Psycholinguistic aspects of Hanji processing in Chinese

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1. Introduction

Human signs are typically classified into the two types known as the *semasiographic* and *glottographic* systems of signs.[1] Both make certain cognitive demands as human decoders process them for first recognition and then semantic content. Semasiographic systems are independent of language, as for example, the system of road signs, but glottographic systems represent aspects of spoken language, and in this crucial feature they differ enormously. Glottographic systems can be *phonographic*, as is the case of alphabetic systems like English, or *logographic*, as is the case with hanji characters in Chinese (Sampson, 1994).

As is well-known, Chinese typically represents morphological units and their meanings, with the advantage that its logographic orthography can represent mutually unintelligible dialects of Chinese, and even different spoken languages (see Chen, 1996). Traditionally, Chinese is said to employ two types of hanji: the *pictograph* and the *phonograph*. Pictographs are historically derived from copying some aspect of the shape of the lexical item which it represents, but only 20% of Chinese logographs can be described in this way. The remaining 80% of Chinese logographs are regarded as phonographs, with two possible types of constituent parts: a radical or *signific*, which refers to meaning, and a *phonetic*, which refers to pronunciation (see Chen and Yuen, 1991).

This paper explores the psycholinguistic dimensions of hanji processing and linguistic recognition in Chinese. In so doing, we review the current psycholinguistic literature on Chinese hanji processing, and attempt to synthesize the conflicting explanations offered by current models of Chinese lexical access, word recognition, and the architecture of the Chinese mental lexicon. The central psycholinguistic question in respect to Chinese hanji processing focusses on the degree to which phonological and semantic processing of hanji interact in parallel or sequential modes. Thus, the debate in Chinese word recognition revolves around whether meanings of words written in logographic hanji can be accessed in the mental lexicon without phonetic codes first being retrieved from the written format.

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From a psycholinguistic viewpoint, there have been two opposing explanations for how fluent Chinese readers access the mental lexicon as they cognitively process hanji characters for recognition and then semantic properties. One view claims that hanji processing does not require any type of orthography-specific processing mechanism. That is, although Chinese orthography is logographic in nature, the processing mechanisms it employs are the same as the processing mechanisms employed by languages which use alphabetic scripts like the roman alphabet. The opposing view maintains that hanji processing is instead unique, employing processing mechanisms which inherently differ from those used for dealing with alphabetic scripts.

2. Psycholinguistic issues in Hanji processing

The basic issue in Chinese hanji processing is whether the phonological properties of a given hanji character must be invoked in order to access its meaning. The psycholinguistic models which attempt to explain how fluent Chinese readers search the mental lexicon are diametrically opposed in respect to the role of phonological information in processing hanji characters. One view claims that hanji processing does not require any type of orthography-specific processing mechanism. That is, although Chinese orthography is logographic in nature, the processing mechanisms it employs are the same as the processing mechanisms employed by languages which use alphabetic scripts like the roman alphabet. The opposing view maintains that hanji processing is instead unique, employing processing mechanisms which inherently differ from those used for dealing with alphabetic scripts. The first explanation, commonly referred to as the Orthography-Independent Processing Hypothesis (also as the Automatic Acoustic Activation Hypothesis) claims that hanji cannot access meaning without first accessing the phonological properties of that hanji. The cognitive route in processing hanji, therefore, would travel from Orthography to Phonology to Semantics, exactly the same as the sound-mediated route which is the general basis of reading in alphabetic and syllabic scripts. The opposing view claims that hanji access meaning without the mediating step of decoding phonological properties. In its strongest version, this model offers a single-step processing explanation, where phonology is secondary to meaning. The cognitive routing proceeds directly from Orthography to Semantics, accessing Phonology only as required.

The Orthography-Independent Processing Hypothesis boasts two versions in actual application, a weaker and a stronger version. The weaker version argues that hanji access meaning without activating the phonology identity of the word, but that this processing step is highly grapheme-dependent and thus differs from alphabetic processing. In contrast, the stronger version of the Automatic Acoustic Activation Hypothesis sees no differences in processing hanji and alphabetic scripts, with both script types automatically invoking phonological properties of the words to be accessed.

A number of studies offer direct support for this notion of automatic phonological activation. For example, Lam, Perfetti, and Bell (1991) tested both bidialectal (Cantonese and Mandarin) and unidialectal (Mandarin) subjects by having them judge whether pairs of characters had the same pronunciation in a given dialect. The naming task produced results in which the phonetic values of the

first dialect was automatically recalled, with judgments both faster and more accurate in that first dialect. Based on the above finding, the authors conclude that regardless of the mono- vs. bi-dialectism difference, automatic acoustic activation necessarily takes place in Chinese.

Tzeng, Hung, and Wang (1977) report two experiments in short-term retention, in which the results suggest the effect of phonological activation. A first experiment visually presented target lists of Chinese characters, which differed in syllable structure from each other, while interference lists were being presented orally. Immediately after visual presentation of the target list, subjects were asked to say aloud the interference words which they had just heard. They were next asked to write down the target characters which they had just seen. If speech recoding did take place, one could expect that any phonological similarity between the target and interference characters would disrupt the memory for items that subjects were to recall. The results demonstrated that phonological similarity did have a significant effect, with vowel similarity in the pronunciation of the characters eliciting interference on recall abilities. The second experiment tested grammaticality judgments for sentences, manipulating normal vs. anomalous sentences and phonologically similar vs. phonologically dissimilar sentences. As in the first experiment, phonologically similarity again interfered with subjects' performance.

Perfetti and Zhang (1995) report similar results from two experiments which manipulated synonym judgments. A first experiment asked subjects to judge whether a given pair of hanji was synonymous or homophonic. The results revealed that negative judgments required longer reaction times when the characters were homophonic. The second experiment, using a similar experimental design with synonym judgments, found that phonological interference took place within 90 msec of stimulus onset, while semantic interference was initiated much later, at the 140 msec boundary. They conclude that phonological processing is activated before semantic processing, with the implication that phonological activation is a necessary component in word recognition.

Tan, Hoosain, and Peng (1995) manipulated targets and masks in two experiments which examined speed and accuracy in target recognition. A first experiment with short presentations of targets (50 msec) and masks (30 msec) found that graphemic masks affected target recognition, but that both phonological and semantic masks failed to do so. However, the second experiment employed a longer presentation of the targets and masks (60 msec and 40 msec, respectively), with significant facilitation effects for phonological masks in the case of high-frequency words with generalized meanings.

Much research in short-term memory (STM) suggests that STM is phonetic in nature rather than visual. The implication is that hanji processing, insofar as memory storage and recall are concerned, may not be able to ignore phonetic decoding in placing linguistic information in the STM store. For example, Zhang and Simon (1985) found that acoustic STM cues were more effective than either visual or semantic cues, for both alphabetic languages and logographic languages like Chinese. Similarly, Hue and Erickson (1988) report that hanji characters in high-frequency use will elicit phonological short-term memory effects, and Liu, Zhu, and Wu (1992) failed to find visual superiority effects for short-term memory probes.

Xu (1991) also provides indirect evidence for automatic phonological activation through his experimental work with Tone Sandhi rules. One of his experiments exposed subjects to stimuli which either required the application of Tone Sandhi rules or which did not. Recall tests demonstrated that the errors with the stimuli involving Tone Sandhi rules were almost double the rate for those which did not involve such rules, suggesting that STM operates with phonological representations in both storage and recall.

Lastly, a review of 14 different STM experiments using an immediate recall paradigm leads Yu, Zhang, Jing, and Peng (1985) to conclude that the short-term memory span which can be phonologically encoded in Chinese is in the neighbourhood of six or seven, whereas the span which can be visually or semantically discriminated is only two or three. The implication here is that phonological encoding is an efficient metric for STM tasks, while visual encoding does not offer any particularly significant visual or graphemic processing advantages associated with hanji recognition or storage.

Supporters of the Orthography-Independent Hypothesis generally agree that hanji processing requires phonological activation at a pre-semantic stage, but not all supporters agree that hanji processing is the same as alphabetic processing. Some suggest that the earliest stage of hanji processing is more grapheme-dependent, and makes more use of the visual information inherent in logographs, than is the case with alphabetic processing. For example, Hung and Tzeng (1981) suggest that, although script-sensitivity is not an issue at higher levels of hanji processing, at the lower level of processing script-dependency is a feature. This same view is also proposed by Leong (1986), who argues that phonemically-based English has an inherent morphological component that needs to be accessed, while morphemically-based Chinese allows, and sometimes requires, phonological information. Thus, cognitive mechanisms involved in processing such disparate orthographies may differ at the initial stage and at the micro level, but likely converge at the later stage and at the macro level.

In reviewing previous work on laterality preferences and hanji processing tasks, Hasuike, Tzeng, and Hung (1986) observe that previous studies which found superiority for the non-linguistic, or pattern-matching gestaltic, right hemisphere in hanji processing did so when there were very short exposure durations for hanji stimuli. Such stimuli must have elicited this right hemispheric superiority because they were essentially treated as non-linguistic stimuli. When stimulus exposure durations exceeded 50 msec, these right hemisphere superiority effects did not appear. Conversely, one may speculate that the non-analytic, non-phonological, right hemisphere has some input at the earlier stage of hanji processing, and that graphemic information is being registered in some way by the cognitive mechanisms allied to interpretative procedures.

In sum, supporters for the Orthography-Independent Hypothesis tend to the view that hanji processing is not exactly equivalent to alphabetic processing. Nevertheless, hanji processing does invoke the phonological properties of the lexical item to be accessed, just like lexical items presented in alphabetic scripts do. The key tenet of this view remains, namely that phonological properties are accessed at a stage preliminary to accessing semantic properties.

The opposite view to this notion of automatic phonological activation is the Orthography-Dependent Hypothesis, which claims that hanji recognition can access semantic properties without the mediation of phonology. One method for demonstrating that hanji access meaning without phonological mediation is to employ a semantic categorization test which uses homophonic stimuli. If stimuli are classified according to appropriate semantic categories without homophonic interference, we can assume that hanji takes a direct cognitive route from Orthography to Semantics.

Van Orden (1987) and Van Orden, Johnston, and Hale (1988) gave English-speaking subjects a category name (for example, *flower*) and then had them decide whether a subsequently presented target word (for example, *rose*) was a member of that category. Both experimental reports found that subjects made more categorization errors, and also spent more time on homophone foils than on spelling controls. For example, if the category was *flower*, and the target word was *rose*, homophone foils like *rows* gave more problems than spelling controls like *snobs*. The implication from these two experiments, of course, is that there is an automatic and independent activation of phonological information in course of recognition for English words.

But when this experimental paradigm is applied to Chinese, however, the situation seems to be quite different. Chen, Flores d'Arcais, and Cheung (1995) report on several experiments which adapted these semantic categorization tasks to the question of hanji processing. A first experiment instructed Chinese subjects to silently read the category name and then to look at a fixation point. The target character was then presented, and the subjects had to judge whether the target was a member of the category just presented by pressing as rapidly and as accurately as possible a response key labelled 'yes' or 'no'. Subjects produced the same proportion of false positive categorization errors and showed the same decision latencies on homophone foils and their non-homophonic controls, indicating that phonological information does not seem to affect the semantic task. The second experiment similarly demonstrated that subjects made more errors and produced longer response times on graphemically similar foils than on the corresponding controls. The absence of phonological effects, in contrast to the clear effects of visual similarity for Chinese characters in semantic categorization tasks leads the authors to conclude that phonological information may not be automatically activated during the processing of meanings of Chinese characters.

Indirect support for the Orthography-Dependent Hypothesis may also be adduced from a diverse range of research which spans the experimental gamut of psychological probes used in tachistoscopic studies, STM research, comparative studies, and Stroop tests. For example, Keung and Hoosain (1989) had Chinese subjects judge whether specific two-character hanji stimuli were legitimate words or not, as these stimuli were being tachistoscopically presented to both left and right visual fields. Hanji words which had low stroke numbers showed slightly better performance in the right visual field (thus indicating left hemisphere superiority), while those words which had high stroke numbers and low frequency showed a left visual field (thus right hemisphere) advantage. Taken as a whole, such results suggest that hanji compound words may invoke gestalt-like, right hemisphere processing preferences in instances where high stroke number and low frequency are salient characteristics. Given the fact that extremely short exposure durations of

12 to 21 msec were coupled with low exposure luminance, these results seem more congruent with the expectations of the Orthography-Dependent Hypothesis than the Orthography-Independent Hypothesis.

Although short-term memory studies generally indicate that STM is predominantly phonetic, there are a few STM studies which suggest that the graphemic information in hanji processing plays a much more significant role than is the case for alphabetic processing. For example, Yik (1978) employed a serial recall task to test whether short-term memory is predominantly phonetic or visual, and to what degree these components might interact. Four sets of hanji stimuli were prepared which differed in the degree of phonological and visual overlap: word pairs with high visual and high phonological overlap; word pairs with low visual and high phonological overlap; word pairs with high visual and low phonological overlap; and word pairs with low visual and low phonological overlap. A recall test showed that the phonological similarity factor was highly significant, but also found a visual similarity effect. Such findings lead Yik to conclude that the average fluent Chinese reader is not that much more dependent on visual encoding, as opposed to phonological encoding, in STM than the English reader. But he argues that it may be more functional or more convenient to use visual encoding to cope with the reading task, and the Chinese reader probably does so with greater ease.

Chen and Juola (1982) also tested the effect of visual information on retention of Chinese hanji in STM. Three types of stimuli, counter-matched in lists of graphemically, phonologically, and semantically similar word pairs, were prepared both in English and Chinese. English- and Chinese-speaking subjects were then required to select one of a pair of test words that was phonemically, graphemically, or semantically similar to a word on a previously studied list. The results revealed that alphabetic words resorted to a more integrated code which involved visual, phonological, and semantic information, while logographic characters produced significantly more visual information in memory.

Several comparative studies shed light on the role of visual information in hanji processing, and generally offer support to the Orthography-Dependent Processing Hypothesis. Chen and Yuen (1991) offer relevant insights from the effect of pinyin learning on children's acquisition of hanji by contrasting analytic abilities by three groups of children from different training protocols. One group of children was from the People's Republic of China and had learned both pinyin and simplified hanji; a second group from Taiwan had learned both pinyin and traditional hanji; and a third group from Hong Kong had learned additional hanji but no pinyin. Three types of tasks were presented to each group of children: pseudo-homophone naming; similarity judgments; and a lexical decision task. In the similarity task, the children from the PRC depended on visual processing, ostensibly because these children were accustomed to processing simplified hanji which required greater visual discrimination than traditional hanji due to the increased similarity among the simplified hanji. Children from the PRC and Taiwan, i.e., those who had learned pinyin, performed better than those from Hong Kong in the pseudo-homophone naming task, suggesting that these children from the PRC and Taiwan were more practiced, and thus more skilled, at extracting phonological information. Different types of hanji experience may resort to different kinds of information processing strategies, and such data remind us that hanji processing is not a simple one-step process for all readers of hanji types.

Stroop studies also provide indirect support for the Orthography-Dependent Hypothesis. The Stroop test is an experimental technique which tests an individual's ability to separate word and color stimuli by contrasting easily confused conditions. For example, some color words are printed in black ink, some symbols are printed in colored inks, and some words are printed in colors which do not match the actual color named by the word. Subjects are typically found to more quickly name colors when the stimuli presented are color patches or symbols in the specific color than when colors are presented as words written in alphabetic symbols which are colored differently than the color to be named. Very simply, it is difficult to verbalize the name for the color *red* when the word is presented in blue print. In Japanese research, it is typically the case that Stroop test color stimuli produce greater interference in the left visual field when subjects were responding to kanji stimuli; such interference is not found for kana stimuli in the same visual field. The interpretation initially put on such results was that the right hemisphere is specialized for processing kanji, but this has been since shown to be a function of experimental task rather than experimental stimuli.

In a Chinese application of this technique to Chinese, Chen and Tsoi (1990) tested English native speakers and English-speaking Chinese bilinguals with stimuli that included math symbols (e.g., + and -) and both English and Chinese words. Subjects performed a Stroop task which had them name logographic symbols and corresponding words in English, with the results clearly demonstrating different patterns of interference effects for Chinese and English subjects. For the native English-speaking subjects, there were no interference effects in the various conditions, but for Chinese subjects, the Chinese word distracters created the largest interference. The implication of these findings is that the Chinese subjects could not avoid processing the whole stimulus together with the distracter, in those cases where Chinese hanji characters were the targets.

Another such study is reported by Tsao and Wu (1981), who presented subjects with slides for 150 msec in each visual field under the three task conditions of interference, reading, and naming. Subjects were required to verbally report as fast and accurately as possible the color words or the color names. Reaction times and error rates showed, as expected, that more Stroop interference was obtained when color words were presented in the left visual field (thus involving the right, non-linguistic, hemisphere). A possible explanation can be found in the fact that color words are typically a single character and high frequency, causing them to be processed as automatic linguistic symbols. If this is true, they may fail to invoke any significant right visual field (left, linguistic hemisphere) superiority.

Lastly, Biederman and Tsao (1979) had an equal number of English native speakers and Chinese native speakers participate in a Stroop test which consisted of four tasks: color naming of patches; color naming of written symbols; and reading words. Under the interference condition, (that is, reading colored words, while ignoring the color of the written symbols) there was a significant Stroop effect. The Chinese subjects were 397 msec slower than the English subjects in naming the colored words, suggesting differences in the obligatory processing of Chinese and English written symbols, with Chinese readers unable to refrain from configurational processing of logographs.

Eye movement studies may offer some insights into how logographic scripts may differ from alphabetic scripts when text is being read and processed. Chen (1996) argues that reading English is accomplished by just one type of eye movement, i.e., the type of saccadic eye movement which skips from one fixation point to another. Chinese reading, he argues, is performed by both saccadic eye movements and pursuit eye movements; the latter type occurs when readers are skimming the content of a text in a speed reading mode, gliding their eyes right through the text. Assuming that gliding eye movements cover a much wider area of information-gathering than saccadic eye movements, it is less likely that phonological information would be gathered in such broad sweeps of the logographic text with the aim of gathering the gist. In such cases, it might be possible that hanji text is processed without mediation of its phonological values. Tzeng, Hung and Garoo (1978) similarly have argued that initial lexical access can be accomplished without the mediation of speech mode, but that speech recoding must occur in processing Chinese characters beyond the working memory stage.

3. Conclusions

In this paper, we have reviewed previous work on Chinese hanji processing. Two opposing theoretical explanations emerge from that psycholinguistic literature: the Orthography-Independent Hypothesis (or Automatic Acoustic Activation Hypothesis) and the Orthography-Dependent Hypothesis. Our review of this literature concludes that there is not sufficient evidence to support either of these hypotheses to the complete exclusion of the other, and we have attempted to synthesize these conflicting experimental findings. We suggest that hanji processing can employ either of two processing routes in accessing to the semantic properties of a lexical item presented in hanji script. We also suggest that this double-route hypothesis is not specific to logographic systems which employ hanji or kanji, but can be extended to deep orthography problems such as are found with applications of the Roman Alphabet. Lastly, we maintain that hanji processing is not in and of itself unique, but shares many basic similarities with other script types, because of the nature of orthographic processing and the cognitive demands it makes upon human decoders.

It is obvious that we can maintain neither of the two opposing Hypotheses in their strong versions. The view that hanji processing is equivalent to alphabetic processing, particularly in the earliest stage of processing is simply untenable, given the experimental literature which points to the contributory role of graphemic information in various types of tasks. Similarly, we must also reject the view that hanji processing has but a single route, going directly from Orthography to Semantics, completely bypassing the contribution of Phonological information.

What is required is a satisfactory synthesis of the available literature, one which compromises between the conflicting evidence. The most plausible cognitive model is effectively a weak version of the Orthography-Dependent Processing Hypothesis. Depending upon the contextual setting, as determined by the familiarity, frequency, and complexity of the given hanji character, one of two processing routes may be taken. Both processing routes access semantic information, but one route is a primary sound-mediated route and the other route is a primary grapheme-mediated route.

It is abundantly clear that, at some point for most normal processing tasks which involve natural language, hanji symbols are just like alphabet symbols in that they must invoke phonological properties as the decoder searches through the mental lexicon. Thus when decoding pre-semantically, most linguistic tasks which are not simple pattern-matching maneuvers, take the decoder from *Grapheme to Phonology to Semantics*. Indeed, this fact squares with the observation that over 80% of Chinese logographs are in fact regarded as phonographs (see Chen and Yuen, 1991). However, given the overwhelming evidence that Chinese attends to the configurational nuances of graphemic decoding even at the earliest stages in processing, this primary sound-mediated route in Chinese may not be totally equivalent to that for alphabetic processing. We would suggest, however, that phonological properties are automatically accessed in most analytical tasks that are not pattern-matching or category-matching in nature.

By also accepting the cognitive routing offered by the primary grapheme-mediated route, we can account for how some tasks do access information about, as well as decisions regarding, hanji logographs that do not require phonological mediation. It is particularly plausible that certain Chinese hanji may employ a direct route, especially in those cases where hanji satisfy such requirements as high frequency and high familiarity. Indeed, there are instances in alphabetic systems like English where the cognitive route travelled is a direct route which takes the reader to deep orthography. For example, there are many instances in English in which the lack of a perfectly transparent sound-letter correspondence is overlooked in cases of morphophonemic identity such as the plural <-s>, the past tense <-ed>, /haws > hawz-/ in *houses*, and so forth. This may also be case where the phonological analysis of repeated instances of highly idiosyncratic spellings are soon ignored, as in words such as *thyme, Gloucester, the admirable Crichton* and so forth. If this is true, of course, claims for the uniqueness of logographic hanji/kanji systems are thereby weakened, for this would appear to be a processing characteristic of writing systems in general. The grapheme-mediated primary route is unique to neither Chinese nor Japanese, therefore, but may be just a matter of degree tied to how often this route is activated as the primary route.

In sum, when one considers universal constraints on how the mental lexicon is searched, cognitive mechanisms which respond to considerations of correspondence regularity, frequency, familiarity, and analytical task type drive the choice of the most efficient route for turning lexical access into word recognition. Thus, the two types of orthography, alphabetic and logographic, are not inherently different in their processing nature, although they differ in representational nature by one being phonologically based and the other morphologically based. If this generalization is correct, then, speculation about a single processing route is unlikely to be maintained, except for the extremely shallow orthographies found in languages like Tagalog, Indonesian, and Serbo-Croatian. A more plausible model of cognitive processing is that graphemic properties and phonological properties will be both processed, as is necessary and useful in such languages where they serve as address routes, as the decoder searches the mental lexicon for the correct interpretation of a lexical item which appears in its written form.

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