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Effects of phonological and orthographic similarities of Chinese characters on Chinese reading

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ABSTRACT

This study investigated the effects of phonological similarity and orthographic similarity of Chinese characters on reading. The subjects were 105 local grade 3, 4, and 5 students in Hong Kong. Proof-reading task of reading sentences was used in the study to approximate real life reading. Contradicting with previous studies, the results of the present study illustrated that orthography is essential in the process of reading as the visual access for semantic activation, and it could be hypothesized that orthographic activation occurred before phonology is activated. Another finding was that phonology did not play a strong role for access to semantics for young readers, but slight development trend was shown. Readers tended to learn the phonological rules after grade 3, relying less on the sound of the characters on reading.

Introduction

Background of study

Reading aloud a character from print is a process which involves orthography, phonology, and semantics. This orthography, phonology, and semantics "triangle" is traditionally used to describe the lexical process of Chinese character (Perfetti & Tan, 1998; Seidenberg & McClelland, 1989; Zhou et al., 1999) (refer to Fig.1). In order to illustrate the reading process in the brain upon encountering a character, researchers tried to study the activation of orthography, phonology, and semantics in reading.
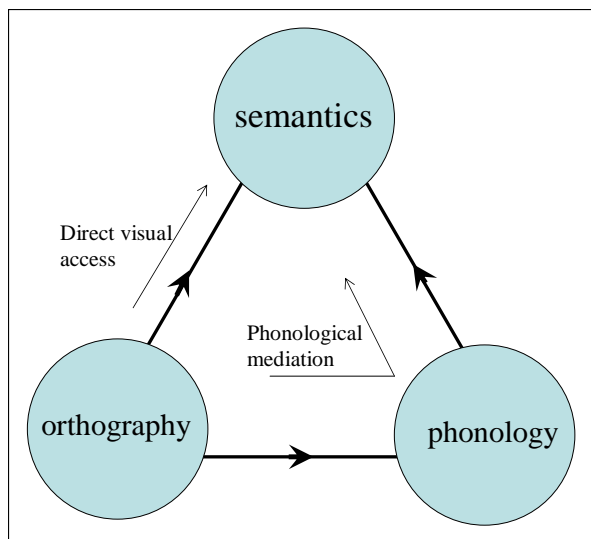

Figure 1. Framework of "triangular" lexical representation of orthographic, phonological, and semantic activations during reading

Many researchers tried to find out the role of phonology in reading (Perfetti & Zhang, 1995, Seidenberg & McClelland, 1989; Taft & van Graan, 1998; Zhou et al., 1999, Zhou & Marslen-Wilson, 1999). The phonology mediated hypothesis suggests that orthography first

activates phonology and then indirectly activates semantics. A contrastive hypothesis of direct visual access suggested that phonology is bypassed, semantics is directly activated by orthography. With the two pathways linking to semantics, interaction of orthography and phonology was also suggested in dual-route theories, indicating that under specific conditions, one of the two has stronger role in semantic activation. Although many studies have been carrying out, consistent results for the activation of orthography, phonology, and semantics in reading could not be found.

In studies on visual word recognition using semantic categorization task, homophones were prone more to be mis-categorized than the unrelated control, which led to the hypothesis than semantic activation is phonologically mediated (Van Orden, 1987). Taft and Van Graan (1998) demonstrated that regular and irregular words (e.g., PLANK and PINT, respectively) showed a difference in a naming task indicating a regularity effect. However not such effect was found in the semantic categorization task. Hence, Taft and Van Graan (1998) hypothesized that semantic activation is not necessarily phonologically mediated.

Daneman, Reingold, and Davidson (1995) studied homophones with eye-monitoring technique by measuring gaze duration on the words. It suggested that in passage reading of skilled readers, encountering a homophonic word which was contextually inappropriate was more disruptive than reading a non-homophonic control word which was also contextually inappropriate. Rayner, Pollatsek, and Binder (1998), however, found that reading a

homophonic word which was orthographically similar to the contextually appropriate word was less disruptive than the control.

Conflicting results might reflect different activation processes partly due to the limitation of alphabetic languages like English, or French. Orthography and phonology of alphabetic languages usually co-vary. When the orthography of the character is changed, the phonology of it is changed too. For example, the word "star" has a different phonology with "scar". The inability to separate orthography and phonology clearly created limitations in studies using alphabetic languages, conclusive statement could not be drawn in the studies on effects of phonological and orthographic similarities on reading.

In contrast to the limitation of alphabetic languages, Chinese is a better language for studying the effects of phonological similarity and orthographical similarity. Chinese characters have large number of homophones which are clearly orthographically different, while phonologically the same; for examples, 稀/hei55/[*rare, sparse*]-犧/hei55/[*sacrifice*], 焚 /fɐn21/[*burn*]-墳/fɐn21/[*grave, bulge*]. There is also large number of Chinese characters with similar orthography but with totally different meanings, for examples, 噪/ts^{h}ou33/[*noisy*]-躁 /ts^{h}ou33/[*irritable*], 跪/kwɐi22/[*kneel*]-詭/kwɐi35/[*cheat, sly*], 綿/min4/[*wool, soft, downy*]-錦 /kɐm35/[*brocade, tapestry; embroidered*]. Hence, Chinese provides a more ideal testing ground to study the effect of phonological and orthographic similarities on reading.

Zhou & Marslen-Wilson (1999) demonstrated that phonological activation was automatic,

but it could not be concluded that this was related to semantic activation. Studying the time course of activation using priming tasks, Perfetti & Tan (1998) supported the claim that phonology was automatically activated, and was earlier than semantic activation. Chen et al. (1995) and Leck et al. (1995) demonstrated the lack of a significant independent phonological effect. Leek et al. (1995) used semantic categorization task, and showed strong orthography effect but very weak phonology effect. Wydell et al. (1993) used another logographic language, Japanese, to study homophones. It was shown that the interaction effect was more significant for orthographically similar homophones than for orthographically similar non-homophones. It was then concluded that with appropriate orthographic information, phonology can influence semantic activation.

Song, Zhang, & Shu (1995) studied the role of graphic code and sound code of the character in reading of simplified Chinese characters. Proof-reading task was used to approximate real life reading. Grade 3, grade 5, and adult group were included as subjects. The comparison was between two types of stimuli: orthographic similar words (which are phonologically different) and homophones (which are orthographic dissimilar) only. Results showed that younger readers performed poorer with homophones than with orthographic similar words; and the adult group performed poorer with orthographic similar words than with homophones. Therefore, Song, Zhang, & Shu (1995) concluded that beginners rely more on phonological code than orthographic code, while more advanced readers rely more on

orthographic code than phonological code.

However, the above study of Song, Zhang, & Shu (1995) had several problems which might have confounded the results. Firstly, the authors did not specify the characteristics of the homophones used in the study. Homophones could have been orthographic similar or dissimilar. Secondly, the two types of stimuli used were not comparable, since they varied both phonologically and orthographically. The study did not include all possible factors in varying the phonological and orthographic similarities, for examples, 2 groups of homophones which are orthographic similar and dissimilar, orthographic similar but different phonology group, and different orthography and phonology group. Thirdly, the authors considered *similar* orthography, but *same* phonology when comparing the 2 groups of stimuli, which would have bias in the results. For comparable analysis, both factors should have similar and dissimilar groups instead. Fourthly, possible interaction effects of orthographic and phonological similarities across grades were not included in the analysis of the previous study. The problems mentioned above might have confounded the results, thus the conclusion above may be wrong.

The present study will be modified from the study of Song, Zhang, & Shu (1995). Same methodology of proof-reading task will be given to observe any orthographic and/or phonological effects. The study will include the homophone groups (orthographic similar and dissimilar) to confirm the results of the previous study. Except these two groups, 4 more groups will be included: orthographically similar phonologically similar (*OsPsi*), orthographically

similar phonologically different (*OsPd*), orthographically dissimilar phonologically similar (*OdPsi*), and orthographically dissimilar phonologically different (*OdPd*). Also, instead of studying skilled readers, the current research will study primary school readers from grade 3, grade 4, and grade 5, who are developing their skills of reading, so that detailed development shift of the effects on reading can be studied.

Research questions

This study aims to investigate how similar phonology and similar orthography affect Chinese reading. It also aims to investigate whether there is developmental trend and shifting of the effects on reading in Hong Kong local students. Sentence level will be used to simulate real life reading. We would like to ask: Are there phonological and orthographic similarity effects in Chinese reading in Hong Kong local students using traditional Chinese characters? Is there interaction effect between phonological and orthographic similarities? Is there a developmental trend and shifting of the effects of phonological and orthographic similarities in Hong Kong local students across grade?

Hypothesis

If the conclusions made by previous study of Song, Zhang, & Shu (1995) are correct, the below predictions could be made.

For lower grade, since it was hypothesized that they rely on phonology, *OsPsi* would perform poorer than *OsPd*, and *OdPsi* would perform poorer than *OdPd*. Also, *OsPsi* and

OdPsi, as well as *OsPd* and *OdPd*, would perform with similar results.

For higher grade, since it was hypothesized that they rely on orthography, *OsPsi* would perform poorer than *OdPsi*, and *OsPd* would perform poorer than *OdPd*. Also, *OsPsi* and *OsPd*, as well as *OdPsi* and *OdPd*, would perform with similar results.

Method

Participants

Three groups of subjects were recruited for the study in a local Chinese-medium primary school. They include grade 3, grade 4, and grade 5 students, so that detailed development trend could be analyzed. Subjects included are studying in Hong Kong since grade one, and are using Cantonese as their first language.

All subjects were screened by Raven's Standard Progressive matrices (Raven, 1986) in which the non-verbal intelligence and logical reasoning ability will be compared with the norm of their according ages. Subjects out of the range of SD $\pm$1.33 (i.e. IQ score out of the range of 80 to 120 were excluded. Hong Kong Graded Chinese character naming test (HKGCNT) was also performed for each subject. Subjects' performances were compared to the norms of their according grades. Subjects out of the range of SD $\pm$1.33 were excluded from the study.

After the two standardized screening tests were performed, a total of 105 subjects were included in the study. 35 subjects were included in each of the three grades. Gender and age of subjects included in the study of the three grades were summarized in table 1.

Table 1.   Gender, age, intelligence, and reading abilities of the three groups of subjects.

Grade	Gender	Age	Raven's standard score	HKGCNT z-score
		Range (Mean)	Mean (SD)	Average (SD)
3	22 M; 13 F	8;2–9;11 (8.70)	100.1 (8.31)	0.226 (0.75)
4	19 M; 16 F	9;3–10;10 (9.78)	92.5 (8.06)	0.541 (0.64)
5	13 M; 22 F	10;3–11;9 (10.71)	98.2 (11.37)	0.615 (0.60)

Design and Stimuli

Since frequencies of occurrence of characters for different grades are different, different sets of sentences were used for different grades in order to control the frequency of characters. Low frequency characters were selected from the Hong Kong Corpus of Primary School Chinese (Leung & Lee, 2002) and only those low frequency characters were used. Low frequency characters were defined to be the lower one third of the occurrences of the total number of different words. There are two rationales to support this. First, ceiling effect with the use of high frequency characters would be avoided. Second, high frequency characters do not require analysis at sub-character level, which would not review the effects of the orthographic and phonological similarities.

Two other issues were taken into concerns. Characters with more than one pronunciation shown in the primary corpus and characters that are commonly mis-pronounced in Hong Kong population were excluded. The reasons for these are that the phonology of the targets could not be controlled to examine the effects of neighbors.

The stimuli were manipulated according to two factors: orthography and phonology.

Orthography was sub-divided into two levels: similar and dissimilar. Orthographical similar characters were defined to have at least 4 strokes, with same orthographic configuration, and differ in at most one radical. Orthographic dissimilar characters were two characters that differ in more than one radical, and do not share the same phonetic radical. The similarities and differences with the character pairs were rated by 20 advanced Chinese language user (university undergraduates in the present experiment). Anchors were given as references, and raters were asked to rate the similarity of two characters with a 7-point-scale (from -3 to +3). Negative values indicate differences between the pairs, while positive values indicate similarities. Pairs were treated as orthographically similar with rating of +3; while orthographically dissimilar with rating of -3.

Phonology was sub-divided into three levels: same, similar, and dissimilar. Phonologically same characters are homophones, i.e. they have same onset, rime, and tone (ORT). Phonologically similar characters are pairs having identical onset and rime (OR), or identical rime and tone (OT). This group of stimuli should be included to avoid bias due to the lack of orthographically identical pairs. Phonologically dissimilar characters have different onset, rime, and tone (NORT), or only same in either one of the onset, rime, or tone (O / R / T).

Six groups of stimuli were created according to the two above factors. Each group included 10 pairs of stimuli, which created totally 60 pairs of characters. The features and examples of the stimuli were summarized in table 2.

Table 2. <u>The features and examples in the six groups of stimuli (numbers of stimuli are shown</u>

<u>underlined in brackets).</u>

Orthographic / Phonological	Similar	Dissimilar
Same	***OsPsa*** Homophones, similar orthography (<u>10</u>) Examples:噪-躁, 瑣-鎖, 睹-賭	***OdPsa*** Homophones, dissimilar orthography (<u>10</u>) Examples:範-泛, 稀-犧, 焚-墳
Similar	***OsPsi*** OR(<u>5</u>) / OT(<u>5</u>), similar orthography Examples: 妨-紡, 跪-詭 OR 晾-掠, 踩-睬 OT	***OdPsi*** OR(<u>5</u>) / OT(<u>5</u>), dissimilar orthography Examples: 怨-緣, 掀-遣 OR 拐-軌, 蔓-邁 OT
Dissimilar	***OsPd*** NORT(<u>4</u>) /O(<u>2</u>) /R(<u>2</u>) /T(<u>2</u>), similar orthography Examples: 綿-錦 NORT　銷-哨 O 誦-蛹 R　　蠻-巒 T	***OdPd*** NORT(<u>4</u>) /O(<u>2</u>) /R(<u>2</u>) /T(<u>2</u>), dissimilar orthography Examples: 賊-監 NORT　氫-繫 O 鑽-捐 R　　贏-盟 T

Sentences were made up by each of the 60 target characters. The target characters were

being substituted by their corresponding pairs in presenting the stimuli to the subjects. For

example, for the target 睹/tou35/[*look at, observe*], the sentence with substituted phonological

and orthographic substitute 賭/tou35/[*gamble*] will be「這位證人目賭事件發生的經過。」

Each of these 60 sentences with a substituted character requires correction. Control group for

each grade consisted of 10 sentences without error. Ten high frequency fillers were also

included to reduce subjects' frustration when working with the low frequency characters.

A total of 80 sentences with the first 5 trial sentences were presented in two booklets (A &

B). Sentences length was controlled, ranging from 11 to 14 characters. Means and standard

deviations of the length of sentences are shown in table 3.

Table 3.　Means and standard deviations (in brackets) of the length of sentences.

Grade	*OsPsa*	*OsPsi*	*OsPd*	*OdPsa*	*OdPsi*	*OdPd*
3	11.9 (0.54)	12.3 (0.78)	11.9 (0.94)	12.2 (0.98)	12.0 (0.77)	12.0 (1.14)
4	12.2 (0.98)	12.4 (0.92)	12.3 (1.00)	12.2 (1.19)	12.3 (1.10)	12.4 (0.92)
5	12.3 (0.90)	12.2 (1.08)	12.3 (1.00)	12.0 (1.00)	12.3 (1.10)	12.1 (0.94)

The order of the stimuli was randomized. Each stimulus was printed in black using the "biau kai" font (標楷體) (which is the same as text printed on common Chinese language textbooks), sized 24 at the centre of a plain white paper in half of an A4 size, with the back of page printed dark for avoiding seeing through. Each sentence was illustrated by a gray-scale clipart to facilitate comprehension. The pages were bind to form booklets.

Procedures

The 105 selected subjects were invited to perform a sentence proof-reading task in a classroom setting. The tasks were administered separately according to grades. Five trials were given for each subject in order to familiarize with the timed task. Each of the subjects was presented with 2 booklets, one after the other. Practice effects were balanced across subjects with ABBA counterbalancing for the two booklets A and B. Subjects were allowed 15 seconds to complete each target sentence. They were asked to put a tick, or to circle any erroneous characters within the fixed time. After the time limit, a "ding" sound was presented, and the subjects were instructed to flip the page to the next sentence. This was repeated until the last question in the booklet was completed.

Data Analysis

The subjects' performances was marked either right or wrong for quantitative analysis, according to whether they were able to circle the substituted wrong character for each sentence. The number of correct identification of errors in each of the six groups of stimuli of each subject was calculated. The numbers (out of 10) were then entered into a 2 x 3 two-way analysis of variance (ANOVA) with repeated measures design.

Since the stimuli for the three grades were different, performances in the three grades were analyzed separately. The pattern of the interactions between two factors was chosen to compare across the three grades for qualitative analysis to note any development shift in reading Chinese.

Tukey HSD test was used for post-hoc analysis for all pair-wise comparisons, in order to investigate which specific factors contribute to the significant effects.

Results

In order to investigate the effects of phonological and orthographic similarities on Chinese

reading, ANOVA was performed separately for the three grades, on the subjects' number of

correct identification of the wrong characters in the 60 stimuli. The results of the three grades

are summarized in Table 4. Tukey HSD test was used as post-hoc test.

Table 4.   Main effects of similar orthography (ORTHO) and similar phonology (PHONO), and

their interaction effects (ORTHO*PHONO) for the 3 grades. (Effects that are

statistically significant are marked with asterisks(*))

Grade	Effects	SS	d.f.	MS	F	p
Grade 3	ORTHO	129.6	1	129.6	112.5	.00000*
	PHONO	*1.2*	*2*	*0.6*	*0.4*	*0.70473*
	ORTHO*PHONO	59.8	2	29.9	20.5	.00000*
Grade 4	ORTHO	139.2	1	139.2	111.2	.00000*
	PHONO	127.1	2	63.6	39.8	.00000*
	ORTHO*PHONO	56.6	2	28.3	24.3	.00000*
Grade 5	ORTHO	14.4	1	14.4	9.65	.00400*
	PHONO	68.6	2	34.3	29.88	.00000*
	*ORTHO*PHONO*	*4.47*	*2*	*2.23*	*2.34*	*0.10400*

For grade 3 subjects, the main effect of orthographic similarity was significant,

$F(1,34)=112.47$, $p<.00001$; while the main effect of phonological similarity was statistically

insignificant ($p>0.05$). However, the interaction between these two factors was significant,

$F(2,68)=20.549$, $p<.00001$.

Although there was no significant main effect of phonological similarity, with the

post-hoc test, it was shown that when orthography was dissimilar, the values of phonologically

similar and dissimilar groups were significantly different ($p < .05$), while same and dissimilar

groups were statistically insignificant ($p > .05$) (dotted line in Figure 2). These were the same

when orthography was similar (solid line in Figure 2), although the better and poorer

performances were reversed.

Figure 2. Interaction effects of orthographic similarity and phonological similarity for grade 3

(the vertical bars in the graph indicate the mean and the range of SD 1.0)

For grade 4 subjects, the main effects of orthographic similarity and phonological

similarity were both significant, resulting in $F(1,34)=111.16$, $p<.00001$, and $F(2,68)=39.814$,

$p<.00001$ respectively. The interaction between these two factors was also significant,

F(2,68)=24.339, *p*=.00000.

Except that when phonologically similar, the two orthography groups were statistically

insignificant (*p* > .05), the post-hoc test proved all the other comparable pairs significantly

different (p < .005)

Figure 3. Interaction effects of orthographic similarity and phonological similarity for grade 4

(the vertical bars in the graph indicate the mean and the range of SD 1.0)

For grade 5 subjects, the main effects of orthographic similarity and phonological

similarity were both significant, *F*(1,34)=9.6482, *p*<.005, and *F*(2,68)=29.877, *p*<.00001

respectively. However, no significant interaction effect between these two factors was found

(*p*>0.05).

Although significant differences were shown for orthographically similar and dissimilar groups, same as the grade 3 and 4 groups, the post-hoc results showed that when characters were phonologically similar, the 2 orthography groups were statistically insignificant ($p > .05$).

Although significant main effect of phonological similarity was shown, with the post-hoc test, it was shown that when orthography was either similar or dissimilar, the values of phonologically similar vs. dissimilar groups were not significantly different ($p > .05$). The post-hoc results confirmed that, with similar or dissimilar orthography, the values of phonologically same and dissimilar groups were statistically significant ($p < .05$).
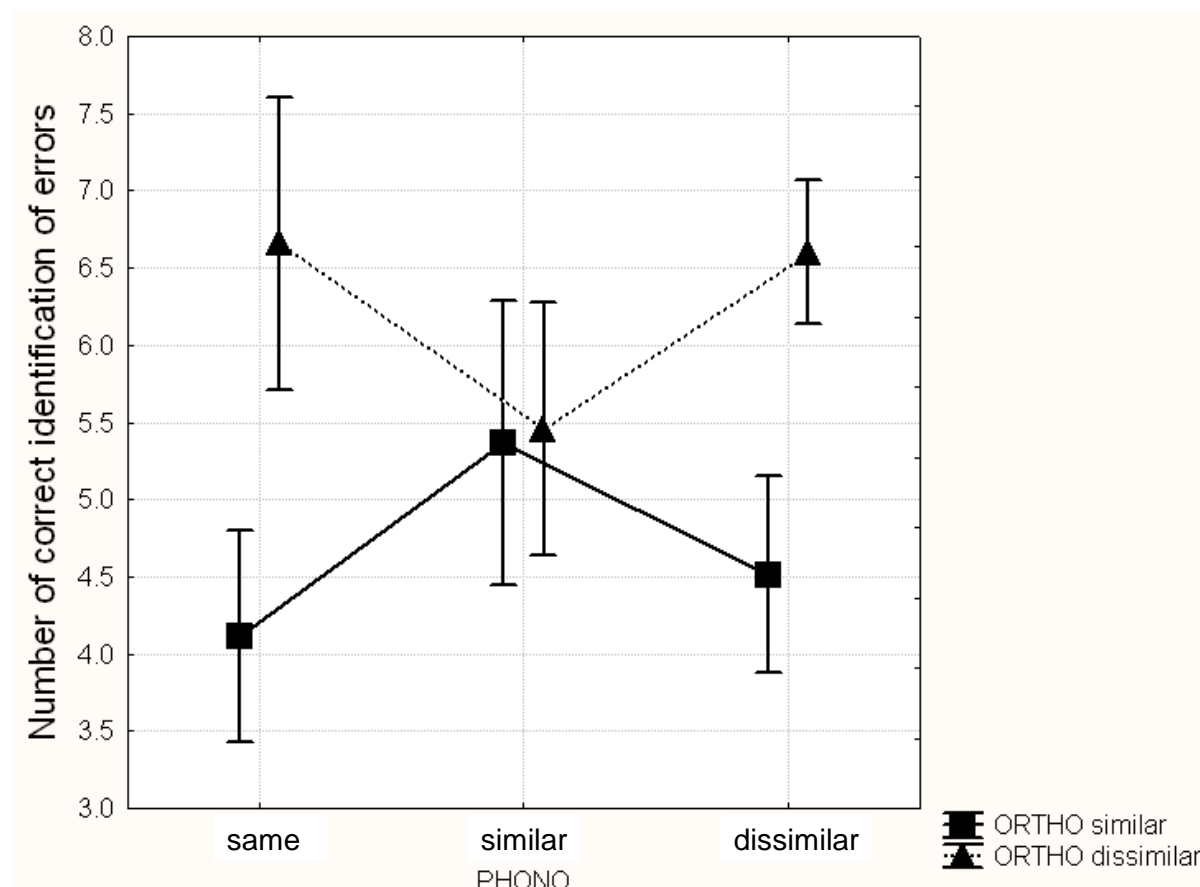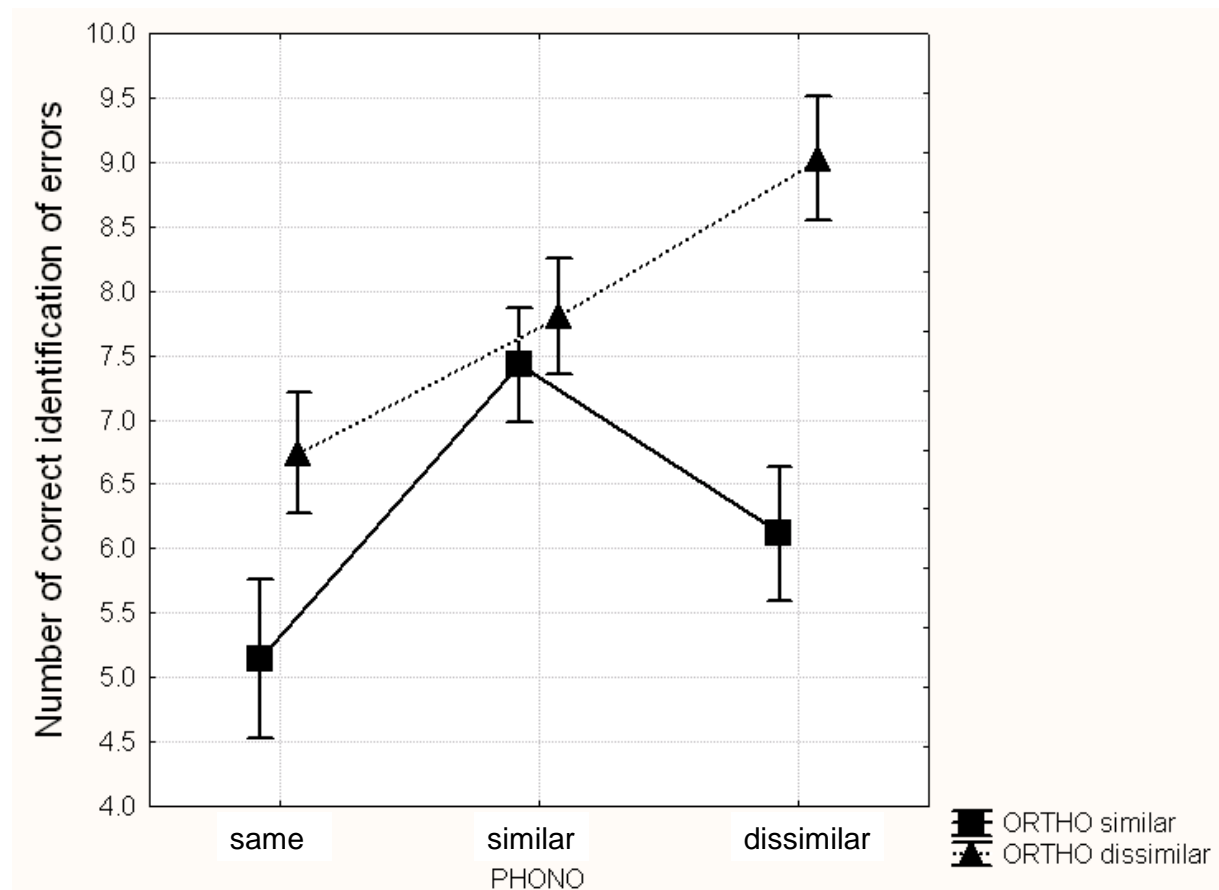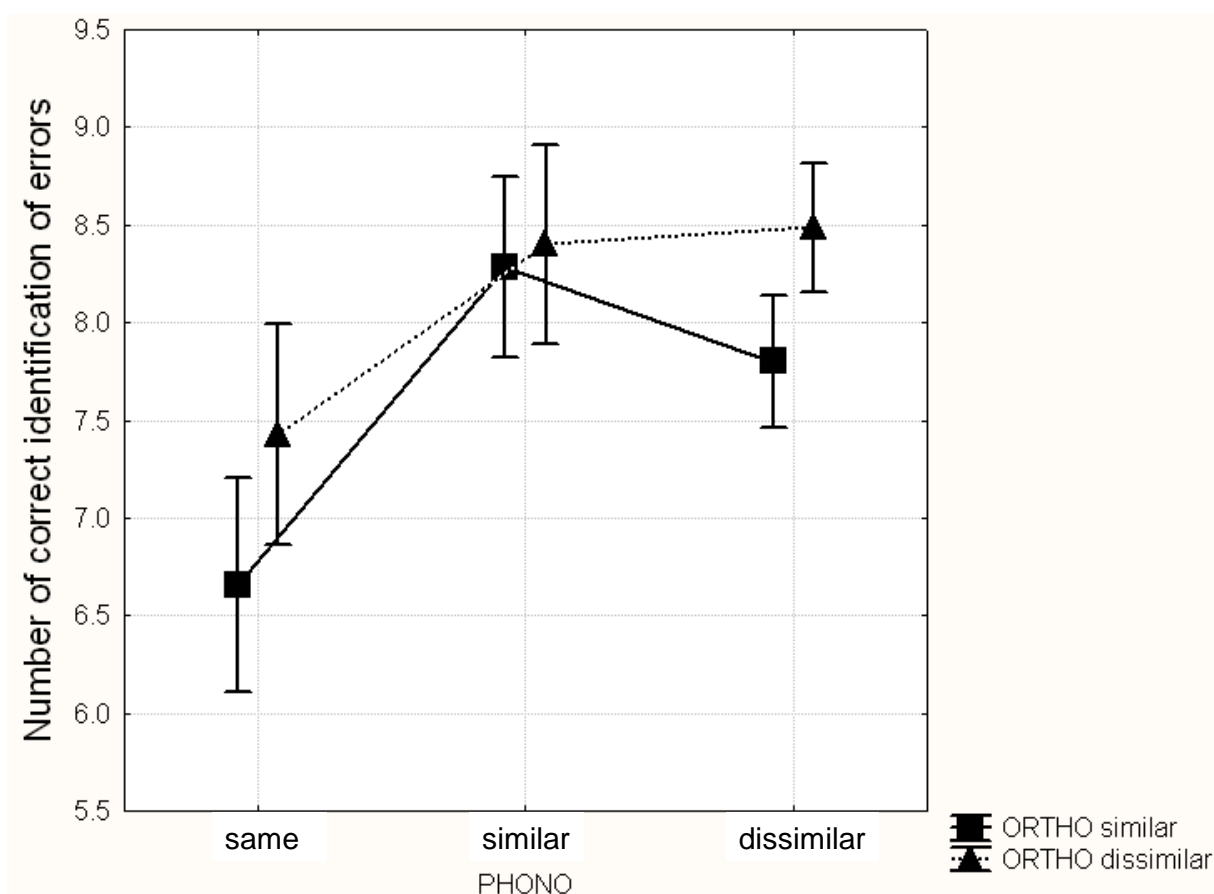

Figure 3. Interaction effects of orthographic similarity and phonological similarity for grade 5 (the vertical bars in the graph indicate the mean and the range of SD 1.0)

Discussion

Main Effects of the Orthography

Across grade 3, 4 and 5, readers tended to perform poorer in identifying orthographically similar characters in the proof-reading task than the dissimilar orthography group. It could be explained by that similar orthography created more confusion with the target characters. The readers might have depended on the orthography of the words to read the sentences and missed out the wrong substituted words which "looked" similar. It can be concluded that all of the three grades rely on the characters' orthography in reading the Chinese characters.

This supports the hypothesis about high grades that *Od* is better than *Os* groups, but contradict the hypothesis about low grades that they are similar.

Main Effects of the Phonology

Comparing groups with same and dissimilar phonology, grade 3 readers performed similarly, while grade 4 and 5 readers tended to perform poorer in identifying phonologically similar characters in the task than the dissimilar phonology group. These contradict with the hypothesis for both high and low grades.

However, if similar phonology and dissimilar phonology are taken for comparison, as for orthography to prevent bias of results of using same phonology group, the performances of the three grades were similar. In other words, readers tended to perform similarly in identifying phonologically similar and dissimilar characters in the task across grades.

The insignificant phonological effect can be explained by that phonology generally does not play a strong role of in reading the stimuli sentences. More detailed analysis shows that the subjects of grade 4 and 5 identified more errors in stimuli of dissimilar phonology than same phonology group (table 5). This result suggested that after grade 3, readers tended to make use of phonological rules. The heavier reliance on the characters' phonology rendered them less able to identify phonologically identical characters which were contextually inappropriate.

Table 5.   Main Effects of Phonology of the three grades of subjects

Grades		Performances across grades	
3	Phonologically similar	*not significantly different*	Phonologically dissimilar
	Phonologically same	*not significantly different*	Phonologically dissimilar
4	Phonologically similar	*not significantly different*	Phonologically dissimilar
	Phonologically same	*poorer than*	Phonologically dissimilar
5	Phonologically similar	*not significantly different*	Phonologically dissimilar
	Phonologically same	*poorer than*	Phonologically dissimilar

Interaction effects

When orthography was dissimilar, effects of phonological similarity were different in the three grades. As shown in table 6, moving up the grades, readers tended to make use of phonology more, performing better than low grades in phonologically similar group.

When orthography was similar, comparing same and dissimilar phonology group, as we move up the grades, readers tended to make use of the differences in phonology to help them identify the errors in the stimuli sentences, hence performance was better for dissimilar group relatively for higher grades.

The interaction effects support the hypothesis of similar phonological performances for

high grades. For grade 3 and grade 4 orthographically similar group, a reverse pattern of

performances was noted, phonological similar group was performed better than the dissimilar

group. This pattern could be explained by that the client strongly rely on orthography, with

favorable phonological factor (dissimilar), the performances were much better for *Od* than for

Os.

Table 6.   <u>Interaction Effects of the Phonology and Orthography of the three grades of subjects</u>

[Keys: "=" indicates *not significantly different*; ">" indicates *better than*; "<" indicates *poorer than*]

Grades	Performances across grades (P: phonology)			
3	Orthographically similar	P-same	=	P-dissimilar
		P-similar	**>**	**P-dissimilar**
	Orthographically dissimilar	P-same	=	P-dissimilar
		P-similar	**<**	**P-dissimilar**
4	Orthographically similar	P-same	<	P-dissimilar
		P-similar	**>**	**P-dissimilar**
	Orthographically dissimilar	P-same	<	P-dissimilar
		P-similar	**<**	**P-dissimilar**
5	Orthographically similar	P-same	<	P-dissimilar
		P-similar	**=**	**P-dissimilar**
	Orthographically dissimilar	P-same	<	P-dissimilar
		P-similar	**=**	**P-dissimilar**

Conclusions

Chinese is a suitable testing ground to examine the effects of orthography and phonology

during the reading of Chinese text due to its nature of independency between the orthographic

and phonological forms. Unlike alphabetic languages, conclusive statement could not be drawn

in the studies on effects of phonological and orthographic similarities on reading, due to the

inability to separate orthography and phonology clearly created limitations in studies using

alphabetic languages. The orthography of the alphabetic languages was special, words are formed by letters. Any conclusion might only reflect the special feature of their orthography rather than a universal theory of reading, at least those conclusion made could not be applied to Chinese language which is logographic.

Contradicting with previous studies, the present study using Chinese as the experiment gave us a new insight in the issue of the role played by orthography and phonology in reading.

In conclusion, orthography is essential in the process of reading for the three subject groups. From the results of the study, it can be hypothesized that primary school readers used visual access for semantic activation, readers make use of the Chinese characters' orthography to link to their meaning in reading, and thus orthographic activation occurred before phonology is activated.

The other finding was that phonology did not play a strong role for access to semantics for young readers of grade 3. There was slight development trend shown, comparing same-dissimilar phonology, readers tended to learn the phonological rules after grade 3, and rely less on the sound of the characters on reading.

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Appendix A   Stimuli of Grade 3

code	target	ipa	char2	ipa	sentence
OsPsa1	緩	wun4	援	wun4	一位老婆婆正在援慢的步行。
OsPsa2	稠	cau4	綢	cau4	香港是個人口綢密的城市。
OsPsa3	僅	gan2	饉	gan2	小明的成績只是饉次於小美。
OsPsa4	托	tok3	託	tok3	蔚藍的天空襯託出陽光的燦爛。
OsPsa5	鱲	laap6	臘	laap6	我乘坐公車到赤臘角機場去。
OsPsa6	攔	laan4	欄	laan4	一塊大石欄住了前面的道路。
OsPsa7	陶	tou4	淘	tou4	小強淘醉於悅耳的音樂聲中。
OsPsa8	徹	cit3	澈	cit3	那一次的實驗澈底的失敗了。
OsPsa9	噪	cou3	躁	cou3	請你不要在深夜製造躁音！
OsPsa10	譏	gei1	饑	gei1	驕傲的白兔饑笑小龜走得慢。
OdPsa1	漏	lau6	陋	lau6	連夜大雨令小屋的屋頂陋水。
OdPsa2	憂	jau1	幽	jau1	媽媽十分擔幽生病了的妹妹。
OdPsa3	租	zou1	糟	zou1	小明糟了一間舖位售賣生果。
OdPsa4	範	faan6	泛	faan6	老師為我們示泛進行實驗的方法。
OdPsa5	痺	bei3	泌	bei3	雙腳會因為坐得太久而感到麻泌。
OdPsa6	糙	cou3	醋	cou3	鱷魚的皮膚表面十分粗醋。
OdPsa7	穀	guk1	谷	guk1	多吃谷類食物會對身體健康。
OdPsa8	貫	gun3	灌	gun3	地下鐵路灌通了整個九龍。
OdPsa9	悠	jau4	猶	jau4	外公退休後過著猶閒的生活。
OdPsa10	泉	cyun4	荃	cyun4	那條小河的荃水真的很清涼！
OsPsi1	妨	fong4	紡	fong2	頑皮的弟弟紡礙著哥哥溫習。
OsPsi2	卷	gyun2	券	gyun3	古人說：「讀萬券書不如行萬里路」
OsPsi3	摩	mo1	磨	mo4	這座磨天大廈是全世界最高的。
OsPsi4	稍	saau2	梢	saau1	你梢微跑快一點便拿到冠軍了！
OsPsi5	蹤	zung1	縱	zung3	警察正在找尋小偷的縱影。
OsPsi6	擴	kwok3	礦	kwong3	山火不停的礦散了十多個小時。
OsPsi7	悅	jyut6	銳	jeoi6	音樂室那邊傳來銳耳的歌聲。
OsPsi8	煤	mui4	謀	mau4	我的家是利用謀氣來煮食。
OsPsi9	暮	mou6	幕	mok6	我們登高欣賞日落美麗的幕色。
OsPsi10	杆	gon1	奸	gaan1	小明跳過跑道上的每個欄奸。
OdPsi1	叭	baa1	壩	baa3	妹妹得意洋洋地在吹喇壩。
OdPsi2	怨	jyun3	緣	jyun4	大家都埋緣大雨令旅行取消了。
OdPsi3	乞	hat1	瞎	hat6	小明瞎求媽媽給他買雪糕。
OdPsi4	川	cyun1	寸	cyun3	星期天，街上的行人寸流不息。
OdPsi5	賢	jin4	彥	jin6	我的媽媽真是個彥妻良母。
OdPsi6	踩	caai2	醜	cau2	星期天，哥哥和我到郊外醜單車。

OdPsi7	拐	gwaai2	軌	gwai2	年老的祖母要軌杖輔助走路。
OdPsi8	掩	jim2	毽	jin2	打噴嚏的時候要把口鼻毽蓋。
OdPsi9	械	haai6	系	hai6	哥哥是個設計機系人的天才。
OdPsi10	蠶	caam4	籌	cau4	籌蟲吐絲變成蛹，最後變成飛蛾。
OsPd1	綿	min4	錦	gam2	錦羊身上長滿純白的羊毛。
OsPd2	鳴	ming4	嗚	wu1	窗外面有一隻小鳥吱吱地嗚叫。
OsPd3	截	zit6	裁	coi4	歌唱比賽已經裁止報名了。
OsPd4	灌	gun3	權	kyun4	天上落下來的雨水權溉著花兒。
OsPd5	踐	cin5	殘	caan4	殘踏草地是沒有公德心的行為。
OsPd6	絡	lok3	略	loek6	畢業之後我們要保持聯略！
OsPd7	壤	joeng6	鑲	soeng1	春天了，小草從土鑲裡探出頭來。
OsPd8	誦	zung6	蛹	jung2	姐姐在朗蛹比賽中獲得冠軍。
OsPd9	俗	zuk6	裕	jyu6	西施是一位脫裕的大美人。
OsPd10	折	zit3	拆	caak3	遇到挫拆時不要輕易放棄！
OdPd1	縫	fung4	襯	can3	姐姐給我襯製了一個布娃娃。
OdPd2	賊	caak6	監	gaam1	捉監是警察其中一個職責。
OdPd3	閘	zaap6	棚	paang4	我站在學校棚門外等候媽媽。
OdPd4	旗	kei4	褥	juk6	紅色的國褥在微風中飄揚。
OdPd5	週	zau1	誌	zi3	這本誌刊一星期出版一次。
OdPd6	孕	jan6	嬰	jing1	媽媽懷嬰十個月後，便誕下了弟弟。
OdPd7	鑽	zyun3	捐	gyun1	閃閃發亮的捐石十分名貴。
OdPd8	餾	lau6	垢	gau3	很多人喜歡在便利店買蒸垢水。
OdPd9	邏	lo6	獄	juk6	警察在街道上巡獄，維持治安。
OdPd10	峯	fung1	岡	gong1	冒險家希望爬上世上最高的山岡。
Corr1	旱	hon5	X	X	農作物因為乾旱而失收了。
Corr2	砌	cai3	X	X	弟弟十分喜歡玩砌圖遊戲。
Corr3	慘	caam2	X	X	這個故事的結局非常淒慘。
Corr4	魄	paak3	X	X	年老的祖父仍然很有魄力。
Corr5	罩	zaau3	X	X	妹妹因為感冒，所以要帶著口罩。
Corr6	阱	zing6	X	X	小兔掉下獵人佈下的陷阱。
Corr7	豚	tyun4	X	X	一條活潑的海豚正在表演玩球！
Corr8	挖	waat3	X	X	探險家在地上挖出一個寶藏來。
Corr9	艘	sau2	X	X	一艘帆船慢慢地在海上經過。
Corr10	承	sing4	X	X	爸爸應承明天帶我到遊樂場。

Appendix B   <u>Stimuli of grade 4</u>

code	target	ipa	char2	ipa	sentence
OsPsa1	瞎	hat6	轄	hat6	瞎子看不見東西，要靠感覺走路。
OsPsa2	募	mou6	暮	mou6	這所老人院正在招募義工。
OsPsa3	搏	bok3	膊	bok3	警察經過一場搏鬥才把犯人拘捕。
OsPsa4	睹	dou2	賭	dou2	這位證人目睹事件發生的經過。
OsPsa5	稠	cau4	綢	cau4	香港是個人口稠密的城市。
OsPsa6	徹	cit3	撤	cit3	那一次的實驗徹底的失敗了。
OsPsa7	瑣	so2	鎖	so2	我很快便把生活瑣事都忘記了。
OsPsa8	鱲	laap6	臘	laap6	我乘坐公車到赤鱲角機場去。
OsPsa9	緝	cap1	輯	cap1	警方正通緝一名危險的罪犯。
OsPsa10	賬	zoeng3	帳	zoeng3	這個月的賬目表已收到了。
OdPsa1	憂	jau1	幽	jau1	媽媽十分擔憂生病了的妹妹。
OdPsa2	毀	wai2	萎	wai2	這次地震摧毀了很多人的家園。
OdPsa3	衷	cung1	蔥	cung1	同學們衷心感激教導我們的老師。
OdPsa4	痺	bei3	泌	bei3	雙腳會因為坐得太久而感到麻痺。
OdPsa5	稀	hei1	犧	hei1	那朵花是一種稀有的植物。
OdPsa6	惘	mong5	妄	mong5	他對複雜的數學題目感到迷惘。
OdPsa7	蔔	baak6	帛	baak6	多吃紅蘿蔔有助視力發展。
OdPsa8	貶	bin2	扁	bin2	叔叔老是貶低別人來抬高自己。
OdPsa9	糙	cou3	躁	cou3	鱷魚的皮膚表面十分粗糙。
OdPsa10	焚	fan4	墳	fan4	這場山火焚燒了許多樹林。
OsPsi1	稍	saau2	梢	saau1	你稍為勤力一點便會考試合格了！
OsPsi2	跪	gwai6	詭	gwai2	古代的人在皇帝面前要下跪。
OsPsi3	諷	fung3	楓	fung1	自大的小明嘲諷小強成績不好。
OsPsi4	褸	lau5	髏	lau4	天橋底有個衣衫襤褸的露宿者。
OsPsi5	鈔	caau1	炒	caau2	香港有六種不同面值的鈔票。
OsPsi6	裕	jyu6	峪	juk6	小健的爸媽是醫生，家境很富裕。
OsPsi7	繡	sau3	嘯	siu3	媽媽在衣服上繡上我的名字。
OsPsi8	踩	caai2	睬	coi2	星期天，我們到郊外踩單車。
OsPsi9	鯉	lei5	裡	leoi5	鯉魚的顏色很美，值得觀賞。
OsPsi10	晾	long6	掠	loek6	媽媽把濕的衣服掛在窗前晾曬。
OdPsi1	挖	waat3	猾	waat6	探險家在地上挖出一個寶藏來。
OdPsi2	噸	deon1	鈍	deon6	這艘貨船運載著十噸貨物。
OdPsi3	盃	bui1	狽	bui3	台上，哥哥興奮的捧著獎盃。
OdPsi4	掀	hin1	遣	hin2	世界盃掀起一片踢足球的熱潮。
OdPsi5	薦	zin3	甄	zin1	老師推薦了五位同學參選領袖生。
OdPsi6	跛	bai1	崩	bang1	那個跛腳的婆婆要拿著拐杖走路。

OdPsi7	脅	hip3	憲	hin3	濫用天然資源對大自然造成威脅。
OdPsi8	拐	gwaai2	軌	gwai2	年老的祖母要拐杖輔助走路。
OdPsi9	沱	to4	濤	tou4	我回家時正下著滂沱大雨。
OdPsi10	侈	ci2	扯	ce2	他常常買名牌，過奢侈的生活。
OsPd1	僥	hiu1	撓	naau4	驕傲的小明僥倖勝出便沾沾自喜。
OsPd2	廓	kwok3	廊	long4	這個女孩的輪廓分明，十分漂亮。
OsPd3	嫌	jim4	賺	zaan6	他鬼鬼祟祟的，惹起偷竊的嫌疑。
OsPd4	蠻	maan4	戀	lyun2	野蠻的弟弟搶走了妹妹的玩具。
OsPd5	銷	siu1	哨	saau3	這本圖書很著名，銷量很高。
OsPd6	稚	zi6	椎	zeoi1	三歲的妹妹唸幼稚園低班。
OsPd7	壤	joeng6	鑲	soeng1	春天了，小草從土壤裡探出頭來。
OsPd8	磅	bong6	螃	pong4	現代化的街市都採用電子磅。
OsPd9	狹	haap3	硤	gip3	救護車正經過狹窄的小路。
OsPd10	揭	kit3	褐	hot3	好市民頒獎禮今天正式揭幕。
OdPd1	丐	koi3	籬	lei4	可憐的乞丐在馬路旁邊討飯。
OdPd2	辯	bin6	誨	fui3	居港權的問題引起公眾的辯論。
OdPd3	澆	giu1	呈	cing4	爸爸每天給露台上的植物澆水。
OdPd4	鷗	au1	涕	tai3	一群海鷗在湖上尋找獵物。
OdPd5	氫	hing1	繫	hai6	我在年宵市場買了個氫氣球。
OdPd6	懼	geoi6	芥	gaai3	自從被狗咬傷，她便對狗產生恐懼。
OdPd7	蠶	caam4	斬	zaam2	蠶蟲吐絲變成蛹，最後變成飛蛾。
OdPd8	翡	fei2	卑	bei1	我喜歡看翡翠台的兒童節目。
OdPd9	邏	lo6	獄	juk6	警察在街道上巡邏，維持治安。
OdPd10	孕	jan6	諾	nok6	媽媽懷孕十個月後，便誕下了弟弟。
Corr1	碑	bei1	X	X	這是一面紀念孫中山的石碑。
Corr2	繳	giu2	X	X	媽媽到便利店繳交電話費。
Corr3	砌	cai3	X	X	弟弟十分喜歡玩砌圖遊戲。
Corr4	率	seot1	X	X	將軍率領著千軍萬馬到戰場迎戰。
Corr5	牢	lou4	X	X	將軍把戰爭中的俘虜送到牢獄去。
Corr6	嘈	cou4	X	X	嘈吵的環境使我不能集中。
Corr7	嚏	tai3	X	X	打噴嚏的時候要掩著口鼻。
Corr8	斧	fu2	X	X	他用斧頭砍伐森林裏的樹木。
Corr9	啄	doek3	X	X	啄木鳥吃掉蟲子，是樹的好醫生。
Corr10	罩	zaau3	X	X	妹妹因為感冒，所以要帶著口罩。

Appendix C   Stimuli of grade 5

code	target	ipa	char2	ipa	sentence
OsPsa1	搏	bok3	膊	bok3	警察經過一場搏鬥才把犯人拘捕。
OsPsa2	悽	cai1	棲	cai1	人民在戰爭時生活很悽慘。
OsPsa3	緝	cap1	輯	cap1	警方正通緝一名危險的罪犯。
OsPsa4	摧	ceoi1	璀	ceoi1	地震摧毀了很多人的家園。
OsPsa5	瑣	so2	鎖	so2	我很快便把生活瑣事都忘記了。
OsPsa6	睹	dou2	賭	dou2	這位證人目睹事件發生的經過。
OsPsa7	誨	fui3	晦	fui3	我們要用心記著老師的教誨。
OsPsa8	嫁	gaa3	稼	gaa3	媽媽在二十五歲時嫁給爸爸。
OsPsa9	鱲	laap6	臘	laap6	我乘坐公車到赤鱲角機場去。
OsPsa10	梁	loeng4	粱	loeng4	梁山伯是中國傳說中的男主角。
OdPsa1	賜	ci3	熾	ci3	皇帝賞賜了很多黃金給他。
OdPsa2	焚	fan4	墳	fan4	這場山火焚燒了許多樹林。
OdPsa3	秘	bei3	痺	bei3	我答應了小美要保守秘密。
OdPsa4	瞰	ham3	礅	ham3	麻鷹在空中盤旋俯瞰大地。
OdPsa5	脅	hip3	怯	hip3	濫用天然資源對大自然造成威脅。
OdPsa6	冶	je5	惹	je5	音樂可以幫助我們陶冶性情。
OdPsa7	拘	keoi1	俱	keoi1	警方拘捕了一位非法入境者。
OdPsa8	沃	juk1	旭	juk1	這兒土地肥沃，很適合耕種。
OdPsa9	貶	bin2	扁	bin2	叔叔老是貶低別人來抬高自己。
OdPsa10	惘	mong5	妄	mong5	他對複雜的數學題目感到迷惘。
OsPsi1	諷	fung3	楓	fung1	自大的小明嘲諷小強成績不好。
OsPsi2	狡	gaau2	蛟	gaau1	狡猾的狐狸欺騙了小紅帽。
OsPsi3	稍	saau2	梢	saau1	你稍為勤力一點便會考試合格了！
OsPsi4	跪	gwai6	詭	gwai2	古代的人在皇帝面前要下跪。
OsPsi5	粹	seoi6	悴	seoi5	那次打破花瓶純粹是意外。
OsPsi6	弦	jin4	炫	jyun4	我最喜愛的小提琴的弦線斷了。
OsPsi7	惟	wai4	淮	waai4	小美是足球隊中惟一的女孩子。
OsPsi8	晾	long6	掠	loek6	媽媽把濕的衣服掛在窗前晾曬。
OsPsi9	募	mou6	驀	mak6	這所老人院正在招募義工。
OsPsi10	踱	dok6	鍍	dou6	外公在花園裡慢慢的踱步。
OdPsi1	鋸	geoi3	矩	geoi2	爸爸小心地使用鋒利的電鋸。
OdPsi2	撼	ham6	堪	ham1	這齣電影的場面真的十分震撼！
OdPsi3	乞	hat1	瞎	hat6	小明乞求媽媽給他買雪糕。
OdPsi4	輻	fuk1	洑	fuk6	手提電話會放出強烈的輻射。
OdPsi5	噸	deon1	鈍	deon6	這艘貨船運載著十噸貨物。
OdPsi6	跛	bai1	崩	bang1	那個跛腳的婆婆要拿著拐杖走路。

OdPsi7	弛	ci4	纏	cin4	運動前要做熱身鬆弛一下肌肉。
OdPsi8	俘	fu1	詠	fui1	將軍把戰爭中的俘虜送到牢獄去。
OdPsi9	汰	taai3	炭	taan3	這個舊款的電話被淘汰了。
OdPsi10	蔓	maan6	邁	maai6	這種病菌正迅速地四處蔓延。
OsPd1	耽	daam1	枕	zam2	你快點出發吧，以免耽誤行程。
OsPd2	擅	sin6	檀	taan4	多才多藝的小美最擅長唱歌。
OsPd3	廓	kwok3	廊	long4	這個女孩的輪廓分明，十分漂亮。
OsPd4	僥	hiu1	撓	naau4	驕傲的小明僥倖勝出便沾沾自喜。
OsPd5	挾	hip3	俠	hap6	那個匪徒拿槍挾持著人質。
OsPd6	稚	zi6	椎	zeoi1	三歲的妹妹唸幼稚園低班。
OsPd7	楷	kaai2	揩	haai1	老師正在教我們用毛筆寫楷書。
OsPd8	幢	dung6/zong1	憧	cung1	這一幢白色的房子很特別。
OsPd9	恒	hang4	桓	wun4	他做事缺乏恒心，常常半途而廢。
OsPd10	蠻	maan4	巒	lyun4	野蠻的弟弟搶走了妹妹的玩具。
OdPd1	丐	koi3	籬	lei4	可憐的乞丐在馬路旁邊討飯。
OdPd2	婚	fan1	郎	long4	姊姊穿上雪白的婚紗，漂亮極了！
OdPd3	漱	sau3	刨	paau4	小明習慣在吃東西後漱口。
OdPd4	蔔	baak6	糍	ci4	多吃紅蘿蔔有助視力發展。
OdPd5	懼	geoi6	芥	gaai3	自從被狗咬傷，她便對狗產生恐懼。
OdPd6	瞞	mun4	娩	min5	小明隱瞞著媽媽到公園玩耍。
OdPd7	翡	fei2	姬	gei1	我喜歡看翡翠台的兒童節目。
OdPd8	褸	lau5	醜	cau2	天橋底有個衣衫襤褸的露宿者。
OdPd9	贏	jeng4	盟	mang4	哥哥努力練習，贏了田徑比賽。
OdPd10	盃	bui1	戚	cik1	台上，哥哥興奮的捧著獎盃。
Corr1	膏	gou1	X	X	我們要用適量的牙膏刷牙。
Corr2	罕	hon2	X	X	那朵花是一種罕有的植物。
Corr3	斧	fu2	X	X	他用斧頭砍伐森林裏的樹木。
Corr4	牢	lou4	X	X	你要牢記著老師的教訓啊！
Corr5	嘈	cou4	X	X	嘈吵的環境使我不能集中。
Corr6	碑	bei1	X	X	這是為孫中山先生而建的石碑。
Corr7	蕾	leoi5	X	X	春天了，可愛的花蕾含苞待放。
Corr8	灸	gau3	X	X	爺爺是一位出名的針灸醫師。
Corr9	疤	baa1	X	X	小玲手上的疤痕是因跌倒而來的。
Corr10	繳	giu2	X	X	媽媽到便利店繳交電話費。