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The Effect of Pinyin Input Experience on the Link Between Semantic and Phonology of Chinese Character in Digital Writing

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Abstract With the development of ICT, digital writing is becoming much more common in people's life. Differently from keyboarding alphabets directly to input English words, keyboarding Chinese character is always through typing phonetic alphabets and then identify the glyph provided by Pinyin input-method software while in this process which do not need users to produce orthography spelling, thus it is different from traditional written language production model based on handwriting process. Much of the research in this domain has found that using Pinyin input method is beneficial to Chinese characters recognition, but only a small part explored the effects of individual's Pinyin input experience on the Chinese characters production process. We ask whether using Pinyin input-method will strengthen the semantic-phonology linkage or semantic-orthography linkage in Chinese character mental lexicon. Through recording the RT and accuracy of participants completing semantic-syllable and semantic-glyph consistency judgments, the results found the accuracy of semantic-syllable consistency judgments in high Pinyin input experienced group was higher than that in low-experienced group, and RT was reversed. There were no significant differences on semantic-glyph consistency judgments between the two groups. We conclude that using Pinyin input method in Chinese digital writing can strengthen the semantic-phonology linkage while do not weakening the semantic-orthography linkage in mental lexicon at the same time, which means that Pinyin input method is beneficial to lexical processing involving Chinese cognition.

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Introduction

Digital writing or on-screen writing was defined as alphabetic meaning-making practices that are digitally mediated, including the use of laptop and desktop computers, online and offline operations, word processing and messaging software (Merchant 2008). According to this definition, digital writing includes producing texts such as office files and assignment-task by using computer word processing program, as well as written messages such as e-mail, short message, instant message, blog or chat room of social network site, BBS and so on by using computers, mobile phones and internet.

No matter digital writing or traditional handwriting, its mental process to produce words starts from semantic system in mental lexical, and then activations of phonological lexicon and orthographic lexicon, finally external glyph through peripheral motor process. Both the working model of written picture naming in English and the functional model of reading and writing in Chinese contain the links among semantic system, phonology and orthography representation (Bonin et al. 2001; Weekes et al. 2006).

Except for a few cases when it involves writing pad (screen), which is similar to traditional handwriting, digital writing requires typewriting in most cases. For example, computer keyboard and virtual keyboard of mobile phone require intermittent keyboarding or a touch screen rather than a relatively continuous handwritten action track. English words are combined by 26 letters distributed on the keyboard. We only need to tap corresponding letters when entering words, for example, taping successively the four letters "w, o, r, d" will produce the word "word" on the screen. Compared with handwriting, although English hand movement is turned into typing, the mental process of producing words indicates no fundamental difference, which goes from semantic to phonological lexicon and orthography. A recent study showed that there were not significant differences of recognition and spelling performances between handwriting and keyboarding when learning English words, which suggests that the two writing methods have same effects on the links of semantic, phonological and orthographic representation of words in mental lexicon (Ouellette and Tims 2014).

But Chinese keyboarding process is completely different from English. Chinese characters have unique planar ideographic features and we can't directly type them because there are just 26 English letters on the keyboard. Thus, we must use input method software to transfer letters into characters, which means that computer can automatically match the corresponding Chinese characters and phrases through internal font library of software with the letter or letter string typed by users. Taking Pinyin-input method used by more than 90% Chinese adolescences as an example, if we want to input "汉字" (it means Chinese character), we may keyboard continuously 5 letters "h, a, n, z, i". We may also omit vowels of a character and just input letters "h, a, n, z", "h, z, i", or "h, z", then there will appear some Chinese glyphs which have same syllables including "汉字", "汉子"(it means man), "汗渍"(it means sweat stain) et al in a selection toolbar on screen for us to choose from. Obviously, unlike typing English words, Chinese digital writing based on Pinyin input method changes the traditional paper-pen writing with handwriting glyph into typing phonetic alphabet and glyph choice without writing. In fact, typing Chinese characters only product phonetic alphabet and glyph production is completed through the orthography recognition. So, Chinese digital writing process is not conforming to the written production theory model on the basis of traditional handwriting. On one hand, the activation of orthography perhaps only presents in the stage of subsequent glyph recognition rather than keyboarding phonetic alphabet; on the other hand, typing process includes the kinesthesia and visual feedbacks of alphabet those handwriting Chinese characters have not, although the latter may automatically activate

phonology. These are very different experiences from handwriting Chinese characters in language use. Then, will the change of writing production mechanism resulted by using Pinyin-input keyboarding Chinese words strengthen the semantic-phonology linkage and weaken the semantic-orthography linkage in mental lexicon?

A small number of researches discussed the effects of Pinyin-input method on Chinese character processing and their conclusions weren't unanimous. Tan et al. (2013) investigated the relation between Chinese children's using Pinyin-input method and their word reading performance. The results indicated a significantly negative correlation between reading score and Pinyin-input method, so they believed that Children's using Pinyin-input method could hinder the development of their reading ability. But seen from the process of keyboarding to produce character, the character choice is after keyboarding letters and children need establish correct phonology-orthography linkage to select suitable character. This means that if children have more Pinyin input experience, they will have more orthographic choices and their phonology-orthography links of mental lexicon are stronger, which would result in children's higher level of reading or characters recognition. Due to the survey's uncontrollable factors as previous spelling ability or network activities, especially, the characters used to test children reading ability are not consistent to those they input in daily life, so the conclusion of the previous study deserves further discussion.

Contrary to the above research, taking 10-year-old primary school students as participants, high-frequency words as materials, a study (Qian and Feng 2004) used homograph and homophone as judgment tasks, in which participants need to judge the orthographic (or phonologic) consistency of two Chinese characters presented at the same time, and the result showed that Pinyin-input method positively affects both orthographic and phonologic processes. Another study (Zhu et al. 2009) presented college students with low-frequency words and asked them to judge whether the syllable of a character includes a certain consonant (as "b") or vowel (as "an") and whether the orthography of a character includes a certain radical (as "忄"), the result indicated that participants with higher Pinyin input experience did better in the above two experimental tasks. It suggests Pinyin-input experience promotes phonologic process as well as orthographic process.

The above two researches reveal that Pinyin input has positive effects on the lower-level processing of Chinese characters such as orthography recognition and phonology judgment. Because characters are presented at first, the two studies belong to the exploration of reading or recognition of Chinese characters. Actually, the process of Chinese character production with Pinyin-input is the process of word production, which involves the activation from semantic system to phonologic and orthographic representation at deeper levels. So, it is especially necessary to explore the effects of Pinyin input on word production.

Only one literature discussed the effects of Chinese character input method on the links of semantic-orthography and semantic-phonology from the perspective of word production. Zhang and Li (2010) took picture-orthography or picture-phonology consistency judgment of picture-word interference paradigm as tasks to explore the orthographic and phonologic processes of college students who respectively used two different character-input methods. In the tasks, picture was presented at first and orthography or syllable appeared after 500 ms. Participants were asked to judge whether the orthography or syllable was the correct name (glyph or pronunciation) of the corresponding picture. The results suggested that participants who used Pinyin-input method did much better in picture-phonology consistency judgment and participants who used Wubi (a glyph-code) input method performed better in picture-orthography consistency judgment. This study actually compared semantic-orthography and semantic-phonology connection strength in the word-production of the different input methods users because it presented pictures to activate semantic system before orthography or syllable judg-

ment. But the problems are: firstly, the study could only illustrate that the semantic-phonology connections of Pinyin-input users are stronger than those of Wubi input method users, but could not explain whether there were semantic-phonology and semantic-orthography differences between Pinyin-input method users with higher and lower experience; secondly, although the picture-activating semantic system method could avoid the orthographic or phonologic interference of materials presented previously, it was not really fit for the actual situation in which people express propositions rather than concepts by using Pinyin-input method. In fact, researchers often take sentences as activating material in the study of language production (Aristei et al. 2011; Segaert et al. 2012).

Based on the above consideration, from the perspective of word production, this study will adopt classic picture-word interference paradigm and idiom–activating-semantic tasks to explore the effects of Pinyin-input experience on semantic-orthography and semantic-phonology of Chinese characters, and meanwhile compare the effect of idiom activating with picture.

Method

Participants

165 grade-one students of a high school in Hunan province of China completed digital writing experience questionnaire (Chen 2015) and self-evaluated the Pinyin input proficiency through a question like Likert 10 scale. Based on the scores from lowest to highest order, we selected 59 participants with normal eyesight from the two tails of score list including 30 with low Pinyin-input experience and 29 with high Pinyin-input experience. T test showed that there were significant differences in digital writing and Pinyin input experience between the two groups ($t_{(57)} = -17.42$, $p < 0.001$; $t_{(57)} = -2.63$, $p = 0.011$). Owing to 4 people's asking for leave before the final experiments, the actual participants were 29 in low-experience group and 26 in high-experience group.

Materials

There are two types of priming stimulus (See "Appendix 1 and 3"). One includes 30 standardized stimulus pictures revised by Zhang and Yang (2003) such as a picture of "cow" and so on. The names of these pictures are high-frequency Chinese individual characters, and their frequency sequences are between 168 and 2548 with the mean of 1170.67. Another type includes 30 commonly-used idioms composed of 4 Chinese characters. The last character of each idiom is vacant such as "七上八( )" with a frequency sequence between 28 and 2936 and the mean of 986.63. There are also two types of response stimulus matched to the above priming stimulus (See "Appendix 2 and 3"). The first type of stimulus are glyphs including correct characters of picture (or vacancy) and their interference characters such as "牛" (or "午)" and "下" (or "卞)". Another type are correct and interferential syllables such as "niu" (or "liu") and "xia"(or "cia").

The materials were assessed before experiments. The interferential glyphs of character-name pictures and character-vacant idioms were selected according to the following method: 50 college students chose the most similar to the correct characters from the 3 resemblances, and the characters with highest ratio of selection were used as interferences in experiments.

The interferential characters of 30 pictures were selected with consistence ratios between .40 and 1.00 ($Mean = 0.75$, $SD = 0.18$), Kendall's $W = 0.526(\chi^2 = 670.93, p < 0.001)$. The interferential characters of 30 idioms vacancy were selected with consistence ratios between .36 and .98 ($Mean = 0.73$, $SD = 0.18$), Kendall's $W = 0.406(\chi^2 = 553.36, p < 0.001)$.The interferential syllables of picture-name characters and idiom-vacant characters were selected by using the similar method. Another group of 49 college students are required to choose the most similar one to the correct syllable from the 2 resemblances, and then the syllables with highest ratio of selection were used as interferential pronunciation. The interferential syllables of 30 pictures were selected with consistence ratios between 0.52 and 0.92 ($Mean = 0.72$, $SD = 0.13$), Kendall's $W = 0.263(\chi^2 = 310.31, p < 0.001)$. The interferential syllables of 30 idioms vacant characters were selected with consistence ratios between 0.49 and .86 ($Mean = 0.65$, $SD = 0.11$), Kendall's $W = .157(\chi^2 = 200.41, p < 0.001)$.

Design

We employ 3-factor mixed design with Pinyin input experience (between subjects: high versus low), tasks (within subjects: glyph judgment and syllable judgment) and priming mode (within subjects: picture priming and vacant-character idiom priming) as independent variables. Dependent variables are accuracy of judgment and RT of correct judgment.

Procedure

The process of experiment includes three stages. The first is preparation stage, in which correct picture (or idiom)-glyphs (or syllables) are provided for participants to be familiar with materials. The second is practice stage. 24 pairs of priming-reaction stimulus are provided for participants to practice typing the keys so as to know well about the experimental tasks and processes. The final is formal experiment stage which includes two separate tasks. One experiment is semantic-glyph consistency judgment primed by pictures and idioms such as a picture of "cow"—"牛" and "七上八( )"—"下", and another one is semantic-syllable consistency judgment such as a picture of "cow"—"niu" and "七上八( )"—"xia". The participants are asked to fulfill the next task 3 min after they finish the first task. Half of the participants firstly judge semantic-glyph consistency, and then semantic-syllable consistency and another half are reversed. All participants are rewarded for finishing their tasks.

Stimuli are presented with E-prime procedure. Their sequences and time of duration are: (1) In semantic-glyph consistency judgment task: "+"(1200 ms) — —picture (or idiom, 500 ms)— —a glyph(Key F is affirmative and Key J is negative or disappear after 2000 ms if no reaction)— —vacant screen (800 ms). Each picture or idiom randomly appears twice and they match with a half correct and a half interferential glyph. To avoid response bias, we randomly put in additional 10 affirmative and 10 negative judgments. So, participants need to judge 140 semantic-glyph consistencies in total. (2) In semantic-syllable consistency judgment task, procedures are the same as semantic-glyph consistency judgment task except that the reaction stimuli are syllables.

The example of core experimental program is as follows (Fig. 1).

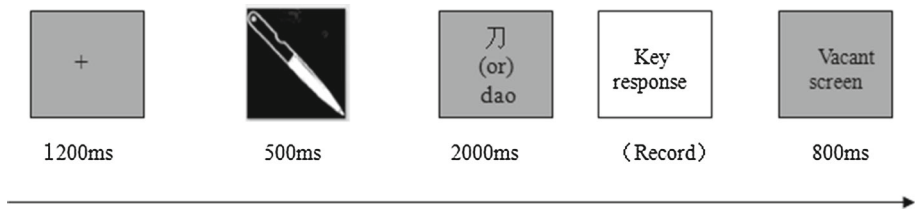

Fig. 1 The example of experimental program

Table 1 Accuracy of participants at different Pinyin input experience (*M, SD*)

	Picture-glyph judgment	Picture-syllable judgment	Idiom-glyph judgment	Idiom-syllable judgment
Low-experienced group	0.95	0.83	0.91	0.74
($n = 27$)	(0.04)	(0.10)	(0.05)	(0.12)
High-experienced group	0.92	0.86	0.89	0.81
($n = 23$)	(0.09)	(0.07)	(0.05)	(0.08)

Results

We first organized the experimental data before analyzing them. In participants' RT list, we calculated the average RT after deleting those which exceeded plus or minus 3 *SD*; then we inspected response accuracy and deleted 5 cases in which the accuracy was below 3 *SD*. Finally, there were 50 valid cases left.

Participants' Judgments Accuracy

The participants' average and standard deviations of accuracy in different tasks are presented in Table 1.

We explored the effects of independent variables on judgmental accuracy by repeated measurement ANOVA. The results indicated that there were significant main effects on priming mode and task ($F_{(1,48)} = 70.82$, $p < 0.001$, $\eta_p^2 = 0.596$; $F_{(1,48)} = 60.46$, $p < 0.001$, $\eta_p^2 = 0.557$), which meant the accuracy of idiom priming was lower than that of picture and the accuracy of glyph judgment was higher than that of syllable. In addition, the pairwise interactions were significant among priming mode, Pinyin input experience and task ($F_{(1,48)} = 6.29$, $p = 0.016$, $\eta_p^2 = 0.115$; $F_{(1,48)} = 4.95$, $p = 0.031$, $\eta_p^2 = 0.094$; $F_{(1,48)} = 7.45$, $p = 0.009$, $\eta_p^2 = 0.134$). Then, we respectively inspected the simple effects of pairwise interactions (See Figs. 2, 3, 4).

The results of simple effect tests indicated that there was no significant difference between low-experienced group and high-experienced group on picture priming task and idiom priming task, but effect size of the latter ($\eta_p^2 = 0.054$) was larger than the former($\eta_p^2 = 0.00$), showing Pinyin-input experience was more sensitive to idiom priming task than that of the picture.

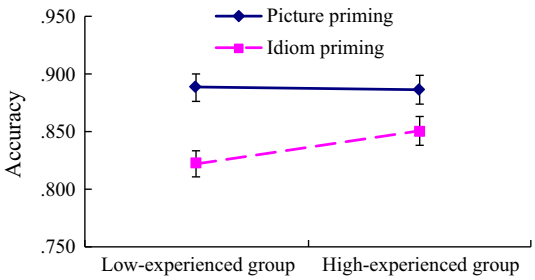

Fig. 2 Interaction between priming modes and Pinyin experience groups on accuracy (*Error bars* mean ± SE)

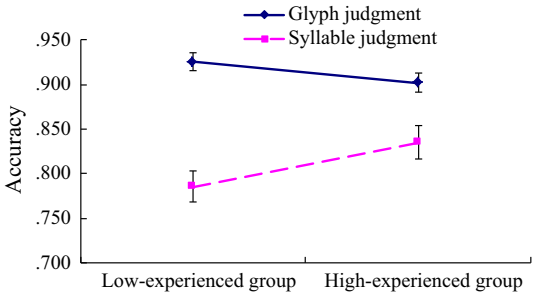

Fig. 3 Interaction between judgment tasks and Pinyin experience groups on accuracy (*Error bars* mean ± SE)

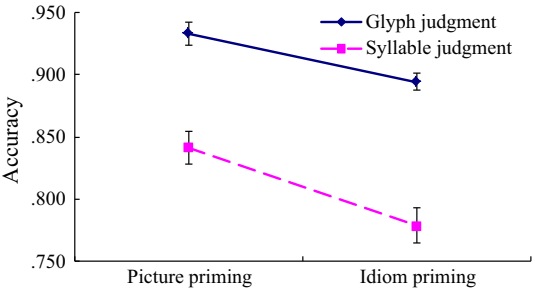

Fig. 4 Interaction between judgment tasks and priming modes on accuracy (*Error bars* mean ± SE)

The two Pinyin experience groups had no significant difference at glyph judgment ($F_{(1,48)} = 2.640$, $p = 0.111$, $\eta_p^2 = 0.052$), but approached significance at syllable judgment ($F_{(1,48)} = 3.653$, $p = 0.062$, $\eta_p^2 = 0.071$).

The accuracy of picture priming was higher than that of idiom priming at two judgment tasks and the effect size of syllable judgment ($\eta_p^2 = 0.550$) was larger than that of glyph judgment ($\eta_p^2 = 0.330$).

Reaction Time of Participants' Judgments

The participants' means and standard deviations of RT in different tasks are presented in Table 2.

Repeated measurement ANOVA is used to analyze the effects of independent variables on judgment RT. The results were that the main effects of priming mode and task were significant ($F_{(1,48)} = 9.48$, $p = 0.003$, $\eta_p^2 = 0.165$; $F_{(1,48)} = 106.05$, $p < 0.001$, $\eta_p^2 = 0.690$) which meant that the RT of idiom priming was longer than that of picture and the RT of glyph judgment was shorter than that of syllable. There was significant interaction between priming mode and task ($F_{(1,48)} = 11.52$, $p = 0.001$, $\eta_p^2 = 0.194$), and the interaction of

Table 2 RT of participants at different Pinyin input experience *(M, SD)*

	Picture-glyph judgment	Picture-syllable judgment	Idiom-glyph judgment	Idiom-syllable judgment
Low- experienced group	690.20	895.97	749.50	893.12.
($n = 27$)	(98.14)	(133.07)	(97.04)	(146.39)
High- experienced group	682.35	822.24	717.86	823.77
($n = 23$)	(78.04)	(129.44)	(78.97)	(145.00)

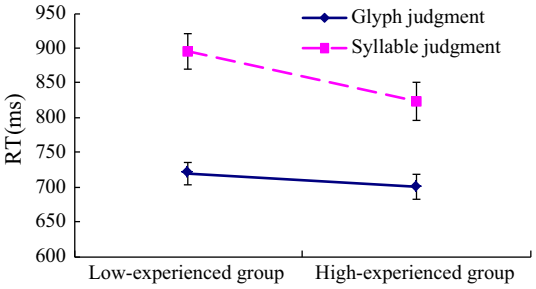

Fig. 5 Interaction between judgment tasks and Pinyin experience groups on RT (*Error bars* mean ± SE)

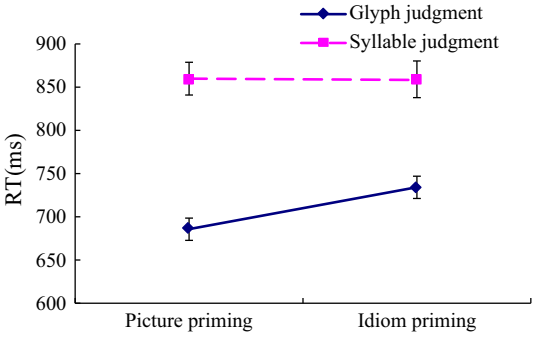

Fig. 6 Interaction between judgment tasks and priming modes on RT (*Error bars* mean ± SE)

task and Pinyin input experience approached significance ($F_{(1,48)} = 3.23$, $p = 0.079$, $\eta_p^2 = 0.063$). Then, we respectively inspected the simple effects of the above two interactions (See Figs. 5, 6).

The results of simple effect tests indicated that there was no significant difference between low Pinyin experience group and high Pinyin experience group on glyph judgment ($F_{(1,48)} = 0.699$, $p = 0.407$), but it approached significance on syllable judgment and the RT of high experience group was shorter than low experience group ($F_{(1,48)} = 3.604$, $p = 0.064$, $\eta_p^2 = 0.070$).

There was no significant difference between picture priming and idiom priming on RT of participants' syllable judgment, but on glyph judgment, the difference was significant with picture priming shorter than idiom priming ($F_{(1,48)} = 26.40$, $p < 0.001$, $\eta_p^2 = 0.355$).

Discuss

The results of present study suggest that Pinyin input experience don't affect semantic-glyph consistency judgment, but it helps semantic-syllable consistency judgment. The accuracy of high Pinyin input experience group is higher than low experience group and the RT versa.

In terms of glyph or orthography, researchers (Zhang and Li 2010) have found that at picture priming task, there was no significant difference between participants using Wubi input method and Pinyin input method on glyph affirmative judgment, which shows a certain consistency with the results of this study. Another study (Zhu et al. 2009) adopted the tasks of low-frequency characters priming and found that Pinyin input experience facilitated the process of both pronounceable and unpronounceable radicals. It means that Pinyin keyboarding helps glyph process, which doesn't accord with the results of our study. The author's explanation is that experienced individual may pay more attention and are more sensitive to glyph because of the connection of Pinyin input method with glyph choice.

Unlike our study, the task of the above study was searching and matching glyph of low-frequency Chinese characters which explored the problems about character reading—the connection between glyph and radical—rather than character production—the connection between semantic and orthography. Additionally, the experimental material may also be one of the reasons that result in its inconsistency because unlike the previous study, participants are more familiar with the high-frequency characters in this research. Therefore, the effects of character frequency should be considered in future researches.

In terms of syllable or phonology, two studies showed that Pinyin input method could facilitate phonology process relative to glyph-code input method (Qian and Feng 2004; Zhang and Li 2010). This study further found that the more Pinyin input experience participants had, the better performances they would have on syllable judgment. The main explanation of this phenomenon is that using Pinyin input method may strengthen the links between semantic and phonology of individuals in mental lexicon resulting their superiority in syllable judgment. This speculation has certain rationality in that application of technology may change human psychological function and its expression and it has been proved in some ways such as memory (Betsy et al. 2011).

But there should be another possibility that the superiority of experienced Pinyin input group in syllable judgment are resulted from the visual presenting syllables rather than real acoustical pronunciations. Because it's hard to tell whether the effect was caused by the strong semantic-phonology links in mental lexicon or the connection between visual presenting mode and visual letters of people's daily keyboarding. Therefore, we need present characters' pronunciations through auditory modality in the further studies so as to separate these two effects.

In the conditions of idiom priming, participants' accuracy of glyph and syllable judgment is lower and RT of glyph judgment is longer than those of picture priming, which means the cognitive costs of participants are less in picture priming. This is owing to the meaning complexity of the material itself because of picture priming concept and idiom priming proposition in semantic system. In real language production, for both oral and written language, proposition is the semantic unit and sentence is the external construction. To improve the ecological validity, researchers need use similar language priming materials to probe into the effect of Pinyin input experience in future related studies. What's more, we have found the variable of Pinyin input experience is more sensitive to materials of idioms than pictures (See Fig. 2).

Conclusions

Pinyin input experience doesn't affect the semantic-glyph consistency judgment of participants on high-frequency Chinese characters, but positively affects semantic-syllable consistency judgment. The priming materials can affect performances of participants' glyph and syllable judgments.

Compliance with ethical standards

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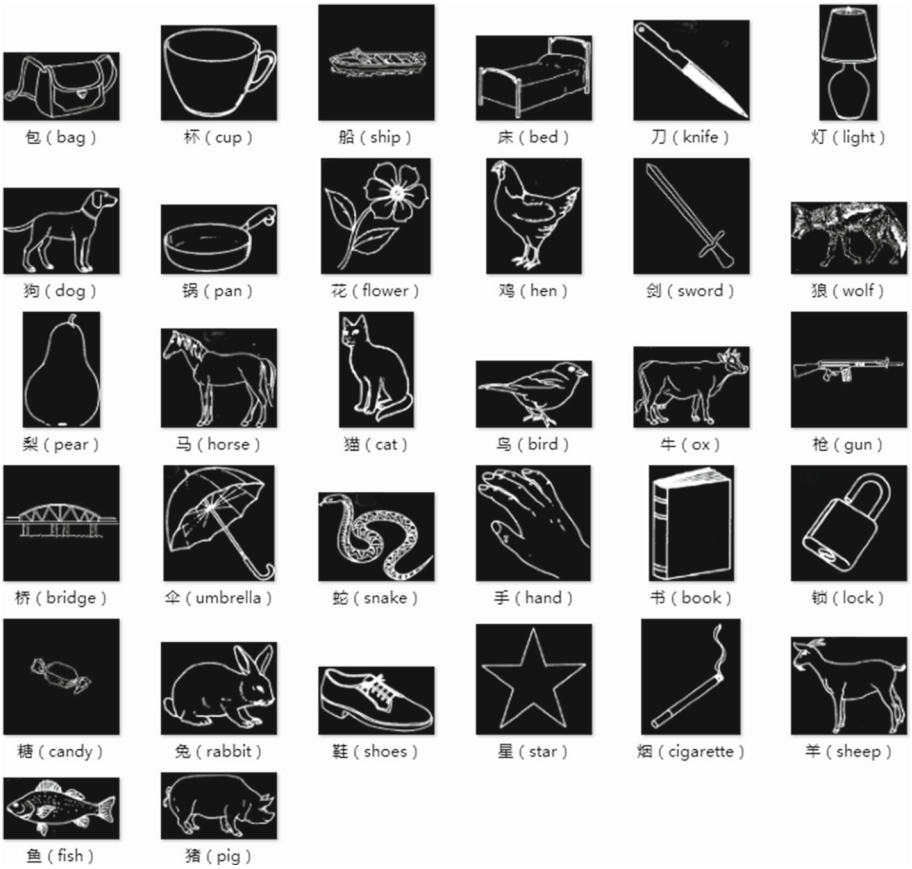
Conflict of Interest The authors declare that they have no conflict of interest.

Appendix 1: Pictures



Appendix 2: Disturbance terms of glyphs and sounds

包（句 pao）	船（般 cuan）	床（庆 chang）	刀（刁 diao）	灯（订 den）
狼（狠 nang）	梨（愁 ni）	马（乌 mo）	猫（猎 miao）	鸟（乌 liao）
牛（午 nu）	书（专 xu）	锁（琐 so）	兔（免 tou）	鞋（跬 xue）
星（旱 xin）	狗（狍 guo）	锅（锅 kuo）	花（茬 fua）	鸡（鸣 li）
剑（刽 jan）	枪（抢 qang）	桥（杯 qao）	伞（仐 sian）	蛇（坨 se）
手（毛 sou）	烟（烟 yian）	羊（半 yeng）	鱼（龟 yü）	猪（绪 ju）

Appendix 3: Priming characters in idioms and their disturbance terms of glyphs and sounds

	Disturbances			Disturbances	
Idioms	Glyphs	Sounds	Idioms	Glyphs	Sounds
七上八（下）	卞	cia	问心无（愧）	槐	kiu
马到成（功）	劝	gon	草木皆（兵）	乒	bin
破釜沉（舟）	母	zhuo	行尸走（肉）	网	you
掩耳盗（铃）	钤	lin	卧薪尝（胆）	朋	dian
落叶归（根）	恨	geng	无地自（容）	客	yong
亡羊补（牢）	宪	nao	石破天（惊）	谅	jin
叶公好（龙）	尤	nong	画蛇添（足）	呆	zou
无精打（采）	妥	chai	袖手旁（观）	现	guang
百鸟朝（凤）	风	fen	口是心（非）	韭	fi
汗牛充（栋）	拣	don	龙争虎（斗）	头	du
杯弓蛇（影）	彰	yin	孟母三（迁）	迂	qan
狐假虎（威）	咸	wie	狗仗人（势）	垫	si
争分夺（秒）	秋	mao	杞人忧（天）	夫	tan
一叶知（秋）	秒	qui	叱咤风（云）	亏	run
望梅止（渴）	谒	ko	水落石（出）	击	qu

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