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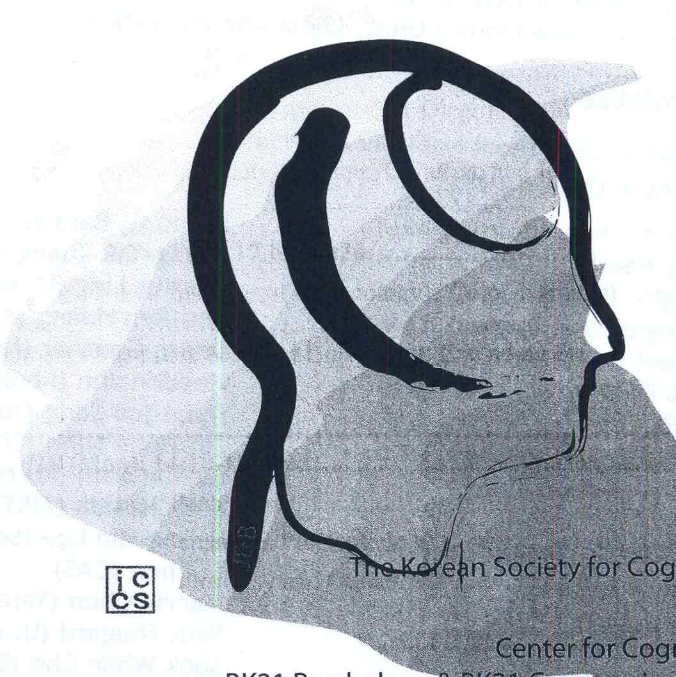

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Phonological and other linguistic effects in recognition of Chinese characters

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Abstract

Phonological factors involved in Chinese character recognition were examined with a naming experiment, while examining and controlling for other relevant influences. Phonological priming had no effect at the 50 ms SOA, but a number of other influences were detected – phonological, visual, orthographic, lexical, semantic, and morphological. The findings indicate the complexity and multiple routes of information, with concurrent inhibitory and facilitory influences, involved in Chinese character and lexical processing.

The most common type of Chinese character contains a semantic radical plus a phonetic component, sometimes known as a phonogram (Karlgren, 1923). Phonograms are found in 80-90% of Chinese characters, and provide cues about the whole character pronunciation, be it an accurate, approximate, or at times rather indirect.

Priming studies of Chinese have found effects for phonological primes in facilitating the recognition of Chinese characters (e.g., Perfetti & Zhang, 1995; Tan, Hoosain, & Siok, 1996; Tan & Perfetti, 1999; Seidenberg, 1985). Past masked priming studies of online recognition of Chinese characters typically employed fairly simple designs and controlled for or examined relatively few factors, mainly lexical or character frequency. Other studies have controlled for or examined phonologic consistency, i.e. the degree of phonological relatedness between the phonogram pronunciation and whole-character pronunciation, as in studies of children's reading proficiency and phonological awareness of Chinese (Shu et al., 2003).

However, the phonological priming studies have sometimes been challenged, in failure to replicate some of them, or by explaining the priming effects as orthographically mediated, with the phonological effects being a by-product of orthosemantic recognition (e.g., Zhou & Marslen-Wilson, 1999a, 1999b; Zhou et al., 1999).

For better understanding of Chinese phonological priming, various factors need to be examined, including potentially those found in priming studies of other languages, and those that might arise from the unique nature of Chinese script. These include the general semantic concreteness effect of word meanings as found in various languages (i.e., tangible, physical, imaginable, as opposed to abstract; e.g, Balota et al., 2004), as has been found for Chinese (Zhang et al., 2006); radical combinability, i.e., frequency of semantic radicals (Feldman & Siok, 1997), morphological family size (Baayen et al., 2006), or frequency of characters in multi-morphemic Chinese compounds (Taft & Zhu, 1997); and syllable frequency in English (Balota et al., 2004; Conrad, Carreiras & Jacobs., 2008).

Examining these variables in phonological priming of Chinese characters might clarify the previous findings, and indicate whether character recognition is a simple matter of one linguistic route mediating another, or whether the process is more complex and multi-route.

Experiment

A naming experiment was conducted, examining two possible types of phonological priming – with traditional homophone primes, and with phonograms as prime, with the hope of examining phonological and other factors involved in each types of priming, for a finger grained picture of influences operative in phonological processing of characters.

Phonological Correspondence

Phonological consistency and regularity effects have been attested for characters in phonological priming studies (e.g., Fang, Horng, & Tzeng, 1986). However, past studies have treated these as unidimensional variables, while in reality, they are multi-dimensional. Regularity, or phonological correspondence between the phonogram and the whole character, can differ for onsets and rimes, as can consistency, or the variability of phonograms in the number of different whole character pronunciations associated with them. For example, 亢 *kàng* appears as a phonogram in 坑 *kēng*, 航 *háng* and 骯 *āng*; 京 *jīng* appears in 鯨 *jīng* and 諒 *liàng*; 句 *gōu* in 拘 *jū*; and 各 *gè* in 客 *kè*, 格 *gé*, and 略 *lüè*. Complex and differing patterns appear for onset correspondences and rime correspondences, due to complex historical sound changes in Chinese. Thus, separate regularity and consistency indices were created for onsets and rimes for this experiment. Consistency is a numerical variable, a ratio of a given character pronunciation over the number of pronunciations associated with a given phonogram, weighted by character frequency (Shu et al., 2003). Regularity is a categorical variable for types of phonological correspondence (for onsets: same onset, or differing by place or manner of articulation, affrication, gliding, or wholly different onset; for rimes: same vowel + tone; same vowel with different tone; different vowel; and wholly different rime structure).

Other Variables

Radical frequency, character frequency, morphemic frequency of characters (frequency of individual characters in multi-syllabic compounds), syllable frequency, neighborhood frequency, and radical family size (number of characters with a semantic radical) were included. Semantic factors were included, and were derived from native Mandarin speakers' ratings of characters for semantic relatedness of radicals to characters, and for semantic concreteness of characters, from which semantic indices were derived for character concreteness, and for the semantic variability or consistency of semantic radicals across characters.

To control for visual or orthographic priming effects, particularly for phonogram primes, the number of shared strokes between primes and targets was entered as a stroke ratio index, along with an index of the number of components in a target character, and a density ratio for targets (a ratio of strokes to components per character) to control for spatial density. The stroke ratio follows Ferrand and Grainger (1994), who likewise used a shared letter index to control for prime-target letter similarity, to control for form priming effects, and to disambiguate orthographic form priming from phonological priming.

Design, Method, and Procedure

150 target characters were presented with the E-Prime experimental software. Targets were preceded by phonogram, or homophone masked primes or control non-character primes (ASCII symbols), counterbalanced across three list conditions. Primes were presented at 50ms prime duration (or SOA, stimulus onset asynchrony); primes were preceded and followed by a brief visual mask, and then the target item was presented. Also included were 335 filler items. Subjects were asked to name the characters as quickly as possible, or say "*bu zhidao*" ("don't know") if they did not recognize it. Responses were recorded on a digital recorder, and response times were recorded by the E-Prime software. 54 subjects from the University of Illinois area were recruited as paid subjects (Mandarin native speakers who lived in Taiwan until at least age 15), as the stimuli used were in traditional characters. The data were analyzed using hierarchical linear modeling (HLM), as in Balota et al. (2004).

Results Inaccurate responses were deleted (9.1% of all responses), and response times above 2.5 S.D. units or c. 1600ms were excluded. Mean reaction times are shown in Table 1. As can be seen, at 50ms no priming effect was evident in the means, and in the analysis it was non-significant. Thus, the results are equivalent to a non-primed naming experiment, and the response times were regressed on the other variables.

Table 1: Mean reaction times.

Condition	N	Mean	S.D.
Homophone	3329	800.2	262.8
Phonogram	3326	792.8	259.5
Control	3331	789.0	254.3
Total	9986	794.0	258.9

The following factors were found to be significant: (1) number of components in the target character, as a control for visual density, with an inhibitory effect – more components lead to slower reaction times; (2) radical family size, inhibitory; (3) phonogram frequency, inhibitory; (4) character frequency, facilitory; (5) radical semantic consistency, i.e., the semantic variability of radicals across characters, with a facilitory effect for greater consistency, facilitory; (6) phonological consistency of onsets; (7) phonological regularity of rimes, facilitory; (8) phonological consistency of rimes, inhibitory; (9) character semantic concreteness, facilitory; (10) syllable frequency, facilitory; and (11) morpheme frequency of characters, facilitory. The shared prime-target stroke ratio was marginally significant. Other effects, such as neighborhood size, spatial density, and interaction effects, were non-significant, and onset regularity apart from onset consistency was non-significant or not detectable, possibly due to greater collinearity between onset regularity and consistency. For rime regularity, two levels of this variable showed significant effects: rimes with same vowels but different tones, and fully identical rimes with same vowels and tones, were both facilitory. Other levels (different vowels, different rime structures altogether) were not significant. Estimates and values are given in Table 2[10].

Table 2: Results of HLM analysis.

Variable	Estimate (β)	Value	*p*
Components	11.5 ms	13.1	.0003
Stroke ratio	37.2 ms	2.7	.01
Radical family size	-17.3 ms	6.8	.009
Phonogram frequency	24.4 ms	51.2	<.0001
Character frequency	-62.2 ms	279.6	<.0001
Radical consistency	-13.3 ms	4.7	.03
Onset consistency	-22.5 ms	6.9	.009
Rime regularity		8.0	<.0001
1) dif. tone	-21.4 ms	-2.3	.02
2) identical	-38.4 ms	-4.0	<.0001
Rime consistency	52 ms	29.3	<.0001
Character concreteness	-20.9 ms	135.1	<.0001
Syllable frequency	-19.5 ms	11.2	.0008
Morphemic frequency	-37.2 ms	48.2	<.0001

[10] HLM provides a powerful statistical method for analyzing complex data with many covariates and unbalanced categorical variables. HLM analyses return F-values for the numerical variables (most of those above), chi-square values for categorical values (rime regularity), and t-values for levels of categorical values (rime regularity: different tone, and identical rimes). For estimates of variables on responses (betas), positive integers indicate inhibitory effects and slower responses, while negative integers indicate facilitory effects, and thus, faster responses.

Discussion

In spite of a lack of any priming effect, the results are informative, as they indicate a whole set of concurrent inhibitory and facilitory effects operative at the 50 ms time frame. Inhibitory effects follow from visual complexity, while facilitory effects follow from concreteness, syllable and morpheme frequency, radical consistency, phonological consistency and rime regularity. Some effects are difficult to explain (e.g., inhibitory effects of phonogram frequency), except perhaps as a result of competitive inhibition with other factors at 50 ms.

Some of the previous disparate results in the Chinese priming literature may have been due to a failure to control for various linguistic and visual factors such as those included here. A future experiment will follow up with multiple SOAs to see if priming effects obtain at other time frames.

A naming task normally favors phonological over semantic processing (Balota et al., 2004), yet character concreteness, radical semantics, and radical family size were operative here. A top-down effect of morphological frequency was also implicated. Phonological processing was found to be more complex, with separate effects for rimes and onsets, and for phonogram and character frequencies.

The number of phonological factors in play here would support a claim of direct phonological activation and processing from phonological information in Chinese character forms. However, phonological activation is concurrent with semantic and morphological processing. The complexity of the effects, and the concurrence of inhibition and facilitation from phonological, morphological, semantic, and orthographic factors, would tend to favor a more complex model than the simpler modular or interactive models in the literature, and would argue against one modality (phonology or semantics) mediating another or preceding another in processing time. Instead, a more complex multi-route model is in order, which allows for different levels or subroutes of phonology (rime, onset, frequency effects) and interactions of different modalities subroutes that operate in parallel.

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