) were significantly different from chance (all $ts > 2.5$, all $ps < .05$). We also found that the children at the three grade levels all named lexical phonetic radicals significantly better than nonlexical ones (all $ts > 4.4$; all $ps < .001$).

A two-way (grade x type of character) ANOVA was conducted on the character decision task. The two main effects and the interaction effect were all significant (all $Fs > 4.2$, all $ps < .01$). Tukey HSD post-hoc comparisons showed a similar pattern of differences as in Study 1 that children at the three grade levels did not differ significantly among themselves in their judgement of frequent characters as character-like or noncharacters as not character-like. Significantly more fifth graders judged rare characters and pseudocharacters as character-like than did the first graders. These findings also suggested that the first graders had gained some knowledge of character structure and the children's knowledge improved as they advanced in grades.

Correlation coefficients were calculated to examine the importance of various types of phonetic radical knowledge for Chinese word reading. Table 4 presents a matrix of partial correlation coefficients among the various measures after controlling for the effects of age and IQ. Character decision, phonological-relatedness judgment, and Chinese phonetic radical naming (lexical items) correlated significantly with both Chinese word reading and pseudocharacter naming (all $rs > .31$; all $ps < .05$). These findings suggest that phonetic radical knowledge, including character structure, the function and sound value of phonetic radicals, is important in reading familiar and "novel" Chinese characters. The Chinese pseudocharacter naming task, being most strongly correlated with Chinese word reading ($r = .70$, $p < .001$), appears to be a good measure of children's overall knowledge of phonetic radicals.

Table 3. Mean Scores, Standard Deviations, and Spearman-Brown Reliability Coefficients of the Tasks Given in Study 2

Task	Max. possible score	Mean	*SD*	Reliability coefficient
Chinese word reading	65			.99
Grade 1		27.9	7.5	
Grade 3		55.0	10.1	
Grade 5		62.2	5.2	
Character decision	96			.92
Grade 1		73.1	6.1	
Grade 3		83.4	5.4	
Grade 5		80.1	7.0	
Radical position judgment	20			.89
Grade 1		12.6	4.5	
Grade 3		15.7	3.9	
Grade 5		16.4	3.9	
Phonological-relatedness judgment	20			.77
Grade 1		12.5	4.5	
Grade 3		15.0	2.9	
Grade 5		14.5	3.2	
Chinese phonetic radical naming	22			.69
Grade 1		16.6	2.6	
Grade 3		18.0	3.2	
Grade 5		18.9	2.5	
Chinese pseudocharacter naming	25			.93
Grade 1		10.6	3.9	
Grade 3		20.7	3.5	
Grade 5		21.7	3.2	

Table 4. Matrix of Partial Correlation Coefficients between the Reading Task and Various Radical Knowledge Tasks after Controlling for the Effects of Age and IQ (Study 2)

	Word reading	Pseudocharacter naming
Character decision	.63***	.57***
Radical position judgment	.10	-.04
Phonological-relatedness judgment	.32*	.33*
Chinese phonetic radical naming – lexical	.51***	.44**
– nonlexical	.14	.09
Chinese pseudocharacter naming	.70***	—

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

General Discussion

To the best of our knowledge, these studies are the first to examine systematically and comprehensively Chinese children's development of radical knowledge. Findings show that radical knowledge is important for children learning to read Chinese. Various measures of semantic radical knowledge, including the position and semantic category of semantic radicals, correlated significantly with Chinese word reading and sentence comprehension in Study 1. Similarly, various measures of phonetic radical knowledge, including the function and sound value of phonetic radicals, correlated significantly with Chinese word reading in Study 2.

Since radical knowledge is important for children learning to read Chinese, a comprehensive single measure of radical knowledge is essential. To meet this end, the authors devised two original tasks, the pseudocharacter meaning judgment task in Study 1 and the Chinese pseudocharacter naming task in Study 2, which were demonstrated empirically as good composite measures of children's knowledge of semantic radicals and phonetic radicals respectively. The two tasks had good internal reliability (all reliability coefficients > .92), and they correlated significantly with reading measures (all $rs > .31$; all $ps < .01$). Findings also show that children's development of radical knowledge progresses from positional regularities to functional regularities.

The Role of Radicals in Learning to Read Chinese

The Positional Regularity of Radicals. Many researchers have suggested that the knowledge of orthographic regularity is important in reading (e.g., Barker et al., 1992; Berninger, 1994; Corcos & Willows, 1993; Venezky & Massaro, 1979).

Although past studies (e.g., Chan & Nunes, 1998; Cheng & Huang, 1995; Shu & Anderson, 1999) have shown that Chinese children possess some knowledge of character structure and positional regularity, these studies are the first to report a reliable association between the knowledge of positional regularity and measured reading performance in Chinese children. These findings show that knowledge of character structure and position of semantic radicals (but not of the position of phonetic radicals) is important for children learning to read Chinese words. As compared with phonetic radicals, semantic radicals have much greater positional regularities. The position of a semantic radical often provides more information than that of a phonetic radical about its identity (i.e., whether it is a semantic or a phonetic radical); this helps a reader to retrieve the information of radicals necessary for character recognition. For instance, a better knowledge of positional regularity may increase a reader's awareness that most left radicals serve the semantic function and right radicals serve the phonological function in characters of left-right structure.

Overall, the knowledge of the positional regularity of semantic radicals seems to be more important for reading at the character/word level than at the sentential level (radical position judgment correlated much more strongly with word reading than with sentence comprehension, as shown in Table 2). Reading and comprehending sentences require some general and linguistic knowledge other than character-level knowledge.

The Functional Regularity of Radicals. Ho and Bryant (1997a) and Yang and Peng (1997) have reported that Chinese children make use of the phonetic radical for phonological cues in naming Chinese characters. Similarly, our findings show that a reader's knowledge of the phonological function of radicals, but not of the semantic function, is important for naming Chinese words. In other words, knowing that the phonetic radical can provide phonological cues helps a reader to name a Chinese character by direct derivation or by analogy, but knowing that the semantic radical can provide semantic cues does not. For instance, in the character 城 [sing]4, the phonetic radical 成 [sing]4 helps a reader to name the character but the semantic radical 土 "soil" does not.

Shu and Anderson (1999) have suggested that morphological awareness (e.g., knowing the function of semantic radicals) is important for learning to read in Chinese. Although knowledge of the function of semantic radicals did not correlate significantly with Chinese word reading or sentence comprehension in Study 1, there were signs showing that the older children did make use of the semantic cues of radicals in understanding Chinese text. As mentioned in the introduction of

this paper, there are different degrees of transparency for the semantic implication of different semantic radicals. Some semantic radicals are relatively transparent and some are relatively opaque. In the Chinese sentence comprehension task in Study 1, only the fifth graders performed significantly better on items with transparent semantic radicals than those with opaque ones. This result suggests that from about Grade 5 children tend to rely on the semantic radicals of Chinese characters for meaning cues in processing a sentence. The use of semantic radicals for meaning cues at the character level may appear earlier. We suggest that the utilization of semantic cues of radicals at the sentential level may require the understanding and interpretation of relatively complicated semantic and syntactic context and how these relate to individual semantic radicals. The fulfillment of these requirements may be beyond the ability of lower primary school children.

Knowledge of the Specific Information of Radicals. After knowing which is the semantic or phonetic radical in a Chinese character and its corresponding function, a reader needs to know the semantic category or sound value conveyed by the radical in order to help him or her in reading. There have been very few studies on the impact of the knowledge about the specific information of radicals on reading.

In Study 1, knowledge of the semantic category of radicals was found to correlate significantly with Chinese word reading and sentence comprehension, and knowledge of the sound value of phonetic radicals was found to correlate significantly with Chinese word reading in Study 2. In both the semantic category judgment task in Study 1 and the Chinese phonetic radical naming task in Study 2, the children at all the grade levels did better on items with lexical radicals than those with nonlexical ones. It is not surprising that by referring to its information as a stand alone character, the lexicality of a radical affects how well a reader retrieves the sound or meaning of a radical.

As mentioned above, children may directly derive the sound of a Chinese character from the sound of its phonetic radical. That is why knowing the sound value of phonetic radicals helps children in naming Chinese characters and words. The semantic cues provided by semantic radicals may activate semantically compatible candidates which may also help in the naming process.

Single Measures of the Knowledge of Radicals

From the preceding discussion, we can conclude that radical is an important processing unit for children in the recognition of Chinese characters. The next question we ask is what would be a good measure for testing this knowledge. The pseudocharacter meaning judgment task in Study 1 was intended to be a composite measure of different semantic radical knowledge including that of position,

function, and specific semantic category. Since this score correlated most strongly with Chinese word reading and highly with sentence comprehension among various semantic radical knowledge measures, it might be considered as one of the best single measures of children's knowledge of semantic radicals.

Similarly, the Chinese pseudocharacter naming task was intended to be a composite measure of different phonetic radical knowledge including position, function, and sound value. The score of this task was found to correlate most strongly with Chinese word reading in Study 2. Thus, this test may be a good single measure of children's knowledge of phonetic radicals.

The Development of Radical Knowledge

Chinese children seem to acquire some rudimentary knowledge of character structure quite early. Most of the first graders judged noncharacters as illegal and frequent characters as legal. However, our finding that only about half of the first graders judged pseudocharacters as legal suggest that their knowledge about positional regularity and character structure was not well developed.

Based on the results of Study 2, it seems that even first graders have acquired some knowledge of the position, function, and sound value of phonetic radicals, and this knowledge improves as they advance in grades. Similarly, Chinese first graders have acquired some knowledge about the position and semantic category of semantic radicals, but they have little idea that semantic radicals serve semantic function. It was not until Grade 3 that the children understand that they can rely on the semantic radical for meaning cues. Moreover, children's semantic radical knowledge was better for semantically transparent, lexical radicals than opaque, non lexical ones. The need for children taking a number of years to understand and use the phonological and semantic regularities in Chinese may be partially accounted for by Shu et al.'s (2003) findings that characters introduced in lower grades are less regular or transparent than characters in higher grades.

Shu et al. (2003) have also suggested that it takes a long time for children to develop phonetic consistency awareness. However, our findings show that even the first graders have a fair level of phonetic consistency awareness (with 63% correct in the phonological-relatedness judgment task). This consistency awareness also develops gradually when children advance in grades (with 73% correct in the task for the fifth graders).

It follows from the above discussion that developmentally, Chinese children seem to learn to read Chinese characters from a visual and arbitrary to an analytic and rule-based pattern, similar to the trend of reading acquisition in alphabetic

languages (e.g., Frith, 1985; Gough, Juel, & Griffith, 1992). Chinese children first develop knowledge in character structure and radical positions. This visually related knowledge does not help children to read novel characters; they may rely on rote memory in learning characters. When they find these strategies inefficient, they start to use some rule-based strategies, like the grapheme-phoneme conversion rules in English and the phonetic principle in Chinese. Learning the function and regularities of phonetic and semantic radicals help children read and understand novel characters and remember more words efficiently. In line with these suggestions, Ho, Yau, and Au (in press) have developed a model of radical knowledge development in Chinese.

Educational Implications

Consistent with some recent research findings (e.g., Ho & Bryant, 1997b; Ho, Wong & Chan, 1999; Shu & Anderson, 1997), our findings confirm that the radical is an important orthographic unit in processing Chinese characters for children. Although instruction was not studied directly, these findings may have implications for Chinese reading instruction. Traditionally, Chinese teachers in Hong Kong have emphasized drilling and rote memorization in teaching children to learn to read Chinese. They normally employ a "whole-character approach," often paying little attention to intracharacter orthographic units, especially the phonetic radical, in enhancing reading. Semantic radicals are mainly taught as a reference unit for looking up characters in a Chinese dictionary. This "whole-character approach" is useful in teaching integrated Chinese characters and irregular/inconsistent characters. However, teaching children the orthographic, phonological and semantic regularities of Chinese characters at an early stage may enhance their character decoding skills (especially those of compound characters) and reading comprehension. Based on the present findings, we suggest that positional regularities of semantic and phonetic radicals be taught explicitly to children in the first grade. Functional regularities of radicals should be introduced later, around second and third grade. The sound of individual phonetic radicals and the semantic category of individual semantic radicals should also be taught gradually from first grade.

In Mainland China, a relatively new character teaching method called "concentrated character learning method" (集中識字法) is becoming popular (Tian, 1987). In this method, characters with the same semantic radicals or phonetic radicals are taught together. Children also read specially written passages containing many characters with same target radicals. In this way, it is easy for children to pick up the regularities of the script.

Limitations and Suggestions for Future Research

Since the present studies are cross-sectional and the sample sizes are relatively small, we cannot provide a precise answer to the question regarding the development of various types of radical knowledge. This will await more thorough examination through longitudinal studies with larger sample sizes. A follow-up study of instruction of radicals would also be educationally meaningful.

In conclusion, our findings show that developmentally children start acquiring the knowledge of character structure, the position, semantic category, and sound value of Chinese radicals from about Grade 1. However, they do not understand the function of semantic radicals until Grade 3. These aspects of radical knowledge also associate strongly with Chinese word reading and sentence comprehension. On the basis of these findings, we suggest that radicals are an important orthographic processing unit in reading development in Chinese, and their positional and functional regularities should be taught explicitly in school to enhance children's character decoding skills.

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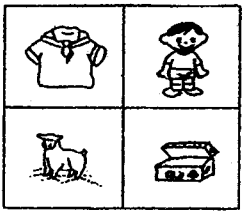
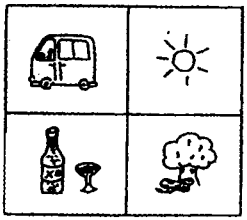
Footnote

[1] All pronunciation notes for Chinese characters in this paper are Cantonese pronunciations. For instance, in the syllable [dang]1, /d/ is the onset, /ang/ is the rime, and "1" means that the syllable is in the first tone, i.e., a high level tone.

Appendix A

Sample Items of the Semantic Radical Knowledge Tasks in Study 1

Task	Example
Character decision	Frequent character: 船 Rare character: 戮 Pseudocharacter: 淢 Noncharacter: 嘆
Radical position judgement	亻 1 2 3 4
Semantic-relatedness judgement *(The correct answer was the common semantic radical character)*	Target character: 獒 Common semantic radical character: 狗 Common phonetic radical character: 植 Control character: 功
Semantic-category judgement	衤 
Chinese pseudocharacter meaning judgement	酢 

Appendix B

Sample Items of the Phonetic Radical Knowledge Tasks in Study 2

Task	Example
Character decision	Frequent character: 船
	Rare character: 戮
	Pseudocharacter 泯
	Noncharacter: 嘆
Radical position judgment	哥 1 2 3 4
Phonological-relatedness judgment *(The correct answer was the common phonetic radical character)*	Target character: 猶 Common semantic radical character: 狗 Common phonetic radical character: 植 Control character: 功
Chinese phonetic radical naming	僉
Chinese pseudocharacter naming	覷