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The role of phonological consistency and family size of phonetic radicals in reading Chinese

characters in school-aged children in Hong Kong

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Abstract

One hundred students from the 3rd and 4th grades were tested on naming low-frequency Chinese phonetic compounds to investigate the individual and combined effects of phonological consistency and family size on reading performance. Consistency effect on naming Chinese characters in developing readers was investigated in previous studies (Tzeng et al., 1995; Yang and Peng, 1997) which used a definition of consistency which accounted for consistency in regular characters with no control over the family size of stimuli. In the present study, consistency of a phonetic radical was defined as one over the number of different phonological realizations of characters containing the phonetic radical (regardless of tonal discrepancy); family size of a phonetic radical was defined as the number of characters that are formed by the same phonetic radical. Significant main effects of phonological consistency, family size and regularity in Chinese characters naming were found. Readers at the 3rd grade can start to use the knowledge of phonological consistency and regularity and awareness on family size has already been developed. Interaction effect between the three factors was significant. It is noted that phonological consistency only affects reading on characters with a large family size while regularity will then override consistency effect and become the main determining factor in reading characters with small family size. The results reveal the independent role of family size in determining reading strategies and the relations between orthographic processing and phonological processing in naming.

Introduction

The nature of written Chinese is very different from that of the alphabetic scripts and theories about reading in an alphabetic script cannot be applied to written Chinese directly. Written Chinese is logographic in nature (Fang, Horng and Tzeng, 1986; Chen, 1996; Ko & Tsang, 2000). Instead of a small set of letters/alphabets as in an alphabetic script, monosyllabic characters were considered as the building blocks of written Chinese (Chen, 1996). There are six

categories of Chinese characters (the "六書"), including pictograph of objects, denotation of events, ideograph, phonetic compound, figurative extension of meaning and phonetic loan(Chen, 1996, pp.44). Among all Chinese characters, it was estimated that around 80% are phonetic compounds (Hoosain, 1991; Chen, 1996; Tzeng, et al., 1995). A phonetic compound (e.g. "枝", /dzi1/, meaning branches) is composed of a semantic radical ("木" on the left, meaning wood or trees) which provides the meaning of the character and a phonetic radical ("支" /dzi1/ on the right) which provides information about the pronunciation of the character. Since most Chinese characters are phonetic compounds which are the only type of Chinese characters that provides information about the pronunciations of the characters, Seidenberg, (1985); Fang et al, (1986); Hue, (1992); Tzeng et al., (1995) and Yang and Peng, (1997) investigated the phonological and orthographical processing of reading Chinese characters by analyzing the reading performance of different phonetic compounds in both skilled and developing readers. Seidenberg (1995) and Fang et al., (1986) introduced regularity and consistency effects in phonetic naming task to explain how phonology was accessed in reading Chinese orthography.

Regularity effect is shown when regular phonetic compounds which sound the same as their phonetic radicals, regardless of tonal discrepancy (Fang et al., 1986), are read better than irregular phonetic compounds whose pronunciations are different from their phonetic radicals. Regular characters are easier to process because they have regular encoding of phonology while in irregular characters mapping between orthography and phonological codes is more arbitrary (Tzeng et al., 1995). Fang et al. (1986), Hue (1992), Yang and Peng (1997), obtained significant regularity effect through pseudo-character and real-characters naming tasks. Fang et al., (1986) explained the results by suggesting that Chinese readers would tend to read aloud one of the components of the phonetic compounds (which would most likely be the phonetic radicals) in naming novel Chinese characters. This tendency of regularizing pronunciations of targets was

referred by Tzeng et al. (1995) as the use of knowledge of orthography-phonology correspondences (OPC) rules in naming Chinese characters.

The presence of regularity effect was used as the evidence of employing the reading strategy of reading the phonetic radicals directly. Another possible way, which used analogy to present lexical representations, to access phonology in reading Chinese scripts was also proposed (Tzeng et al., 1995). It is believed that by studying the effect of phonological consistency of phonetic radicals in reading performance, more can be found about the use of phonological information of existing lexical representations in reading Chinese characters.

Consistency effect in reading Chinese for both skilled readers and children was addressed in various studies (Fang et al., 1986; Hue 1992; Tzeng et al., 1995 and Yang & Peng, 1997). Tzeng et al. (1995) investigated the effect of phonological consistency in pseudo-characters naming in Mandarin-Chinese in elementary school readers while the definition of consistency value was based on regularity and numbers of neighbors of the phonetic radicals used to construct the pseudo-characters. They adopted the definition of "consistency value" from Fang et al.'s study, which stated that "the consistency measure is defined as the relative size of a phonological group within a given activation region" (Fang et al, 1986, pp 13). The consistency value of a particular character was defined as the ratio of the number of characters having the same phonetic radical sharing the same pronunciation (disregarding tonal discrepancy) to the size of the whole neighborhood; that is, all characters having the same phonetic radical, including the phonetic radical itself as a character. For example, the consistency value for "由" was 0.42 (5/12) as there were 5 characters containing this phonetic radical that had similar pronunciation of /you/ (in Mandarin) out of 12 characters (they are "由", "油", "柚", "鈾", "釉", "迪", "笛", "軸", "宙", "抽", "袖", "岫") sharing the phonetic radical "由", including "由" itself. Tzeng et al.(1995) found consistency effect in pseudo-characters and simple characters naming latencies in both the 3rd and 6th graders and suggested that OPC knowledge was used by the young readers

to decode real characters and pseudo-characters. Consistency effect in real-character naming latencies in Mandarin-Chinese developing readers was investigated by Yang and Peng (1997). In their study, consistency was defined as "sound similarity of ALL the phonograms containing the phonetics and the phonetic radical itself" (Yang & Peng, 1997, p.323). Four types of characters were generated and these were "Consistent phonograms", "Inconsistent phonograms", "Exception phonograms" and "Non-phonograms". They found that both the 3rd and 6th graders read consistent phonograms significantly faster than inconsistent and exception phonograms and they believed that the influence of the phonetic radicals and neighbors on Chinese characters naming changed with the development of reading skills. Although both studies mentioned above showed significant consistency effects in reading performance of developing readers, questions were raised about the definitions of phonological consistency and methodologies of the studies.

First of all, Tzeng et al. (1995) adopted the calculation of consistency value proposed by Fang et al. (1986). When they were measuring the sound consistency of the phonetic radicals, the calculation of the consistency value was largely affected by regularity of neighbors and phonetic radicals' family size. This definition of consistency deviated from that proposed by other researchers both in Western and Chinese literatures. In Western literature, phonological consistency was defined as the extent a letter string in one word was pronounced equally in other words (Martensen, Maris & Dijkstra, 2000) or simply the sound consistency of a grapheme (Seidenberg, 1985). In Chinese literature, Chen (1996) stated that sound consistency of a phonetic radical should represent how consistent the phonetic radical in suggesting similar pronunciation across characters that contained this phonetic radical. All of these definitions showed that the determination of the phonological consistency of written units (either letter strings or phonetic radicals) should not be affected by regularity nor family size. For example, the phonetic radical "責"(/dzat3/ in Cantonese), is considered as being consistent and irregular because it suggests the same pronunciation /dzik1/ in its family members, i.e. "漬", "績", "積",

"嘖"and "蹟" (assuming that this child has only learnt these characters with the phonetic radical "責"), and all the family members sound different from the phonetic radical. However, in Tzeng et al's study's, there were only three main types of phonetic radicals, Regular/Consistent, Regular/Inconsistent and Irregular/Inconsistent but not Irregular/Consistent. In this case, all irregular characters were considered as inconsistent. Using Tzeng et al.'s definition, the phonetic radical "責" will then be considered as an inconsistent phonetic radical as all compound characters it formed are irregular characters, even all these compound characters sound similarly. As a result, without comparing the effects of Irregular/Consistent and Irregular/Inconsistent phonetic radicals and consistency effect in naming irregular characters was not investigated. A similar problem was found in Yang and Peng's (1997) study which used the same definition of consistency as Fang et al.(1986), and Tzeng et al.(1995). As defined in Yang and Peng's study, "Consistent phonograms" and "Exception phonograms" must be regular and irregular respectively whereas "Inconsistent phonograms" were those whose sounds were similar with those of their major neighbors, that is most of the family members, but there were still some exceptions in the families" (Yang and Peng, 1997, p333). Since there was only one example from each character type, one could not tell the regularity of these "Inconsistent phonograms" with this definition. And if regularity of "Inconsistent phonograms" of the stimuli were not controlled, consistency effect found might be confounded by regularity effect and once again, consistency effect in irregular characters was not addressed.

On top of regularity, another important factor would be family size. In the consistency measure used in Fang et al.'s study (1986), family size of a particular phonetic radical was incorporated in the calculation of the consistency value, rather than a separate factor. In fact, family size, which was the numbers of words that are formed by changing one letter of the target word (Coltheart, Davelaar, Jonasson, & Besner, D. ,1977), was found to be another contributing factor affecting reading performance per se (e.g. Andrews, 1992; Pollatsek et al, 1999). Andrews

(1992) found that naming latencies for low frequency words would be facilitated by a large family size in adults. Laxon, Coltheart and Keating(1988) also found that children made fewer errors in naming words and non-words with many neighbors than in naming words that had no close neighbors. There were relatively few studies addressing the effects of family size (neighborhood size) on reading Chinese. Hong & Yelland (1997) studied the effects of family size in different construction levels on masked-priming lexical decision in skilled readers. They found that family size which stated the number of characters that could be created by changing only a single stroke had significant effect on masked-priming lexical decision in adult population. These results indicate that family size is actually an important factor that would affect reading performance and that reading written units with large or small family size can result in major discrepancy in reading performance. If family size does have an effect on reading performance, and as Tzeng et al.'s (1995) definition of consistency was largely affected by family size of the phonetic radicals, results on consistency effect would be confounded by family size effect. Despite the fact that numbers of neighbors were controlled within each grade of subjects in Yang and Peng's (1997) study, as stated in their appendix, the numbers of friends/enemies of the stimuli tended to be smaller for the younger subjects (the 3rd graders) while the figures were larger with the elder subjects(the 6th graders).

In the present study, it is believed that phonological consistency, regularity and family size should be considered as three separate factors that affect reading performance independently and there might be interaction between these factors. Main effects of individual factor indicate how each of the factors affect reading performance generally. More importantly, a clearer picture about phonological and orthographical processing of Chinese script can be shown by investigating the effects of individual factor on each level of another factor. The hypothesis that the three factors should be considered separately in assessing their effects on reading performance can be exemplified if main effects of consistency, family size and regularity are found and interactions between these three factors and change of these interactions across grades

would give us a better understanding the way these factors affect our reading and reading development. It was of particular interest the effects on children reading since reading performance of developing readers can provide valuable information about the emergence and acquisition of different reading strategies in Chinese script, by identifying the development trends of different factors that affect reading performance. This has important educational implication on introducing reading strategies to both normal developing children and those with defected reading ability, so as to help them to develop as a more skillful reader.

One methodological problem was that, the use of the same set of pseudo-characters in the naming task for both grades of subjects in Tzeng et al's study (1995) could lead to faulty relative frequency count. Since older subjects have more exposure to more characters than the younger subjects, one character that might be high frequency for a 6th grader might have occurred only once or twice in a 3rd grader's vocabulary inventory For example, the character "魯" has a frequency of zero in the Hong Kong Corpus of primary School Chinese (Leung and Lee, 2002) at the 3rd grade while its frequency count becomes 47 at the 5th grade. Frequency count based on the respective educational levels of the subjects is believed to be more accurate.

In Tzeng et al's study (1995), consistency value was calculated based on the family size of the phonetic radicals while the family size was calculated using the word counts from the same source for both grades of subjects. The consistency value of one stimulus would then be the same for both grades of subjects. In fact, some characters that were inconsistent to adults might be consistent to children as they might have not yet learnt the exception characters. For example, among the family members of the phonetic radical "半"/bun3/, a 3rd grader has only learnt "半"/bun3/, "胖"/bun6/, "絆"/bun6/ and "伴"/bun6/ but not "判"/pun3/ or "泮"/pun3/, according to the Hong Kong Corpus of primary School Chinese (Leung & Lee, 2002). This made "半" a consistent phonetic radical to the 3rd grader. From an adult's perspective, "半" was more inconsistent, as there were more exceptions characters "判" and "泮" when compared with the

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child's repertoire. Similarly, one phonetic radical that is consistent to a 3rd grader may become inconsistent to a 6th grader, and the respective consistency value of the same phonetic radical should also be different for the two students. Although relative frequency of stimuli to different grades of subjects was controlled in Yang and Peng's (1997) study, since they did not suggest a consistency value or other measures in determining the degree of consistency of stimuli, it was not clear if the writers took into account the vocabulary sizes of different groups of subjects when considering the consistency of each stimuli. It is suggested that in order to study the consistency and/or family size effects in developing readers of different grades, consistency value and family size of the stimuli for different grades should change according to the numbers of family members that the subjects should have seen. Investigation on the genuine phonological consistency effect with consistency value controlled is warranted.

The purposes of the current study were 1) to investigate if there are effects of phonological consistency and family size on real-character naming in school-aged children in Hong Kong 2) to identify interactions between these 2 factors and regularity and 3) studying the change of effects across different grades of elementary school students. Phonetic compounds naming was employed in the present experiment so that access of phonological information is necessary during the task. In the present study, consistency value of a particular phonetic radical was defined as one over the number of different realizations of characters containing the phonetic radical (regardless of tonal discrepancy) A larger value indicated that the phonetic radical was more consistent and vice versa. This definition was preferred to the old one proposed by Fang et al's (1986) because it avoid embedding the regularity and family size into the one single measure.

Method

Subjects. One hundred and twenty Cantonese-speaking 3rd and 4th graders from a local elementary school were preliminarily recruited. 3rd and 4th graders were chosen to participate in the study because it was suggested (Ho, Wong and Chan, 1999) that decomposition of both

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phonetic and semantic radicals from characters was supposed to be introduced in the 3rd or 4th grade Chinese language syllabus in Hong Kong. All students were assessed using the Raven Standard progressive Matrices (Raven, 1956) and the Chinese word reading sub-test of the Hong Kong Test of Specific Learning Difficulties in Reading and Writing (Ho, Chan & E.D., HKSAR Government, 2000) for their intelligence and reading abilities respectively. Students with IQ scores 1 S.D. below average or reading scores 1.33 S.D. below/above average were excluded from the study. Students with age 2 years older than the smallest student in that grade were also not recruited for the study as they might be exposed to more Chinese characters than their younger counterparts. As a result, 46 and 54 students from the 3rd and 4th grade respectively were selected as the subjects of the current study. The age, sex, intelligence and reading abilities of the subjects were summarized in Table 1.

Table 1. *Age, sex, intelligence and reading ability of the two groups of subjects*

Grade	No. of subjects	Sex		Age	Raven Progressive Matrices	Chinese Word Reading test
		Male	Females	Range	Mean Score (S.D.)	Mean Score (S.D.)
Primary 3	46	23	23	8;0-9;8	112.13 (11.82)	11.94 (1.73)
Primary 4	54	25	29	9;1-10;4	108.70 (12.47)	10.46 (1.79)

Stimuli.

In this study, all stimuli were real characters since this reflected the process of natural reading. Pseudo-character naming was not used as it might be bias because of the possibility of direct naming of phonetic radical embedded in phonetic compounds. The stimuli were Chinese phonetic compounds with either left-right or top-down construction. All stimuli were chosen from the Hong Kong Corpus of primary School Chinese (Leung & Lee, 2002). They were compound characters with phonetic radical that could be real Chinese character on its own (free phonetic radicals). Characters that shared the same phonetic radical and the phonetic radical as a character on its own formed one family and were referred to be members of the same family.

The phonological consistency value for a particular phonetic radical was defined as one over the number of different realizations of members in that family (regardless of tonal discrepancy) while a larger value indicated that the phonetic radical was more consistent and vice versa. The family size was defined as the number of characters in that family, including those phonetic radicals which act as free characters on its own. The consistency value and family size of characters for each grade were calculated based on the numbers of characters in the family that appeared in each grade so that family size and consistency of the phonetic radical might be different in two grades as the 4th graders were exposed to more characters. For examples, the phonetic radical "者"/dze2/ has a consistency value of 1/4 and family size of 7 in grade 3 (者 /dze2/, 豬/dzy1/, 著/dzy3/, 都/dou1/, 煮/dzy2/, 暑/sy2/ and 睹/dou2/) while its consistency value and family size becomes 1/7 and 11 respectively in grade 4 (者/dze2/, 豬/dzy1/, 著 /dzy3/, 都/dou1/, 煮/dzy2/, 暑/sy2/, 睹/dou2/, 諸/dzy1/, 署/tsy5/, 奢/tse1/ and 緒/soey5/). Characters with a consistency value of 0.5 (1/2) or above were referred as consistent characters while those with a consistency value of 0.33 (1/3) or below were referred as inconsistent. Two was chosen as the maximum numbers of realizations in consistent conditions as this allowed the existence of the conditions consistent/irregular in which the stimuli would have different pronunciation as the phonetic radical. Phonetic radical with a family size of 5 or above are categorized as large family size those radicals which had a family size less than 5 family members are categorized as small. Radicals that had family size of one were withdrawn from selection. Characters with same pronunciation regardless of tonal difference, i.e. same onset, rime (and tone), as their phonetic radicals were considered as regular characters. Characters with different onset and/or rime from their phonetic radicals were considered as irregular characters.

Only characters with low whole–character frequencies were used in the study as it has been shown that both consistency and regularity effects were only observed in low-frequency characters but not in those with high whole-character frequencies (e.g. Hue, 1992; Yang and

Peng, 1997). Relative frequencies of stimuli for each grade were calculated in a cumulative fashion, e.g. the relative frequency of a character for a 3rd grader would be the total of frequencies of that character for the 1st, 2nd and 3rd grades. The average relative cumulative frequencies of the stimuli in each condition were controlled between 1.31 per 10, 000 characters to 2.94 per 10, 000 characters for both grades.

The combination of two levels of the phonological consistency, family size and regularity yielded eight conditions with 10 characters chosen for each condition. Students from each grade were tested by a separate set of stimuli. Each set of stimuli contained 80 phonetic compounds chosen according to the cumulative frequencies corresponding to the respective grade. Each set of stimuli were further split into two blocks. Each block contained 40 characters, 5 from each condition while characters with the same phonetic radical were put into different blocks. The order of presentation of characters in each block was randomized. Half of the students from each grade were first presented with Stimuli Book 1 (the first block of stimuli) and then Stimuli Book 2 while the order of presentation for other halves of students were reversed. The organization of stimuli and examples of stimuli in each condition were shown in Table 2.

Table 2. *Organization of stimuli and examples of stimuli in each condition.*

	Consistent				Inconsistent			
	Large family size		Small family size		Large family size		Small family size	
Grades	Regular	Irregular	Regular	Irregular	Regular	Irregular	Regular	Irregular
Primary3	嚨	祥	恢	娛	跤	坡	呱	純
Primary4	瑚	蹟	狙	陡	峭	徘	琨	姪

Design. A 2(grade) X 2(consistency) X 2(family size) X 2(regularity) mixed design was used for ANOVA in the current study. One between-subjects factor and three within-subjects factors were manipulated. The between-subjects factor was grade. The within-subjects variables were phonological consistency (consistent and inconsistent), family size (large and small) and regularity (regular and irregular). Regularity was also manipulated as it was found to affect the naming performance in previous studies (e.g. Yang & Peng, 1997).

Procedures. Four 3rd and 4th graded students were recruited in a pilot study prior to the actual testing to ensure the validity of the procedure and eligibility of the test stimuli. The time needed to complete all tasks was determined and validity of instructions was also revised by recording the whole process of testing. After analyzing their results, no floor or ceiling effects were observed.

The testing was conducted in a local elementary school. Each student was tested individually by a trained experimenter. Suitable candidates who passed both the screening tests mentioned in the subject section, were led to a classroom where he/she sat in front of a table next to the experimenter. Five students were tested in the same classroom at the same time. The stimuli were each presented horizontally in the centre on one page of a B5-sized booklet. All characters were printed-out in dark color and in font size 170 using Biau Kai font ("標楷體"). The experimenters read the standardized instructions at the beginning of presentation of each booklet to the subjects. During the instruction, subjects were asked to "read aloud the characters according to what he/she thought the characters should be pronounced", but were not encouraged to "guess" the pronunciation. Each student had to read aloud a total of 80 characters and there was no time limit for the students to finish the task. The experimenters recorded the students' responses and one mark was given for every correct response. No mark was given for no response or incorrect responses. Only responses that matched exactly with the pronunciations suggested by the corpus in terms of their onsets, rimes and tones would be considered as correct responses. For incorrect responses, the experimenters transcribed the error orthographically or using LSHK Romanization immediately. The whole process was recorded using MD recorders or MP3 recorders.

The inter-rater reliability was estimated by asking a second experimenter to listen to 10% of the MD recording and scored again the subjects' performance. Raters were found to be in 98.1% agreement.

Result

A 2 X 2 X 2 X 2 four-way ANOVA was conducted on the scores, with grade being the between–subject factor while consistency, family size and regularity were the within-subject factors.

The main effect of Grade was not significant. The main effects of consistency [$F(1,98)=18.18$, $p<0.001$], family size [$F(1,98)=282.88$, $p<0.001$], and regularity [$F(1,98)=99.68$, $p<0.001$] were found to be significant. The percentage scores in each level of the three factors were shown in Table3

Table 3. *The percentage scores in each level of the three factors*

| Factors	% scores	Factors	% scores	Factors	% scores
Consistent	43.16%	*Large family size*	47.73%	*Regular*	45.15%
Inconsistent	39.68%	*Small family size*	35.11%	*Irregular*	37.69%

A 3-way interaction effect between consistency, family size and regularity was also found to be statistically significant [$F(1,98)=6.33$, $p<0.05$]. Tukey's HSD tests were then carried out to identify source of significant difference. Pair-wise comparisons showed that consistency effect was only observed in reading regular characters with large family sizes. With small family sizes, regularity effect became significant whereas regular characters were read better than irregular ones. Overall percentage scores and means scores in each condition were shown in Table 4.

Table 4. *Overall percentage scores and mean scores in each condition.*

Grades	Overall Percentage Scores(%) Mean (S.D.)		Mean Percentage Scores(%)			
			Large family size		Small family size	
			Regular	Irregular	Regular	Irregular
Primary3	41.36(12.04)	Consistent	55.43	49.35	49.13	23.04
		Inconsistent	37.17	50.65	4.630	1.978
Primary4	41.48(12.46)	Consistent	48.52	57.22	46.30	16.30
		Inconsistent	31.11	52.41	47.22	32.78

Interaction between family size and grade did not reach significance, indicating no significant difference was observed between the effects of the family size on reading performance of the two grades. Interaction between consistency and grade reached significance

[F(1,98)=7.27, p<0.01]. Post hoc analysis showed that the consistency effect appeared in the reading performance of subjects in grade 3 but no significant difference was achieved in reading performance of consistent and inconsistent characters for the 4th graders (see Figure 1).
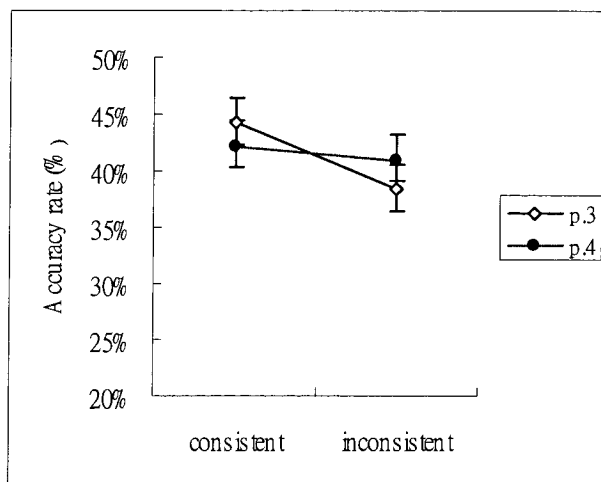
Figure 1. Interaction effect between grade and consistency.

A 4-way interaction analysis was done to find out what factor contributed to the insignificance in difference between reading performance of consistent and inconsistent characters in the 4th grade. The 4-way interaction effect between consistency, family size, regularity and grade was also found to be statistically significant [F(1,98)=12.41, p<0.001]. Pair-wise comparisons revealed that consistency effects were found in reading regular phonetic compounds with large family size in both grades. Significant difference was also achieved with the 4th graders reading irregular characters of small family size while inconsistent characters were read better than their consistent counterparts.

Discussion

In the current study, no significant main effect of grade was obtained, suggesting that the reading performance of subjects across grades did not differ. This might be attributed to the fact that two different sets of stimuli were used for the subjects and the relative frequency of characters across grades of subjects was controlled. This helps to ensure that when studying the effects of phonological consistency, family size or regularity, any significant difference in performance obtained across grades should not be explained by the frequency effect of stimuli.

As it was predicted, which was also consistent with previous studies (e.g. Hue, 1992; Yang & Peng, 1997), a significant regularity effect was obtained in the current study where elementary school readers read regular phonetic compounds better than irregular ones. This suggests that phonological information provided by the phonetic radical embedded within characters is used in reading low-frequency characters by elementary school readers. It is therefore believed that developing readers, as young as the 3rd graders, already start to employ the orthography-phonology correspondences (OPC) rules in phonological processing when they are learning to read new characters.

A significant family size effect was also obtained in the current study. Low-frequency Chinese characters with a larger family size were read better than those with a small family size in elementary school readers, which was consistent with findings in the western literatures on alphabetic scripts (e.g. Laxon, Coltheart, & Keating, 1988). This suggests that when elementary school readers are learning to read new Chinese characters, numbers of neighbors of the target characters will affect reading performance while a larger number of neighbors will facilitate naming accuracy in these children. It appears that the family size of phonetic compounds affects Chinese character naming independently.

A significant phonological consistency effect was observed in elementary school readers reading low-frequency Chinese characters with consistent characters being read better than inconsistent characters. Since consistency in the current study showed the extent that a phonetic radical consistently suggests similar pronunciations across characters formed by the phonetic radical (family members), regardless of regularity of the target characters, the result implies that reading low frequency characters in elementary students, as young as the 3rd graders, will be affected by phonological information provided by neighbors (family members) of the characters. This can be explained by the conspiracy models proposed by Taraban and McClelland (1985) which maintained that during naming of a target word, words which were orthographically most similar to the target (i.e. the target's neighbors) would be activated by gaining greatest amount of

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activation from the sub-words levels and these activated neighbors would compete with each others to provide phonological features that eventually became the phonological string that was pronounced. Among these neighbors, friends which shared many of the same phonological features as the target would support the activation of target pronunciation while enemies of the target character would inhibit the activation of phonological features of the target but in favor of their own (Taraban and McClelland, 1985, p.609). Therefore, for consistent words, the target pronunciation would be more easily synthesized, as they had friends which provided similar phonological features as the target and supported greater amount of activation of target pronunciation but little or no inhibition from enemies. Consistent words would hence be named better than inconsistent ones. Accordingly, when reading consistent characters, one or at most two possible pronunciations can be generated from the phonological features that are activated by these orthographically similar neighbors as they all sound similar to each others. The target pronunciations of consistent characters are more easily synthesized and these characters will be read better. When reading inconsistent characters, as the consistency value decreased, more possible pronunciations will be activated while the major discrepancy in phonological features that are suggested in turn inhibited the activation of the target pronunciations. It takes greater effort to generate a pronunciation that agrees with all the possible phonological features that are activated. Consequently, it is more difficult to deal with inconsistent characters which will then be read poorer than that the consistent ones.

Although consistency effect was also observed in previous studies (e.g. Hue, 1992; Tzeng et al., 1995; Yang & Peng, 1997), their definitions of consistency were different from the current study. As they did not investigate consistency effect in irregular characters and control family size of the stimuli, results they found could only show a combination of family size and consistency effects in reading performance on regular characters of school-aged children. The definition used in the present study was believed to be more representative of the genuine consistency effect in reading Chinese characters because it dissociated phonological consistency

with regularity and family size which were also found to be factors that affected Chinese characters reading in the current study. It suggests that consistency, family size and regularity need to be considered as three separate factors when studying their effects on reading performance and that consistent phonetic radicals are not necessarily regular. The fact that eight conditions of stimuli from the subjects' written vocabulary inventory varying in levels of consistency, family size and regularity were generated exemplifies the need to clearly distinguish these factors each of which should be studied as one distinct variable. Among the eight conditions formed in the current study, Tzeng et al.'s (1995) study only covered at most two conditions, the consistent/regular and inconsistent/regular with either large family size or small family size. It is therefore believed that the present study provides a more comprehensive measure on effects of phonological consistency, family size and regularity in reading Chinese. Phonological consistency was studied again also because it was argued that in order to investigate the consistency effect on children's reading ability, consistency values should be calculated with respect to the children's perspective so that a character was consistent or not should depend on the numbers of enemies or friends that have already appeared in the children's vocabulary inventory. This methodological issue was not addressed in previous studies.

It is maintained that the new definition of consistency value in the present study which separates regularity and family size with consistency, allows investigation on the genuine consistency effect, which are not confounded by regularity or family size effects, in developing readers. Relative frequency, family size and consistency were also calculated based on numbers of characters that appeared in the subjects' written vocabulary inventory already. A consistency effect found in present study gives us stronger evidence that elementary school readers actually consider pronunciations of neighboring characters that contain the same phonetic radical in phonological processing when learning to read new phonetic compounds.

The present study also investigated the different roles played by the three factors in reading and how the combined effects of the three factors would affect reading performance of the

developing readers. Consistency effect not only interacted with family size and regularity separately resulting in significant two-way interaction effects, a significant three-way interaction effect between consistency, family size and regularity was also noted. Consistency effect was only found in reading regular characters with large family size(see Figure 4)
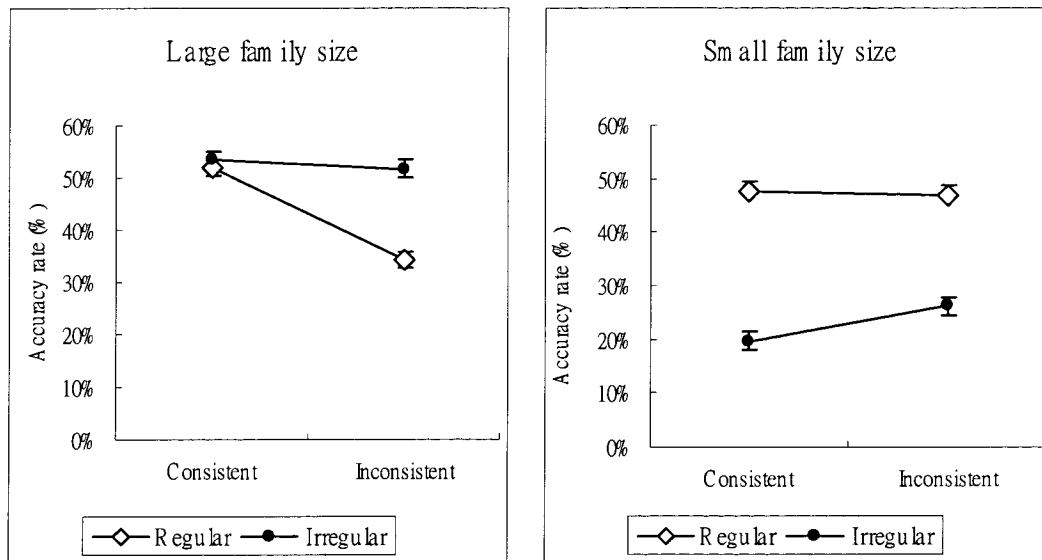

Figure 2. Interaction between consistency and regularity in large and small family sizes.

In previous studies (Tzeng et al., 1995; Yang and Peng, 1997) concerning consistency effect in children's reading performance, consistency effect was only investigated in regular characters while family size of stimuli were not manipulated. The consistency effect in regular characters was also studied in the current study as shown by the lines with square tabs in Figure 2. The present finding agreed with what was observed in previous studies where consistent characters were read better that inconsistent ones in regular conditions. In addition, the present study also provided further information on how the effect of phonological consistency on reading performance of characters changed with different family sizes and consistency effect in irregular characters. As it was shown in Figure 2, consistency effect was only observed in regular characters with large family size while there was no significant consistency effect in reading regular/irregular characters with small family size. While consistency did not seem to affect reading performance in characters with small family size, it was obvious that the regularity

effects became the major factor in affecting reading accuracy and regular characters were read significantly better than the irregular ones. In irregular characters with large family size, though accuracy rate in reading consistent characters was still higher than that in reading inconsistent characters, difference in performance did not reach statistical significance.

Then why was consistency effect only found in characters with large family size? As previously suggested, consistent characters are read better than inconsistent characters because the target pronunciations of the consistent characters are more easily synthesized from fewer possible phonological features extracted from family members while when reading inconsistent characters, more discrepancy and inhibition are generated from large numbers of possible pronunciations from family members of inconsistent characters. In this process, as family size becomes larger, there will be more friends or enemies and hence, the target pronunciation will receive larger amount of activation/ inhibition from the increased numbers of friends or enemies to a critical level that differentiates naming performance in reading consistent and inconsistent characters. On the other hand, with small family size, numbers of friends or enemies are so small that the size of effect in enhancing or inhibiting the activation of target pronunciation may not be large enough to make the difference in reading performance. As a result, consistency effect becomes not effective in differentiating the reading performance of the young readers.

Although consistency loses its effect in reading characters with small family size, phonetic radicals may play a more important role in reading characters in this condition. As it was shown in Figure 2, regularity effect became significant in the right graph which illustrates the reading performance of characters with small family size. It may be because that with small family size, activation of pronunciations of phonetic radicals, which are believed to be simpler in construction and learnt early in life, receives minimum competition from phonological features of neighboring characters as there are no or at most two neighbors in the family other than the phonetic radical. Phonetic radicals become a better clue to the target pronunciation and regularity takes over the major role in affecting reading performance. Therefore, significant consistency

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effect could only be found in reading characters with a large family size while regularity was more significant in characters with small family size. Since family size was not strictly controlled or manipulated in previous studies (e.g. Tzeng et al., 1995; Yang and Peng., 1997), the change of determining factors on reading performance between large and small family size could not be demonstrated. If all the characters used in their studies were with large enough family size, it would be misleading to claim that there was consistency generally in reading all Chinese characters.

It could also be observed that in developing readers, significant consistency effect was not found in irregular characters even with large family size. One possible explanation is that in irregular characters, the pronunciations of the phonetic radicals become different from that of the targets. Even the phonetic radicals may suggest phonological information consistently in other neighbors, pronunciation of the target characters face keen competition from the pronunciations of the phonetic radicals, which are commonly simpler in construction and learnt early in life. In these cases, pronunciations of the phonetic radicals may override phonological information from neighboring characters and become a better clue to the target pronunciations. Although no significant consistency effect was found in naming accuracy of irregular characters in elementary school readers recruited in the present study, it was noted that with large family size, though statistical significance was not reached, the consistent characters were still read better than the inconsistent ones. This may imply that the knowledge of consistency effect in reading this type of characters will start to develop but is not yet well acquired by the 3rd grade. It is therefore worthwhile to do further researches on consistency effect in reading irregular characters with large family size in more skilled readers i.e. elder children and adults.

The significant three-way interaction between consistency, family size and regularity indicated that these separate factors not only affected naming accuracy of low-frequency characters in elementary school readers on their own, they also interacted with one other influencing the size of effects of individual factor. Consistency effect affects reading

performance on regular characters with large family sizes while regularity effect takes over the major role in affecting reading performance in characters with small family sizes.

Now that the combined effects of consistency, family size and regularity were discussed, the next step is to look at the developmental trends of individual effects. Interaction between family size and grade was not statistically significant. This indicated that family size effect in naming low-frequency characters did not change as subjects go from the 3rd grade to the 4th grade and this can be explained by the fact that family size awareness has already developed before the children got into the 3rd grade. It is therefore proposed that the 3rd graders can make use of characters that are orthographically similar to the target to generate the target pronunciations when reading low-frequency characters,

Although significant interaction effect between consistency and grade was found, significant consistency effect was only found in naming accuracy of the 3rd graders but no significant difference was found in reading consistent and inconsistent characters by the 4th graders. This suggested that the 3rd graders would use the rule of consistency better in naming low-frequency characters than the 4th graders. If the use of knowledge of consistency effect had already developed in the 3rd grade, why would the 4th graders not use it anymore?

Post-hoc comparisons between pairs of conditions in the four-way interaction between grade, consistency, family size and regularity might answer this question. It was mentioned earlier that generally, consistency effect could only be found in characters with regular pronunciations and large family size. In fact, significant consistency effect was found in both grades when subjects were reading regular characters with large family size (see Figure 3). This showed that actually both the 3rd and 4th graders can make use of the pronunciations of neighbors of the target characters as a clue to character naming and consistent characters will be named better as long as the characters are regular and with large family size. Therefore, it is believed that consistency do have effects on reading performance in both grades while the insignificance consistency effect found in naming accuracy of the 4th graders may result from reading

performance in other conditions that do not favor the use of consistency rule. Consistency effect in other conditions (i.e. small family size/regular, large family size/irregular or small family size/irregular) in both grades did not reach significance, except the small family size/irregular condition in the 4th grade whereas the 4th graders had significantly lower scores in naming consistent characters with small family size and irregular pronunciations and in this condition, inconsistent characters were read better than consistent ones (see Figure 4). The small size of consistency effect found in the 4th grader should be attributed to the adverse finding in this condition. It is postulated that other factors may be affecting reading performance of the subjects in this particular condition. This can be further evidenced in the error analysis.
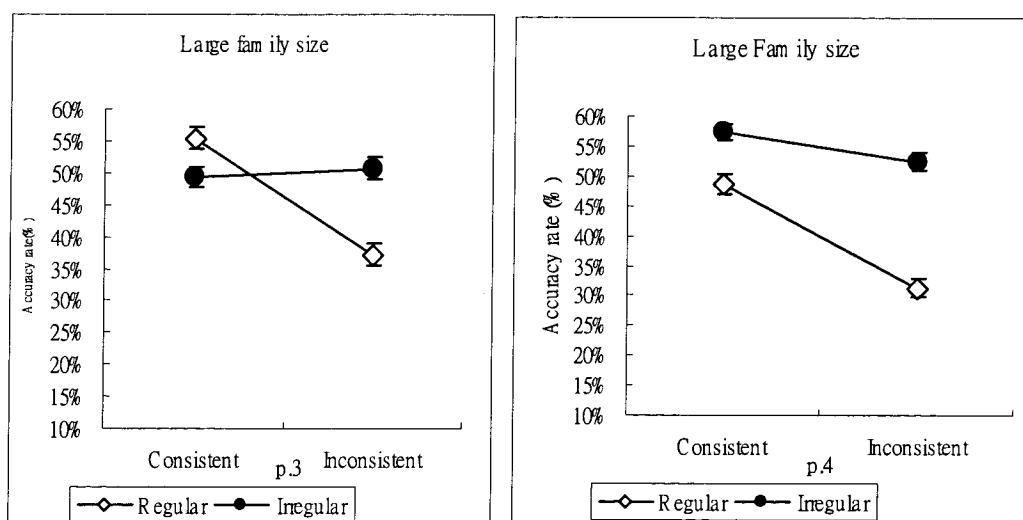
Figure 3. Interaction between consistency and regularity with large family size in two grades.
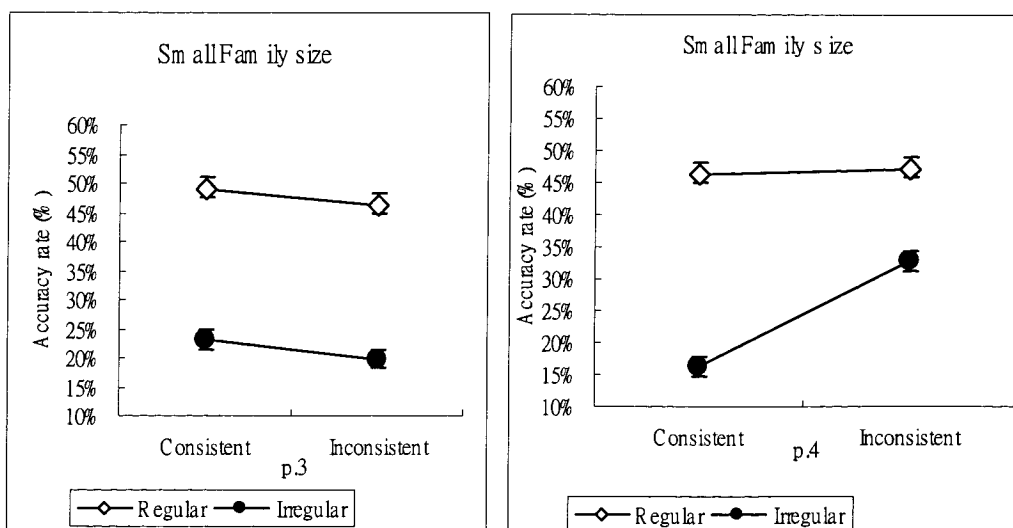
Figure 4. Interaction between consistency and regularity with small family size in two grades.

In order to get more information on the actual naming processes of young readers, error responses were analyzed. Errors that subjects made were categorized into four main types, namely "phonetic errors", "neighbor errors", "other errors" and "no responses". By examining the numbers of errors falling into each of the first two categories can help us to determine which strategies, direct use of phonetic radicals' pronunciations or making use of neighboring characters pronunciations were being employed in each condition. More "other errors" indicates the group might use more other strategies (for example semantic activation) or just provide any responses that were not related to the target. Numbers of errors falling into "no responses" can be used to estimate the tendency of subjects in rejecting to provide a pronunciation for the test items in various conditions.

The first type of errors was "phonetic errors" in which the target characters were named as the phonetic radicals of the characters. For example, the compound character "撫" (/fu2/) was named as its phonetic radical "無" (/mou3/). Since regular characters used in the present study include characters that have the same onsets and rimes but different tones with the characters' phonetic radicals, phonetic errors, i.e. naming of the phonetic radicals instead of the targets, were also found in regular conditions. The presence of phonetic errors reflected the activation of the pronunciations of the phonetic radicals and the subjects' use of regularity rule in naming. The second type was "neighbor errors" where the target characters were named as other characters (the neighbors) having the same phonetic radical as the target. For example, target compound character "繞" (/jiu2/) was named as its neighbor "曉" (/hiu2/) which had the same phonetic radical "堯". The presence of neighbor errors indicated the subjects would have considered characters from the same family as the target and the activation of phonological information of neighboring characters during naming. The third type was "other errors" which included any responses that were not categorized as phonetic or neighbor errors. They might be characters that were orthographically similar to the target, e.g. "川" being named as "州"; characters that were

semantically related to the target, e.g. "嘔" being named as "吐" which also shared the similar meaning of "throwing up"; or other unrelated errors. The last type of errors was categorized as "no responses", when the subjects did not give any response or claimed that they did not know how to pronounce the targets. The numbers of different errors in different conditions in each grade were summarized in Table 5.

When comparing errors made by the two groups of subjects, major difference was only found in the numbers of "other errors" and "no response" while the 4th graders made more errors than the 3rd graders in both types. The larger number of "other errors" suggests that the 4th graders may employ other strategies, such as semantic activation, more readily in naming low-frequency characters that they find difficult. A higher number in "no response" indicated that these 4th graders might be more conservative than their 3rd grade counterparts in naming difficult characters. As all subjects were not forced to guess the pronunciations of the targets, while numbers of other types of errors were found to be similar between the two groups of subjects, a significant higher number of "no response" suggests that the 4th graders may tend to refuse to answer when they are not sure about the pronunciations of the targets more readily than the 3rd graders.

From the total numbers of errors in different conditions, it was shown that the 3rd and 4th graders made similar numbers of errors in "phonetic" and "neighbor" errors. This suggests that the 3rd and 4th graders do not differ much in the tendency to employ phonological information either embedded within the phonetic compounds or provided by family members in reading. This implies that the development of consistency and family size effect do not change significantly between the two grades. This is consistent with the result of insignificant interaction effect found between family size and grade. Nevertheless, this do not support the result about the development of consistency as it was shown in accuracy rate analysis that consistency effect was not found in the 4th graders. As previously suggested, the insignificant consistency effect found in reading performance of the 4th graders was mainly contributed by the significantly poor

performance in reading consistent, irregular characters with small family size. Referring to the errors made in this particular condition, it was found that a relatively large number of phonetic errors was made by both groups of subjects comparing to other conditions while only a few "neighbor" errors were noted. This implies that both the 3rd and 4th graders tend to use the rule of regularity and rely on naming the phonetic radicals in this particular condition. It is therefore believed that characteristics of the phonetic radicals will also affect naming performance of irregular, consistent characters with small family size. Calculation was made and it was found that the average relative phonetic frequency of the stimuli from this condition for the 4th grade subjects was 84.96 per 100,000 characters, which was significantly higher than that for the 3rd grade subjects (15.66 per 100,000 characters). The activation of the pronunciations of the high-frequency phonetic radicals would compete with and act against that of the targets as the phonetic radicals will now become the enemies as the target are irregular characters. As the 4th graders encounter bigger competition between the activation of the pronunciations of the phonetic radicals and that of the targets, they may tend to make more no responses and hence affecting the accuracy rate significantly in this condition. This not only explains the inconsistent results found between accuracy rate and error analysis and the absence of consistency effect in the 4th grade subjects' reading performance, but suggests the important role played by phonetic radical frequency in naming, which was not manipulated in the present study.

Table 5. *Numbers of errors in different conditions in each grade of subjects.*

| | | Consistent | | | | Inconsistent | | | | |
| | | Large Family size | | Small Family size | | Large Family size | | Small Family size | | |
		Regular	Irregular	Regular	Irregular	Regular	Irregular	Regular	Irregular	Total
p.3	Phonetic	24	38	66	166	30	30	24	75	453
	Neighbor	38	53	3	5	67	78	38	65	347
	Others	32	34	32	50	67	31	43	71	360
	No Response	111	108	133	133	125	88	142	158	998
p.4	Phonetic	27	40	60	162	28	18	65	74	474
	Neighbor	62	49	8	14	60	75	41	41	350
	Others	65	49	50	58	104	38	47	59	470
	No Response	124	93	172	218	180	126	132	189	1234

The error analysis supported the notion that consistency effect was only found in characters with larger family size. As it was shown in Table 5, numbers of neighbor errors were higher than the numbers of phonetic errors only in conditions with large family size while the reverse trend was observed in naming characters with small family size. This reflects that subjects, in both grades, consider using neighboring characters more readily when the target characters have a larger family size. This provides another reason why consistency effect in accuracy rate only became significant in naming characters with a large family size. It is believed that only when there are enough family members, the readers start to rely more on using the phonological information provided by the neighboring characters, and by then, consistency effect can now become influencing on the reading performance. On the other hand, when the family size of the target character is not large enough, the pronunciation of phonetic radical will "win" over phonological features provided by the small numbers of neighboring characters and results in a larger numbers of phonetic errors found in these conditions. Hence, the regularity effect takes over the major role in affecting the naming performance of the subjects from consistency effect when the family size of the target characters is small.

It was suggested in Yang and Peng's study (1997, p.339) that the less skilled readers (the 3rd graders in their study) relied more on phonetic radicals while the more skilled readers (the 6th graders) "would be more affected by family members, not the phonetics", as skilled readers might have the knowlege that relying on phonetic radicals merely was not reliable. However, results of the current study indicate that both the 3rd and 4th graders prefer to use phonetic radicals as the major clue to pronunciations of the targets only when the family size of the target is small. When the family size of the target becomes larger, both the 3rd and 4th graders would consider neighbors' pronunciations as the major clue to the target's pronunciation. One reason for the discrepancy might be that in Yang and Peng's study (1997) the numbers of friends and enemies of the 3rd grade stimuli (from 2.1 to 3.7) used in the experiment were generally smaller than that of the 6th grade stimuli (from 2.3 to 5.5). It was found the current study that, in the 3rd

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grade inventory, there were characters with large enough family size that could make phonological consistency a determining factor in the students' reading performance, and these 3rd graders have already developed the awareness to consider pronunciations of family members in characters naming. Therefore, though it was agreed that vocabulary development would affect the use of pronunciation of family members in reading, no evidence showed that the 6th graders would use family members more readily because they have better reading ability and the 3rd graders should have already acquired the skill to use this rule. In fact, one major finding that was missed in previous studies is that family size is actually an important and influencing factor, that determines the strategies a developing child will use when he/she needs to pronounce "difficult" characters. Either using pronunciations of the phonetic radicals directly or making analogies to pronunciations of neighboring characters to decide the pronunciations of the targets, will much depend on the orthographic information (numbers of orthographic lexical representations), and hence the phonological information (pronunciations of the activated orthographic lexicons) available within the family, so that more members within the family favors the use of pronunciations of neighbors and vice versa.

Conclusion

The present study reveals that there are separate effects of phonological consistency, family size and regularity in Chinese characters naming in developing readers in Hong Kong. Readers as young as 3rd graders could start to use the knowledge of rules of Orthography-Phonology Correspondences and make analogies of characters having the same phonetic radical in learning to read new characters. Interestingly, it was found that on top of having individual effects, they interacted with each other in affecting the reading performance of young readers. It is noted that phonological consistency is only influencing in reading characters with a large family size while regularity will then override consistency effect and become the main determining factor in reading characters with small family size. This finding implied that Glushko's (1979) proposal of the activation-synthesis model where an integration of phonological information (as evidenced in

regularity and phonological consistency effects) and orthographic knowledge (as shown in family size effect) were activated in the course of reading can also account for reading Chinese. As mentioned before, it was found that family size is an important factor in deciding which strategies children will use in naming. This shows the significant role played by orthographic processing even during a phonology-oriented task like naming. This also suggests that orthographic processing and phonological processing are interacting and influencing each other in the course of characters recognition and pronunciation retrievals. Nevertheless, change in development of phonological consistency and family size was not found and it was observed that reading performance of the 3rd graders would already be affected by these two factors while phonological consistency effect would become robust with large family size characters. This was observed in both groups of subjects and these skills in using the phonological and orthographic information should be acquired earlier in life.

Further study

As it was observed that reading performance of the 3rd graders will be affected by phonological consistency and family size of stimuli, young readers should have acquired this knowledge at an earlier stage of learning. Further studies on the development of these effects are therefore recommended to identify at which specific stage these effects start to develop.

Although significant consistency effect was not observed in reading irregular characters in the subjects recruited in the present study, reading irregular/consistent characters still resulted in fewer errors than reading irregular/inconsistent characters while use of neighboring characters was also observed in these conditions. It is worthwhile to investigate if phonological consistency plays a role in reading irregular characters in more skilled readers, such as adults or school-aged children at a higher grade.

Implication

It is of great value in to find that phonological consistency and regularity operate at different level of characters' family size in facilitating the reading performance of young readers.

Teachers of elementary schools are not merely recommended to teach groups of similar sounded characters with the same phonetic radical at the same time and to highlight the similarity in pronunciations these characters shared. They are also suggested to be aware of the regularity and family sizes of the characters and change the strategies used accordingly. For examples, when reading characters with small family size even, it might be more effective to teach the students to read aloud the phonetic radical directly.

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Appendix I

Stimuli for the 3rd graders

Consistent and regular characters with large family size 嚨, 瑚, 彷, 騙, 驅, 碼, 症, 杬, 哦, 齡

Consistent and irregular characters with large family size 鷗, 佗, 版, 詳, 魔, 祥, 嘔, 龐, 翔, 聞

Consistent and regular characters with small family size 湧, 惦, 鍛, 蚓, 喉, 撕, 仗, 倖, 恢, 纜

Consistent and irregular characters with small family size 凝, 撫, 圳, 阱, 娛, 泄, 吼, 擠, 蹤, 礦

Inconsistent and regular characters with large family size 痘, 棋, 幕, 貢, 披, 咕, 盯, 餘, 錐, 跤

Inconsistent and irregular characters with large family size 盼, 咀, 措, 帕, 侍, 坡, 江, 奸, 睹, 秒

Inconsistent and regular characters with small family size 致, 琨, 屬, 呱, 甥, 繞, 啞, 豫, 梅, 瑰

Inconsistent and irregular characters with small family size 拙, 僥, 笛, 純, 誘, 瞎, 姪, 灑, 嘿, 飼

Stimuli for the 4th graders

Consistent and regular characters with large family size 嘔, 聆, 瑚, 杬, 俄, 睜, 螃, 僑, 拱, 艇

Consistent and irregular characters with large family size 版, 拒, 蹟, 摩, 柱, 哄, 詳, 佗, 矯, 嘔

Consistent and regular characters with small family size 惦, 狀, 綁, 狽, 鑣, 譜, 喏, 噸, 犧, 褥

Consistent and irregular characters with small family size 醇, 陡, 掀, 唡, 溢, 滯, 賄, 諾, 撒, 儒

Inconsistent and regular characters with large family size 錐, 吩, 峭, 饒, 杬, 豫, 雌, 釘, 裏, 洽

Inconsistent and irregular characters with large family size 唯, 徘, 緒, 租, 賂, 奸, 抽, 帕, 撓, 稍

Inconsistent and regular characters with small family size 伺, 琨, 鎮, 淑, 勉, 搓, 拯, 銹, 裨, 妮

Inconsistent and irregular characters with small family size 圳, 拙, 姪, 棍, 嘿, 侈, 涸, 靴, 祈, 詭

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