"RADICAL" THINKING ABOUT CHARACTER PERCEPTION:
SPECIFYING PRE-LEXICAL AND SUB-LEXICAL PROCESSES OF CHINESE READING

by

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Previous research has examined cross-linguistic importance of phonological and morphological awareness in Chinese and English word recognition, yet few studies have focused on the earlier, pre-lexical aspects of character recognition and evaluated why orthographic awareness is central to Chinese literacy development. Comparing spread of lexical activation between orthographic, phonologic and semantic stores in English and Chinese reading have helped to specify the lexical pathways underlying character decoding and reading comprehension as part of word recognition. The visual orthographic complexity and coarse form-form mappings of the logographic character system, considered in conjunction with the observations of the Lexical Constituency Model and other reading research, suggests that Chinese pre-lexical processing is exclusively orthographic and threshold-based. Sub-character radicals are decomposed sub-lexical (but not "pre-lexical") representations and are utilized in unfamiliar reading (based on radical frequency and regularity, and other factors). Radical parts are only accessed after orthographic lexical representations are already assembled, meaning their access involves top-down morpho-orthographic decomposition. The first study proposal uses two character recognition training tasks to examine the pre-lexical decoding mechanism that results in perceptual assembly of lexical orthographic representations. Beginning with the basic premise that the semantic cues provided by radical parts also contribute

to reading of unfamiliar graphic forms, two follow-up proposals compare the relevance of visual, orthographic and semantic salience of radical components to both real and pseudocharacter recall. It is anticipated that graphic and semantic salience of radicals will have independent and additive effects on recall of unfamiliar forms and both may be able to be incorporated into L2 pedagogies.

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1.0 INTRODUCTION

Cross-linguistic comparisons of word recognition for alphabetic and logographic scripts have helped to shed light on some of the similarities and difference that exist in reading between Chinese and English. The Lexical Constituency Model (Perfetti, Liu, & Tan, 2005) in particular has provided an overview of the way in which lexical activation spreads in various orthographies. One important implication of this model is that orthographic lexical representations must mediate all access to meaning and sound in logographic character reading, a claim supported by a broad base of research. Certain sub-lexical properties of character recognition underlie the centrality of orthographic awareness to logographic Chinese reading, yet little evidence exists specifying the nature of this pre-lexical processing. Beginning by reviewing the wealth of evidence that points towards a single, orthographic, pre-lexical path to lexical activation, this paper explains why it is unlikely that phonological features or radical parts play a role in Chinese pre-lexical processing.

If pre-lexical character processing is purely perceptual (or visual orthographic) in nature, how does activation spread to the lexical level in Chinese? An experiment is proposed to answer this question through evaluating the nature of the visual orthographic process that results in rapid, threshold-based assembly of sub-character "chunks" into orthographic lexical representations. This initial literature review and experimental design neglect to specify potential contributions of radical components. The second portion of the paper focuses on the role of radicals in unfamiliar character reading, with their non-lexical contributions termed "sub-lexical" since they are seen as only occurring *after* (orthographic) lexical activation, through a character decomposition process.

Two follow-up research proposals compare the contributions of the "pre-lexical" (logographeme) and "sub-lexical" (radical) parts, gauging their relative relevance to character reading and recall.

1.1   DECODING ACROSS ORTHOGRAPHIES: VARIATIONS IN FORM MAPPING

The last two decades have seen the development of many frameworks for comparing ties between graphic form (symbols) and phonological form (sounds) across languages. Such form-form comparisons are cornerstones of orthographic depth hypothesis (ODH) (Katz & Frost, 1983) and grain size theory (Ziegler & Goswami, 2005). While offering slightly different descriptions of the contrasts across alphabets, abjads and syllabaries, these two theoretical outlooks both posit that the lack of consistency between grapheme-phoneme ties in languages such as English makes decoding a more complex process than in more phonetically transparent languages (i.e. Italian), with grain size theory in turn calling for analysis of phonological units above the phonemic level.

The utility of these theoretical frameworks is in the way that they enable writing systems to be placed on a continuum, based on their "depth" or the consistency of form-form mappings at various phonological grain sizes. These continua of phonetic transparency have ramifications for the nature of decoding, and have been used extensively as a means of developing and evaluating pedagogical approaches for teaching both first and second language literacy (Share, 2008). In his 2008 paper, Share claims that many of the views emerging from the ideas of orthographic depth and phonological grain size were distorting empirical research and pedagogical practices, with an "anglocentric" account neglecting to account for ways that the ease of phoneme-level decoding in transparent orthographies influence the development of subskills related to reading. According to Share more emphasis must be placed on a universal *unfamiliar-to-familiar* dualism inherent to all reading, replacing the narrowly-focused ideas of grain size or depth that emerged largely from

research on the "outlier" orthography of English (with its inconsistent sound-symbol mappings). Current character reading research supports this sort of unfamiliar-to-familiar dualism, yet also shows that Share's critique is "alphocentric", as it is focused on phonology and GPC processing.

1.2 THE CHINESE SYSTEM: ALTERNATIVE FORM OF FORM-FORM MAPPINGS

The Chinese writing system is morphosyllabic in nature, with each character representing *both* phonology at the unit of the syllable and a morpheme. The character 请, for example, has a pronunciation of /ʒing/ and has a meaning of *please* or *to express courtesy*. This writing system has evolved over thousands of years from *pictographs* that explicitly resembled the meaning that they conveyed to *logographs* (also known as ideographs) that do not directly resemble the idea that they symbolize within written text. For instance, the character for *horse,* 马, no longer really resembles a horse, but the original pictograph had a strong likeness to the meaning it embodied. Returning to examination of form-form mappings, neither 请 nor 马 provide cues to sub-syllabic phonological units, with no part of these characters mapping onto phonology at the level of the phoneme, onset, rhyme, or any sub-syllabic grain size described by Ziegler & Goswami (2005).

The orthographic depth hypothesis and phonological grain size theory, while effectively accounting for variations among alphabets, do not allow for clean-cut categorization of character reading (hereby referred to as a *logographic* system, though the term *ideographic* is also in use). Despite the lack of sub-syllabic form-form mappings, and the fact that a single syllable generally maps onto many characters (the oft-described rampant homophony of Chinese) it nevertheless is the case that a single character grapheme maps reliably onto a single syllable-sized phonological unit. 请 can only be pronounced /ʒing/, 马 can only be pronounced /ma/, and for the most part all characters similarly have stable and reliable grapheme-to-phoneme connections. Of course, these

form-form mappings exist only at the level of the syllable, and thousands of characters therefore need to be memorized as mapping onto a morpheme *and* a syllable of pronunciation. Herein lies the failings of the orthographic depth hypothesis and grain size theory to categorize this writing system in any sort of meaningful way. Technically the reliable grapheme-phoneme mappings at the level of the character/syllable mean that Chinese has a shallow orthography, yet coarse grain size of these mappings means they are extremely different than the more fine-grained transparent alphabets that were traditionally described as shallow orthographies by Katz and Frost. The idea that characters be considered the main grapheme of analysis in Chinese reading research is to be taken up in the first portion of the paper, with logographic chunks proposed as an alternative unit. Phonological grain size theory does not account for the role of (sub-lexical) radical components in unfamiliar character reading: the role of radical cues is central to the second part of this paper.

The Chinese logographic writing system is different from alphabetic orthographies in that it lacks the same fine-grained phonetic transparency. Writing systems that only have opaque ties to phonology (as well as less consistent and orally evident connections) do not require phonemic awareness due to the absence of fine-grained form-form mappings (Ziegler & Goswami, 2005). While the consistency of symbol-sound mappings varies across alphabets, all such systems have grapheme-phoneme mappings that allow for unfamiliar words (or pseudowords such as "*blor*" in English) to be serially sounded out through a cascaded conversion process, described in the DRC model of Coltheart et al (2001). The course-grained structure of characters prevents fine-grained form-form mappings, influencing phonological units relevant to reading (Toyoda & Scrimgeour, 2009). Research at Chinese University of Hong Kong has suggested that awareness of phonemes does not coincide with emerging literacy in Chinese children (Tong et al., 2009; McBride-Chang et al., 2008). While sub-lexical phonological units are present in characters (phonetic radicals),

the grain size of characters means they are not accessed serially through symbol-sound mappings.

Phonemic awareness and the serial grapheme-phoneme conversion (GPC) described in the DRC

model is not part of character decoding; there is an absence of Coltheart et al's non-lexical route.

Figure 1: The DRC dual route word recognition model (Coltheart et al., 2001)
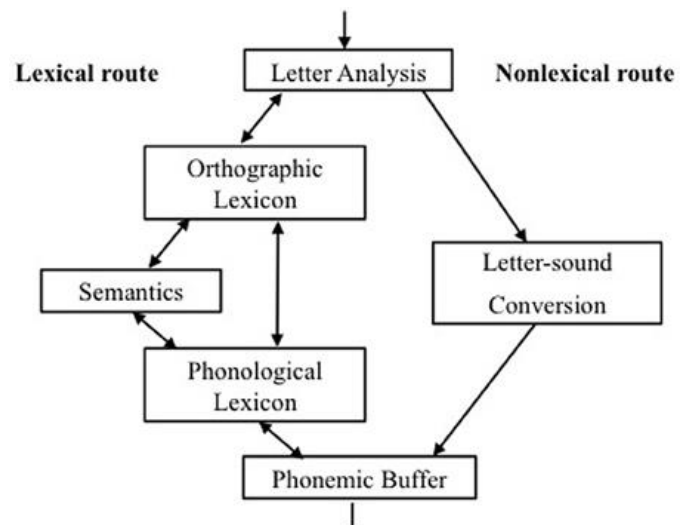
2.0 UNIVERSALITY: ORTHOGRAPHIC AWARENESS AND CHARACTER READING

2.1 CROSS-LINGUISTIC EVALUATIONS OF LEXICAL ACCESS

How many pre-lexical pathways lead to activation of constituent lexical representations in Chinese reading and what is the nature of said pathway(s)? The phonetic transparency of alphabetic orthographies means that the reading of unfamiliar or pseudo-words proceeds down a primarily phonological pre-lexical pathway; fundamentally different than the way familiar words are read in alphabetic reading (Share, 2008). Given the lack of a grapheme-phoneme conversion mechanism in Chinese reading, lexical activation is instead only mediated by visual orthographic assembly, with pre-lexical processing resulting in the composition of orthographic lexical entries, through orthographic processes similar to the way familiar-word decoding operates in alphabets (Grainger et al., 2012). Few studies have compared logographic and alphabetic reading, yet past research suggests that orthographic awareness has an *early* and *essential* role in Chinese reading; functions that are different than for reading in transparent scripts (Toyoda & Scrimgeour, 2009).

This paper consolidates evidence supporting the centrality of orthographic awareness to logographic reading and proposes research designs that test the claim that *all* character decoding (both familiar and unfamiliar forms) involves mediation by orthographic lexical representations. The orthographic depth hypothesis (ODH) (Katz & Frost, 1992) posits that the lack of consistent sound-symbol mappings means that morphological richness replaces phonemic awareness as the main mechanism (or supportive subskill) used in unfamiliar reading in alphabets lacking reliable form-form mappings, such as English. This paper modifies this idea slightly, using an absence of

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fine-grained symbol-sound mappings in Chinese, and analysis of perceptual-salient "chunks" and character radicals, to assert that orthographic awareness is uniquely central to character decoding. The ODH is reconceived to recognize that character decoding relies on orthographic awareness. Grain size theory must also be modified to account for logographic decoding, though it does help explain why phonemic awareness and pre-lexical phonology are not relevant to character reading.

2.2 PHONOLOGICAL UNITS: ABSENCE OF GRAPHEME PHONEME CONVERSION

Fine-grained phonemic awareness is often not observed in monolingual Chinese readers. The reading ability and phonemic awareness of L1 Chinese tend to only be correlated when these readers possess knowledge of alphabetic representations of characters (known as Pinyin and used in Mainland China as a staple of L1 literacy education), the ZhuYinFuHao pronunciation system (used in Taiwan), or the international phonetic alphabet (McDowell & Lorch, 2008). The more recent work of Newman et al (2011) includes strong assertions that phonological mappings at the level of the phoneme are highly correlated with overall reading ability and literacy development, providing empirical evidence that phonemic awareness emerges between the ages 6-8 years in L1 Chinese children. Since this study was undertaken in Mainland China, however, awareness of phonemes coincided with Pinyin introduction. Pinyin instruction leads to awareness of alphabetic principle and phonemes that in turn helps to support vocabulary growth and literacy development in children (Hold & Dodd, 1996; Huang & Hanley, 1997; Shu, Peng & McBride-Chang; 2008).

Research comparing the way individuals read in English and Chinese has helped further highlight the discrepancies in phonological awareness between alphabets and logographic scripts. Compelling evidence comes from a study comparing L1 and L2 (English) reading development of young Chinese dyslexic children (Chung & Ho, 2010). This study found that reading-related

cognitive abilities were transferable between L1 and L2 reading for these students, but phoneme awareness was only predictive of English reading performance. The phoneme awareness deficits of the dyslexic children did not show up in phonological testing within their native language, due to the coarse grain size of orthographic character units, as well as the inconsistent sound-symbol mappings present in Chinese. English is also considered an inconsistent orthographic system, yet their mappings across phonological grain sizes are much more systematic and constrained than in Chinese character reading (Perfetti, 2003). Variations in grain size and consistency of form-form connections between alphabetic and logographic orthographies results in the inability of Chinese children to isolate fine-grained phonemes on auditory discrimination tasks (Wang & Geva, 2003), especially phonemes absent from their L1 Cantonese such as the /v/ of English. The grain size of phonology prevalent in a child's L1 orthography affects their ability to manipulate L2 phonemes.

This study by Wang & Geva also showed that Chinese L1 students could quickly adapt to and become aware of the more fine-grained phonemic representations of English. A second study by these same researchers reveals that while Chinese children develop the ability to differentiate and distinguish English phonemes, they do not consistently incorporate such fine-grained aspects of phonology into L2 reading. Unlike Koreans- whose L1 has fine-grained form-form mappings- Chinese students were shown to have no enhanced ability to remember pronounceable English letter strings, suggesting that their initial analysis was not phonemic (nor phonological) in nature (Wang & Geva, 2003). A more recent study corroborates such Chinese and Korean comparisons, with phonemic processing ability predictive of English reading for Korean bilinguals, but not for their Chinese-English counterparts (Wang et al., 2008). Conversely, general auditory processing was predictive of English reading for the Chinese bilinguals. Phonological skills are relevant to Chinese reading, but not at the phonemic level like in more transparent scripts. Experience with

alphabetic reading – or the extensive exposure to the pinyin system described previously- brings awareness of fine-grained phonological mappings to L1 Chinese readers (Leong, Cheng and Tan, 2005). The absence of sub-syllabic print to speech mapping means that pre-lexical processing in Chinese reading relies more on visual skills and orthographic awareness (Siok & Fletcher, 2001). An absence of correlations between phonemic awareness and reading success among L1 Chinese children is a product of the course-grained form-form mappings present in logographic systems. Phonemic awareness cannot serve as a strategy for grapheme-to-phoneme conversion (GPC) of unfamiliar forms; radical awareness replaces GPC as the central sub-lexical decoding mechanism, with this alternative sub-lexical support pathway elaborated on in the second section of the paper.

Perhaps the most compelling evidence for the lack of a GPC "phonological route" comes from research examining the reading of children from various L1 backgrounds (Feng et al., 2009; Lin & Collins, 2012). Feng et al. use eye-tracking measures to evaluate the number and duration of fixations during the reading of children and college students in both the US and China. It was found that the effects of writing system on such measures were more pronounced in the children than the college students, which makes sense considering that the task involved *unfamiliar* word reading for the children but *familiar* reading for college students (which is similar across scripts). L1 English children relied on GPC conversion to serially sound-out unfamiliar words, resulting in longer fixation durations and more within-word refixations compared to L1 Chinese children. Decoding unfamiliar alphabetic words relies on GPC and takes more time (Grainger et al., 2012).

The pre-lexical, cascaded conversion of graphemes of different (sub-syllabic) grain sizes into phonological units is a decoding strategy that is instrumental to literacy development within more phonetically transparent alphabetic scripts. The orthographic depth and coarse grain size of characters makes this sort of rule-based, sub-syllabic form-form conversion system impossible in

Chinese reading, yet does not change the fact phonology is still involved in character reading, as outlined in the Universal Phonological Principle. The stroop effect is observed in Chinese (using homophones of colors) just as it is in alphabets, revealing that lexical-level phonology is rapidly activated in silent character reading (Perfett & Harris, 2013). English readers that are too young to manipulate phonemes are able to read effectively through similar sorts of holistic recognition, utilizing direct access to orthographic lexical representations (Fletcher-Flinn & Thompson, 2000). Serial GPC has dominated decoding research, but is not the only type of pre-lexical processing.

2.3   PHONOLOGICAL AWARENESS AND LITERACY IN CHARACTER READING

Though not a "core component" of reading development (Ho et al, 2012), phonology is still activated as part of character recognition. Syllable deletion and onset/rime tasks have shown that lexical level phonological abilities are strongly correlated with character reading (McBride-Chang et al, 2000; Siok & Fletcher, 2001). Studies conducted by Dr. Charles Perfetti have helped establish that phonology is automatically activated during character decoding in accordance with a Universal Phonological Principle (UPP) (Perfetti & Harris, 2013). The coarse grain size of symbol-sound mappings in the Chinese logographic system means that skilled reading relies more on morphological *and orthographic* awareness, and not fine-grained phonological recoding. Despite the fact that lexical access is mediated solely by graphic assembly (and does not involve serial, GPC), it is nevertheless the case that lexical-level phonology and the "phonological loop" aid character decoding, based on contributions they make to working memory (Baddeley, 2003).

The absence of GPC assembly in regular character reading is supported by neuroimaging research. The cascaded conversion of graphemes into phonemes- the mechanism that is believed to underlie decoding of unfamiliar alphabetic forms) involves left temporo-parietal brain regions,

and these areas generally lack stimulus driven activity during character reading (Pugh et al., 2000; Tan et al., 2005; Perfetti et al., 2007). Even Chinese study designs using phonological processing tasks fail to show activation in these regions, unlike early activation found in alphabetic reading (Paulesu et al., 2000; Booth et al., 2006). Though fMRI research suggests that the tempo-parietal regions are more active during reading of characters with phonetic radicals (Yang et al., 2011), this activation is absent in pseudocharacter decoding- regardless of whether transparent phonetic radicals are present. It is concluded that tempo-parietal activation generally reflects phonological recoding, implicating it in cascaded GPC and use of the alphabetic principle (Tan et al., 2005).

The orthographic complexity of the Chinese logographic character system, described in detail by Chang (2015), means there may be special perceptual or orthographic abilities involved in accessing the lexical level. The lack of phonetic transparency for Chinese characters combined with the lack of a GPC mechanism might mean that pre-lexical processing is purely orthographic (and not phonological) in nature and threshold-based (rather than cascaded). Some studies claim to show pre-lexical phonological processing in character reading. Event-related potential (ERP) research (measuring electrophysiological responses to stimuli in the brain) by Zhou et al (2014) found radical interference effects (for primes which are homophonic with an embedded radical) that consistently occurred earlier than interference effects for character-level homophones. This was measured through a primed naming study. They observed this effect for semantic radicals as well as phonetic radicals. Similarity in sound or meaning between the *radical* of the prime and target character had a larger influence on naming than character-level homophony or synonymy.

This study suggests that radical phonology is accessed rapidly, yet this radical processing is not pre-lexical. Early (N170 and P200- negative response at 170 ms and positive one at 180 ms) interference effects found for the radical-related primes provides evidence that radical *phonology*

is accessed before lexical-level *phonology*. Describing this radical effect as "pre-lexical" implies that radical representations are also accessed prior to lexical-level orthographic entries. Analysis of the reading performance of English and Japanese second language students of Chinese shows that the Japanese students integrate radical phonology into reading of unfamiliar characters better than their L1 English counterparts through incorporating in frequency and neighborhood effects. This suggests that radical awareness is a higher-level skill that is not directly linked to phonology (Lin & Collins, 2013). Having established that the coarse granularity of characters prevents the sub-syllabic form-form mappings and GPC mechanism that is so central to literacy development and unfamiliar form decoding in alphabets, reflected in consistent variations in neural activity for phonological processes in Chinese and English (Tan et al., 2005), we turn attention to research suggesting character pre-lexical processing is purely orthographic and involves a single pathway.

3.0 THE LEXICAL CONSTITUENCY MODEL

3.1 THE UNIVERSALITY OF SKILLED READING

Any investigation of pre-lexical processing must also provide an account of the spread of lexical activation, because pre-lexical processing models must support this lexical architecture. The Lexical Constituency Model (LCM) describes the spread of activation between orthographic, phonological, and semantic lexical representations. All orthographies contain these three distinct lexical stores, but activation latencies vary based on the specific structure of the writing system. The absence of any direct sub-lexical mapping between graphemes and phonemes in logographic scripts means that access to the phonological lexicon is invariably mediated by activation of the orthographic lexicon during character reading. The LCM does not claim phonological awareness is irrelevant in logographic reading, instead citing studies of pseudocharacter primes in asserting that the role of phonology in Chinese reading must be mediated by orthographic representations operating at the lexical level (Perfetti et al., 2005). The lexical constituency model focuses on the spread of activation *between* the lexical representations. By positing that lexical activation originates with the orthographic lexicon, however, it supports an understanding of pre-lexical processing as involving the assembly of salient graphic chunks into orthographic (lexical) entries.

Figure 2: An overview and illustration of the Lexical Constituency Model (Perfetti et al., 2005)

- A cross-linguistic, symbolic, *implemented* model of word reading.

- Possesses a conceptual basis, and computational instantiation (right).

- Stimulus onset asynchrony (SOA) for graphic, phonological and semantic primes shows orthographic (lexical) activation fastest, semantic stores last.
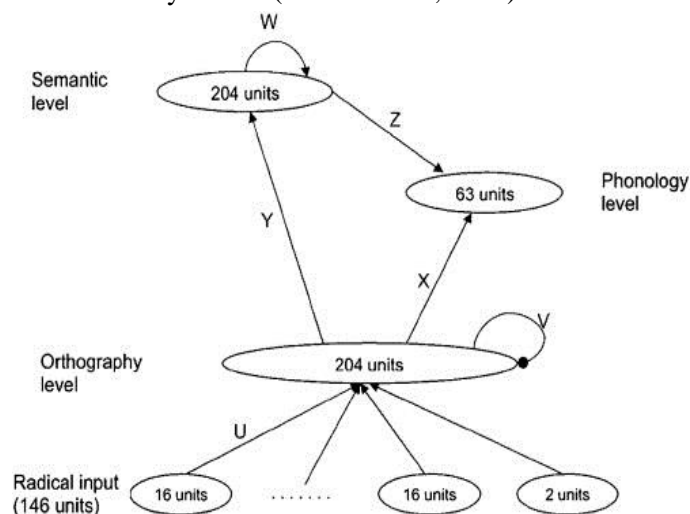
The previous description of orthographic activation as preceding phonological activation does not necessarily provide support for the major assumption of the lexical constituency model; the activation of an orthographic lexical representation must *mediate* activation of corresponding phonological and semantic entries. The early activation of orthographic awareness could simply occur down one processing pathway, with phonological activation proceeding along a different channel at a slightly slower speed. More recent work involving an auditory lexical decision task and ERPs provides strong support that the sort of mediation described by the lexical constituency model actually occurs (Zou et al., 2012). Through manipulating the ties between orthography and phonology for the first syllable in each prime-target pair during the auditory lexical decision task, these researchers found that there were significantly reduced N400 amplitudes when targets were preceded by an orthographically similar prime, and that the reduced N400 amplitudes correlated strongly with the reading skill of the Chinese L1 participants. The N400 is a pattern of electrical activity that peaks around 400 ms and typically occurs after exposure to visual or auditory words. The large orthographic and inhibitory phonological effects suggest a direct route to lexical access.

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In an innovative, cross-modal lexical decision design, Zou et al. (2012) provided a prime to the participants (who were all Chinese university students) orally. The prime was a real word, such as "猛撞" (written "mengzhuang" in Pinyin). After an interstimulus interval (ISI) of 150 ms, a target disyllabic Chinese word or pseudoword would appear on the computer screen in front of the student. The task for the students was to make a decision about whether the visual target was a real word or not (by clicking different keys on the keyboard). In response to a real-word target (all targets were real words) such as 猛撞, it was observed that orthographic similarity led to the most false-positive responses (with 猛懂-"mengdong"- being mistakenly considered a real word), as well as faster correct responses if the target was a real word. Effects of phonological overlap were not as strong (e.g. 猛壮 "mengzhuang") was used as a target, indicating that orthographic entries are activated automatically and rapidly during Chinese *spoken* word recognition as well.

The above assertions (and the lexical constituency model) do not mean that there is never phonological mediation involved in accessing semantics during Chinese character reading. The phonologically mediated priming studies of Zhou and Marslen-Wilson (1999) found primes that were both homophonic and orthographically similar to semantic primes led to faster responses. This indicates that phonology can facilitate semantic activation at the lexical level in Chinese, though the fact that these researchers found that only orthographically similar primes could also facilitate (homophonic primes did not) indicates that phonology is only relevant as a prime when *supported* by orthographic form. Phonological facilitation complements orthographic facilitation; effects are additive because orthographic form mediates phonological access (Zhang et al., 2009). Findings of lexical-level phonological facilitation should be expected given the high correlations between onset/rime and syllable-level awareness shown in both cross-sectional and longitudinal work (Siok & Fletcher, 2001; Chen et al., 2004; McBride- Chang et al., 2005; Chow et al., 2005).

Beyond simply asserting that orthographic entries mediate access to sound and meaning, the lexical constituency model also advocates the *dual-route hypothesis* for semantic activation. This hypothesis states that there exist two lexical pathways to accessing semantic information in logographic reading; one mediated by phonology and another that proceeds directly from graphic form to meaning. Two other ERP-based studies, one employing both semantic and homophone judgment tasks (Zhang, Zhang, & Kong, 2009) and another that replaced valid characters with illegal ones that were either homophones, orthographically similar, synonyms, or controls (Liu et al., 2011) both support the dual-route hypothesis by showing that there exists a direct pathway to semantic activation from the orthographic lexical constituent. The fact that both of these studies showed that semantic activation could occur before phonological activation in Chinese reading provides strong support for the lexical constituency model. They indicate that pre-lexical aspects of Chinese word recognition processing gives the orthographic lexicon a central role in reading, and also helps account for activation latencies for semantic and phonological representations that are different than in the more phonetically transparent scripts. The findings from developmental studies add support to the dual route hypothesis; supporting a direct lexical semantic pathway and providing an account of how orthographic, phonological and morphological awareness skills develop in cases of normal and impaired character reading (Bi et al., 2007; Tong et al., 2009).

The dyslexia evaluations of Ho & Ma (1999) summarize the consequences of an impaired direct lexical pathway and show the potential of phonology-based reading strategies as a support for dyslexic children. The impairment in these Chinese children would seem to indicate that they are unable to access semantics without phonological mediation; character and radical phonology must mediate meaning access. Pedagogy focused on character and radical form-form connections greatly improved the reading comprehension of these impaired readers to a certain extent; they

began to access semantics by making explicit attempts at linking graphic symbols with syllables. There also are descriptions of Chinese dyslexia in which readers are only able to access meaning and not phonology of characters (Liao et al, 2008; Leong et al, 2011), seemingly providing more evidence that there exists a direct lexical route to meaning in Chinese (as advocated in the LCM).

Inquiries into the nature of Chinese dyslexia provide evidence that there are two distinct lexical routes to meaning; one mediated by phonology and another involving direct access from orthography (Law & Yeung, 2010). Case studies of dyslexics therefore mirror neuroimaging and priming studies in lending strong support to the LCM and the notion of multiple lexical routes to meaning. Having summarized the ways that activation spreads between lexical representations during character reading, we next turn to the matter of describing the sub-lexical support system that precedes (and propels) lexical access. Empirical studies suggest that all character recognition begins with the threshold-based activation of orthographic lexical-level representations. Before beginning to investigate the nature of the bottom-up orthographic process that leads to this lexical access, it is important to first provide an overview of the neurocognitive research, priming studies, picture-naming tasks, eye-fixation experiments and recall research that all contributes to an understanding of character pre-lexical processing as invariably visual-orthographic in nature; orthographic lexical representations serve as gateway to lexical access and literacy development.

4.0   THE CENTRALITY OF CHARACTER ORTHOGRAPHIC REPRESENTATIONS

4.1 ORTHOGRAPHIC LEXICAL ENTRIES: THE GATEWAY TO LEXICAL ACCESS

The primacy and centrality of orthographic abilities in character recognition is supported by the findings of studies spanning disciplines of psychology, cognitive science and linguistics. Despite the diverse nature of the research findings outlined below, together they suggest that the absence of GPC decoding in Chinese makes orthographic abilities critical to all character reading, and suggest that the "visuospatial sketchpad" may be particularly important to working memory during character decoding, with a more central role than the phonological loop (Baddeley, 2003).

Several ERP studies have provided evidence that orthographic lexical access in character reading occurs before phonological representations are activated. Such studies are focused on the negative-going deflections that exist 300-500 milliseconds post-stimulus onset (called N400). Meng et al. (2008), examined the time course of orthographic and phonological activation for L1 Chinese children and adult readers through an experimental design that presented homophonic or orthographically-related incorrect characters. This study not only found that N400 effects were stronger for the orthographic mismatch condition compared with the homophonic condition, but also that the onset of the N400 effects was earlier for L1 Chinese adults than children, suggesting that orthographic awareness may become more central to reading with increased proficiency.

Figure 3: Examples of sentences that include orthographic and phonological mismatch (Meng et al, 2008)

Orthographic mismatch sentence (one character replaced by orthographically similar form):

过新年，孩子们都穿上漂亮的<u>衣报</u>。（衣服）(real word "yifu" replaced by "yibao")

On the New Year's Day, children all dress up with beautiful <u>YIBAO</u>. ("yifu" = clothes)

Phonological mismatch sentence (one character replaced by a homophone):

节假日，人们喜欢到郊外观自然<u>风井</u>。(风景) ("fengjing" replaced by homophone)

On holidays, people like to travel out of town to enjoy the natural <u>FENGJING</u> (风景 = scenery)

More recent ERP research has measured ERP signals during the reading of more and less clear character scripts (Lv & Wang, 2012). This study found large negative-going ERPs in a N400 window of 250-500 ms for *both* real and pseudo-characters presented in the less clear font. Despite the fact that timing and distribution of the effects for real and pseudo-characters did not differ, N400 effects for pseudo-characters was found to be more negative. These neural findings suggest that pre-lexical processing in character reading is purely perceptual and based on the assembly of visually-salient parts into orthographic (lexical) entries.

These ERP findings are supported by evidence from picture-word naming experiments, with the masked priming of pictures used to evaluate the latency of phonologic and orthographic facilitation effects on target character reading (Zhang & Weekes, 2009). Orthographic awareness had a more immediate impact than phonology within this picture priming, word naming design. This study involved presenting characters to skilled L1 Chinese character readers on a computer. After 500 ms of presentation, that character vanishes and is replaced by an image that is (1) the object symbolized by that character, (2) an object with Chinese pronunciation akin to that of the

previously shown character, (3) an object that is orthographically similar to the character shown, or (4) an object with similar spoken and written form to the previously presented character form. Primes in the pronunciation condition did not elicit faster picture naming, but orthographically similar primes did have a positive effect on recall. Interestingly, when paired with orthographic similarity, phonological form overlap had a positive effect and led to even larger priming effects (as illustrated below). Cascaded GPC leads phonology to be utilized early in alphabetic decoding, yet orthographic entries are activated first in character reading; observed in the way that graphic similarity dictates phonological priming effects as well as in the homophone and visual similarity effects that have consistently been found in reaction-time research (Liu & Perfetti, 2002).

Figure 4: An illustration of the picture- word prime naming research design of Zhang & Weekes (2009)
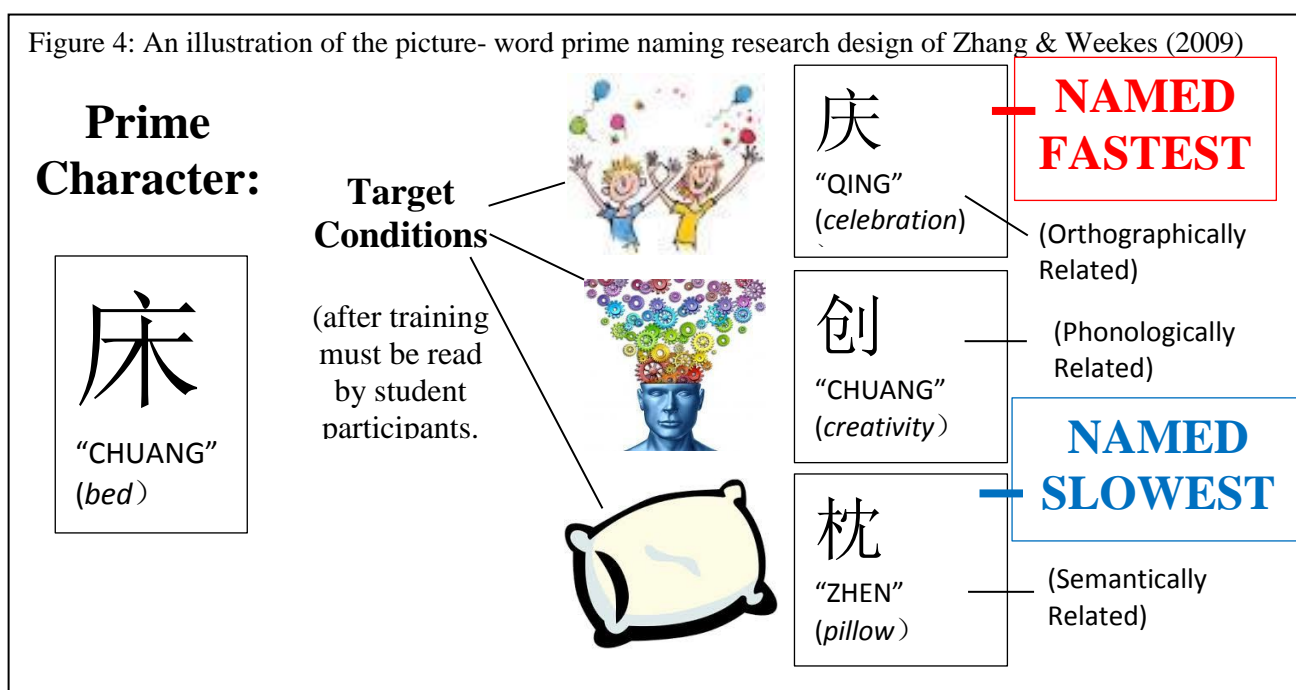
One potential pitfall of picture naming experiments is that they require study participants to first view pictures and then produce oral responses. One way of avoiding this potential pitfall is to directly evaluate character recognition through eye fixation research. Wong & Chen (1999) made use of a wide range of eye movement measures in examining reading behavior of Chinese

college students as they read sentences with characters written incorrectly in carefully controlled ways. The incorrect character was presented within the middle of an otherwise properly formed clause and was always the first character in a two character word. The replacement character was 1) orthographically *and* phonologically similar to the original character, 2) only orthographically similar, 3) only phonologically similar, or 4) had no similarity. Orthographic and phonological similarity were both found to be correlated with the total reading time, yet only the orthographic condition was indicative of early disruptions in eye movement that effected first fixation duration and other more focused measures. The carefully controlled design of this study (the replacements were all pretested for predictability and each eye tracking participant read eighty sentences) leads to the conclusion that orthographic abilities have an early and dominant role in character reading.

4.2 ALL ROADS THROUGH ORTHOGRAPHY: ONE PATHWAY TO LEXICALITY

This diverse set of studies- exploring everything from ERP measures to eye-monitoring- shows that orthographic activation occurs early in Chinese, yet none rule out the possibility that there exist multiple processing pathways to lexical access in character reading (as in alphabets). The fact that homophone and homograph picture priming effects are additive (Zhang et al., 2009) does seem to suggest that orthographic lexical activation might mediate phonological access, and even more compelling evidence for the early and unwavering mediation of orthography is found in the on-line speech processing work of Cheung & Chen (2004). A lack of phonemic awareness among non-Pinyin Chinese readers leads them to be less analytical during processing of spoken syllable, leading to an absence of sub-syllabic priming effects in the non-Pinyin reading subjects during a primed shadowing test. The phonemic awareness of Pinyin-proficient Chinese readers helps them to recognize and analyze the sub-syllabic onset consonant and coda information, and

also aids them in quickly repeating shadowed target syllables when primed with phonemic cues. Lacking this sub-syllabic GPC mechanism, non-Pinyin readers rely on lexical level orthography, resorting to whole character decoding strategies. An absence of phonemic awareness effects the ways in which non-Pinyin readers decode; this on-line speech processing research echoes fMRI findings of Tan et al (2005) in revealing that only syllable-level phonology is relevant to reading.

Support for the idea that there is one single pre-lexical pathway to lexical activation in Chinese also comes from research comparing the legitimate and illegitimate letter string spelling performance of Chinese ESL and English L1 children (Wang & Geva, 2003). English L1 readers performed better on spelling to dictation tasks for pseudowords that were made up of legitimate letter strings, but the performance of Chinese ESL students did not change regardless of whether or not the letter strings were pronounceable. For example, English L1 students were able to recall the legitimate letter string *poch* better than the illegitimate letter string pcch; Chinese L1 students conversely recalled both equally well. It is concluded that L1 English readers activate sub-lexical phonological representations early in the reading process, yet the logographic nature of Chinese leads ESL students to utilize orthographic awareness in English pseudoword reading and recall. Transfer effects from character reading leads Chinese readers to predominantly attend to graphic (and not phonological) features when decoding alphabetic script; evidence that lexical activation in character reading is mediated by orthographic representations. Beyond simply being activated earlier than phonology, it is likely that only orthography is involved in pre-lexical processing. In terms of the phonological grain size theory (Ziegler & Goswami, 2005) the Chinese orthography only maps onto phonology through syllabic units, while the orthographic depth hypothesis could take Wang & Geva's findings to mean that character reading occurs down a holistic, lexical route.

Studies focused on the transfer of a wide range of linguistic abilities also support the idea that Chinese reading relies heavily on orthographic awareness. The aforementioned use of Pinyin helps Chinese L1 students with aspects of both homophone awareness and phonological recoding, yet only visual-spatial awareness and not phoneme awareness is correlated with Chinese reading success in the early grades (Siok & Fletcher, 2001). In a separate study, Wang, Yang and Cheng (2009) tested Chinese-English bilingual children on a battery of tests related to morphological, phonological, orthographic, and general reading skills. They found reliable transfer effects for morphological and phonological ability, but no evidence for transfer at the orthographic level. These findings point to an absence of phonology in early Chinese word recognition, despite the fact that it plays a pivotal pre-lexical role in early literacy development for alphabetic languages.

The effects of orthographic awareness on character recognition have also been found in studies examining reading development of L2 Chinese learners. Wang, Perfetti, and Liu (2003) showed that students are sensitive to the orthographic structures of characters through a battery of lexical decision and naming tasks. Characters with illegal components in illegal positions were rejected the quickest. Characters with legal parts in illegal places were not rejected as quickly, but were rejected faster than legal parts in legal positions. An example of such pseudocharacters could be created by placing the semantic radical 氵 next to the phonetic radical 月. When configured 氵月 (legal positions) it requires longer to reject than when in illegal 月氵. A second study built on these findings, with a battery of naming, working memory, and orthographic knowledge tasks showing that students with more advanced orthographic skills perform better on text comprehension tasks. The fact that orthographic abilities play such a major role in character recognition suggests there is only one pre-lexical pathway to lexical access and that semantic and phonological activation is mediated by orthographic entries as in the LCM (Perfetti et al., 2005).

Figure 5: The Chinese second language reading developmental study of Wang, Perfetti, and Liu (2003)

Materials:

Examples of Stimuli in Lexical Decision Task

Real Characters		Noncharacters	
Types	*Characters*	*Types*	*Characters*
High simple (HS)	小	Legal radical, Legal position (LR–LP)	泪
High compound (HC)	她	Legal radical, Illegal position (LR–ILP)	帋
Low simple (LS)	生	Illegal radical (ILR)	㳠
Low compound (LC)	机	Symbol	&

L2 student lexical decision performance across noncharacter conditions:

Symbols graphically unlike characters were rejected the quickest.

Noncharacters with illegal parts ("chunks") were rejected the next fastest.

Noncharacters with real (legal) radicals in illegal positions were rejected less quickly.

Noncharacters with real (legal) radicals in legal positions were rejected the slowest (least quickly)

LATENCY OF THE LEXICAL DECISION

4.3   EVIDENCE OF OA FROM DEVELOPMENTAL AND DYSLEXIA RESEARCH

Strong support for a view of early processing as only involving graphic assembly- and no phonology- comes from research examining L1 Chinese reading. In evaluating more than 10,000 spelling errors of Chinese children, Shen and Bear (2000) found developmental patterns in their spelling strategies; with advancing grade level an original reliance on phonology is replaced by graphemic and semantic spelling strategies. Similar findings for the reading of literate Chinese adults illustrate just how central orthographic awareness is to skilled character reading (Zhang & Damian, 2011). The fact that these researchers have found phonological awareness not predictive of reading ability in Chinese readers suggests that pre-lexical processing is a purely perceptual

process. Lexical activation originates with orthographic lexical representations, assembled from visually-salient character "chunks" and involving key orthographic and morphological subskills.

The Shen & Bear study involved character production and the findings therefore must be taken with a grain of salt in considering any relevance to reading. Recent developmental research more focused on character reading in Hong Kong children has also showed that orthographic and morphologic abilities are much more essential in literacy growth than phonological abilities (Tong & McBride, 2010; Leong et al., 2011). Chinese children with dyslexia have been shown to struggle with both exception and pseudocharacter reading and their dyslexia is subsequently classified as belonging to the surface (and not phonological) subtype (Ho et al., 2007). Another study of children in Hong Kong with dyslexia further specifies the nature of their impairment. Elementary-aged children with and without dyslexia were tasked with copying unfamiliar print in three foreign languages (McBride-Chang, Chung and Tong, 2011). The ability of the students at copying the Vietnamese, Korean and Hebrew scripts was found to be significantly predictive of their Chinese reading and dictation skills. It can be inferred that orthographic impairment may underlie dyslexia in Chinese, with an inability to assemble orthographic lexical representations holding back literacy development. As seen in the following section, cross-linguistic research of L2 English acquisition across students with diverse L1 backgrounds also supports the notion that non-alphabetic decoding relies more centrally on orthographic abilities than alphabetic decoding.

4.4   L2 CROSS-LINGUISTIC RESEARCH: EVIDENCE OF OA TRANSFER

The mediating role of orthographic lexical entries during logographic character reading is not only evident in comparing Chinese L1 readers based on Pinyin proficiency, but also through comparing the English reading of L1 Chinese with their Korean ESL counterparts. Wang, Koda,

and Perfetti (2003) assessed reader reliance on orthographic and phonological form through an English word identification task. Korean students made more false positive errors in interpreting stimuli that were homophones to category exemplars, but L1 Chinese students did not show such effects and were better at responding to stimuli that were less similar in *spelling* to the exemplars. For example, after being primed with the category "flower", Korean students made more errors than the Chinese when asked if "rows" fits this category. Conversely, the Chinese students made more errors when confronted with words that were not homophonic but were spelled similarly to exemplars (*melt* when *meat* is a category exemplar). These variations in performance indicate Chinese students rely more on orthographic information during English word reading and recall, a result of the logographic structure of their L1 and the presence of *one single* orthographically-mediated path to lexical activation in Chinese. The same absence of a GPC mechanism (and the related phonemic awareness skills) that is illustrated in the absence of Pinyin-proficiency is also suggested by this unique and consistent reliance on orthographic awareness during ESL reading; phonological recoding- described by Grainger et al (2012)- is not a route utilized by L1 Chinese.

Other cross-linguistic studies have shown that L1 Chinese readers process English words differently than ESL readers with alphabetic L1s. When word shape is manipulated in an English text by alternating words between upper and lowercase script, reading of L1 Chinese students was observed to be more adversely affected and less efficient (measured through reading speed) than the reading of L1 Persian readers. The overall shape of graphemes is concluded to be an aspect of orthography more salient for the processing of logographic readers (Akamatsu, 2003). While Akamatsu described this special logographic reading tendency as a visual-spatial tendency rather than as an aspect of orthographic awareness, this cross-linguistic design paved the way for follow-up research more focused on cross-linguistic ESL variations tied to orthographic abilities.

More recent work of Wang and Koda (2007) compared English word decoding of Korean and Chinese ESL students and found strong cross-linguistic influences. The Koreans were more accurate decoders, regardless of word regularity or frequency. Koreans students were also much more apt to make regularization errors when naming low-frequency exception words, suggesting they might be relying more on cascaded GPC due to the fact that such strategies are available in their L1 too. Reliance on serial symbol-sound conversion by Korean ESL students not only helps them read real words accurately, but also helps them to recall pseudowords more effectively than Chinese L1 readers; the Korean readers rely on serial form-form decoding to recall pseudowords with regular pronunciations (Koda & Hamada, 2008). L1 Chinese were unable to retain meaning and pronunciation of regular pseudowords as well as Koreans because their sublexical decoding strategies were centered on orthographic assembly and not cascaded form-form conversion. The fact that the L1 Chinese readers recalled all English pseudowords equally well, regardless of the regularity of their form-form mappings, provides added evidence that their pre-lexical processing is primarily orthographic and not reliant on sub-lexical decoding to the same extent as Koreans.

More research must be done to establish the relationship between orthographic awareness and L2 Chinese character recognition. Given a lack of previous research into this area of inquiry, it is relevant that similar studies investigating second language Japanese reading have resulted in strong associations between the general orthographic skills of L2 Japanese readers and reading comprehension (Chikamatsu, 2006). Earlier lexical decision task research by Chikamatsu (1996) compared the L2 Japanese processing strategies of Chinese and American students and observed that the former utilized more orthographic awareness during decoding. All of this cross-linguistic evidence supports Cunningham et al's (2010) call for orthographic awareness to be studied as an independent construct that contributes to word recognition, and similarly supports the notion that

logographic character decoding involves assembly of orthographic wholes, not cascaded GPC. The dual-route modifications of Share (2008) and developmental description of word recognition by Ehri (2014) suggest that orthographic awareness (OA) is crucial to *familiar* alphabetic reading; absence of GPC means "chunk" assembly is critical to *all* Chinese decoding as a subskill of OA.

4.5   NEUROCOGNITIVE EVIDENCE SUPPORTING THE CENTRALITY OF OA

There is a neural basis for believing that Chinese character representations are accessed down a unique, orthographic path. Guo and Burgund (2010) examined activation of various brain areas during phonological, semantic, and orthographic character reading tasks. The fMRI results revealed that the left and right mid-fusiform gyrus are both involved in processing orthographic information during character reading. These same brain areas are not active during reading tasks focused solely on phonological or semantic processing, showing a sharp division in orthographic and phonological brain area activation in Chinese reading. The right mid-fusiform gyrus does not play a prominent role in alphabetic reading, suggesting there may be something unique about the nature of orthographic assembly and the absence of phonology in Chinese pre-lexical processing.

Research manipulating the orthographic structure of real and pseudocharacters suggests that processing occurring in the mid-fusiform is purely pre-lexical in nature (Wang et al., 2011). When L1 readers are shown real characters and pseudocharacters with components in either legal or illegal positions, the mid-fusiform was found to be most active for "illegal" pseudocharacters that readers quickly and easily distinguished as not real on an accompanying lexical decision task. The researchers claim this is evidence that the mid-fusiform gyrus is involved in special ways for logographic reading, functioning as a "high-level visual area". When parts are in "illegal" places they cannot rely on lexical or radical representations, placing more pressure on the visual system.

The mid-fusiform gyrus is not the only brain area shown to be more active in L1 Chinese character reading than during L1 English reading, as summarized in a report by Perfetti, Cao and Booth (2012). The visual areas associated with alphabetic reading are strongly lateralized, that is they are generally limited to the left side. The left fusiform gyrus is one of the brain areas active during alphabetic reading, for example. This same region is also implicated in Chinese reading, yet crucially the right fusiform gyrus shows the same patterns of persistent activation. Bilateral activation of the fusiform areas does not mean both sides are carrying out a comparable function. On the contrary, ERP evidence seems to suggest that the left fusiform gyrus first converts visual input into character visual components, and then the corresponding right region consolidates this input into spatial configurations (Liu & Perfetti, 2003). More activation is also evident in the left frontal gyrus during character reading, compared with alphabets (Perfetti, Cao and Booth, 2012).

Another separate fMRI study showed activation in both the left mid-fusiform gyrus and the left middle frontal gyrus during L1 reading of real and pseudo characters, but not artificial characters containing uncommon graphic components (Liu et al., 2008). The observations mirror activity in the Visual Word Form Area (VWFA) during alphabetic reading, but also highlight a major difference. While alphabetic GPC conversion leads to early activation in temporoparietal regions, Chinese character reading involves activity in the left middle frontal cortex. More recent fMRI studies suggest the bilateral cuneus and right lingual gyrus also play key roles in character reading (Sun et al., 2011), with left ventral premotor cortex and bilateral parieto occipital lobes also implicated (Huang et al., 2012). Qiu et al (2007) help highlight the relevance of frontal lobe regions in character reading, and specify areas involved in stroke searching and mental imagery. This broad base of neurocognitive research shows that there are brain areas uniquely involved in pre-lexical character assembly. More research needs to be done to pinpoint the focused functions

of these regions, yet they all likely have links to orthographic awareness and underlie a process of perceptual assembly distinct from the sub-lexical GPC mechanism (GPC is thought to occur in tempo-parietal regions such as the mid-superior temporal gyri). It would be interesting to see if the neural regions activated in Chinese and Kanji reading are active in reading of Japanese Kana; this can help clarify if activation is linked to phonological grain size or orthographic complexity.

5.0   CHINESE PRE-LEXICAL PROCESSING AND LEXICAL ACCESS

5.1   THE EARLY ROLE OF VISUAL-ORTHOGRAPHIC "CHUNKS" AND OA

Past studies have often assumed that radicals must have a role in pre-lexical activation (Lai et al., 2010; Wang et al., 2011). Recent research, however, suggests that visual orthographic, not phonological, abilities underlie the early assembly of orthographic lexical representations. These studies, discussed in the following few paragraphs, reveal how previous research has often erroneously assumed that the early perceptual processing of characters is the same for all people, regardless of whether or not they are experienced Chinese readers (Hsu, Lee and Marantz, 2011). Based on the established position that there is no "GPC route" in character decoding, it is time to recognize that the orthographic assembly of visually-salient character components develops, just as morphological awareness and radical recognition skills are acquired with reading experience.

The phonological and semantic cues provided by radical components are not closely tied to their orthographic value as character "chunks". Six-year-old Chinese children are able to reject nonwords (in which radicals are found in atypical positions) but accept pseudocharacters that do not violate position constraints (Chan & Nunes, 1998). An accompanying creative writing task showed that while children as young as six are sensitive to the placement of radical components, Chinese children do not typically develop awareness of radical phonology until the age of nine. This differentiation in the development of orthographic and phonological awareness of radicals

suggests that early activation of radicals has nothing to do with phonology (Leong & Ho, 2012), and explains why perceptual/visual orthographic skills are an essential part of character decoding. As visually-salient character subcomponents, radicals aid in the assembly of orthographic wholes.

A masking study of Chinese and German readers show that character visual components are rapidly assembled by experienced logographic readers (Elze et al., 2011). This study exposed participants to a target character (i.e. 木), originally indicated either by a surrounding character (i.e. 广) or four dots. After an interstimulus interval of varying length, the target is substituted for a masking stimulus that is either, (1) the same as the earlier indicator (the surrounding character or four dots), (2) a new intact character (i.e. 学) or (3) a scrambled version of (2). Despite always appearing in a different location, intact character masks impaired Chinese participants' ability to identify targets (scrambled masks did not result in similar delays). Character masks were found to slow target discrimination of Chinese readers when presented less than 100 ms after targets. These masking effects indicate that logographic reading experience influences the orthographic awareness of readers. Rapid orthographic assembly leads Chinese readers to develop competing hypotheses for the masked stimuli, which in turn impedes their ability to discriminate characters, through high-level perceptual processing akin to the observations of Grainger & Holcomb (2009).

Figure 6: An illustration of how character masking research was conducted by Elze et al. (2011)

Indicator (10 ms)

床

or

⸬木⸬

0-500 ms

Mask (500 ms)

学

or

∴∴

(WHICH WAS SHOWN ORIGINALLY?)

(大 or 木)

(Lexical decision)
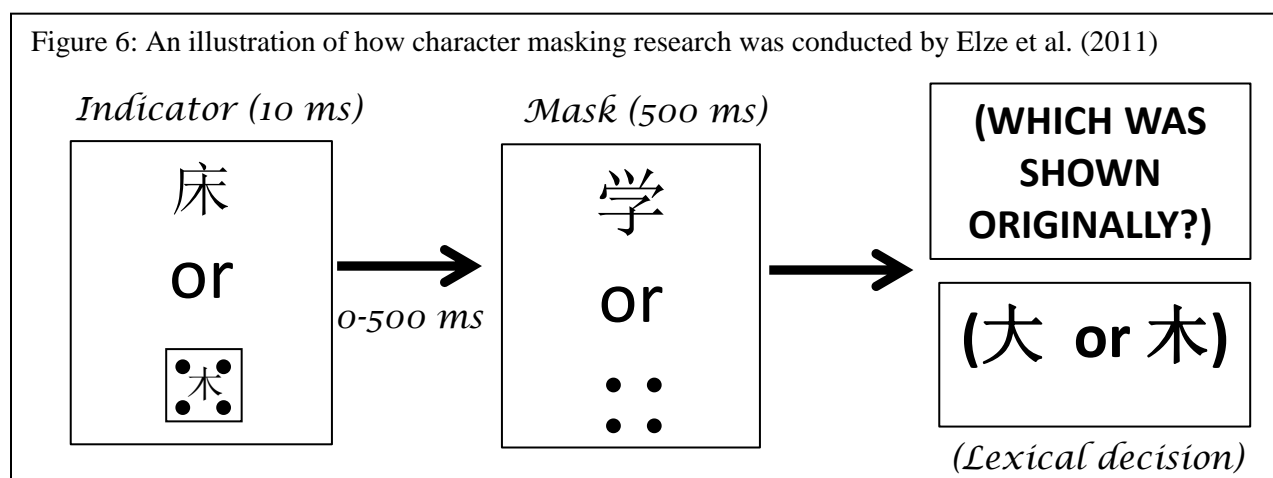
The fact that the same masking effects were not found for the Germans reading Chinese, or for longer inter-stimulus intervals (ISIs), indicates L1 readers develop rapid perceptual skills. The orthographic complexity of Chinese hints that the pre-lexical contributions of radicals are a product of their visual salience, not sub-lexical cues to pronunciation or meaning (Chang, 2015; Leong & Ho, 2012). Why should ideas of pre-lexical visual orthographic processing be restricted to perceptual parts or "chunks" that are (later in processing) associated with a particular meaning or pronunciation? Why is it that characters are invariably considered the essential graphemes of the Chinese orthography? The notion that visually-salient character components are processed as part of early orthographic lexical assembly is indirectly implied by much research to date.

Chinese pre-lexical processing, devoid of phonology, allows for rapid, skilled assembly of orthographic lexical representations, as evident in the LCM. What is the nature of this implicit perceptual processing? What sub-lexical character components are involved in this orthographic assembly? Yan et al. (2012) show stroke perceptual assembly to be an inadequate explanation. This eye movement experiment evaluated the ability of L1 Chinese readers to recognize common characters that were missing a certain percentage of strokes. Characters missing 15% of strokes were read with relative ease, but characters missing 30% or 50% of them were more difficult to decipher. Crucially, when strokes maintaining the overall configuration were removed characters were much more difficult to recognize than when less salient strokes were deleted. Strokes have a role at the bottom of a "hierarchy of increasingly complex representations" leading to the rapid assembly of orthographic lexical representations. The fact that all strokes do not share the same significance during reading suggests that larger visually-salient parts may also assist in assembly. This is backed up by electroencephalogram research of Wu et al. (2009), who found much more activation in visual areas when characters were decomposed into chunks compared with strokes.

The observation that all strokes do not have the same effects during character recognition, paired with the observation that the most essential strokes are those that preserve character shape, leads to the possibility that larger, visually-salient chunks could play a role in the composition of orthographic lexical constituents. Stroke perception is a first step in visual orthographic assembly, but character composition probably also involves larger logographic chunks. fMRI findings show that different brain areas are activated when Chinese L1 readers read characters being composed with one, two, or three successive stroke errors, suggesting there may be fundamental differences between single stroke and large logographic "chunk" errors (Yu et al.., 2011). Much more robust activation was elicited in the left fusiform gyrus when three successive stroke errors were present, implying that this region plays a prominent role in what should be described as pre-lexical visual configuration of logographemes. In a separate fMRI study the left mid-fusiform gyrus was found to be most active when character chunks are arranged in Chinese nonwords, with less activation in pseudowords (which follow positioning constraints) and the least in reading of real characters (Wang et al., 2011). The fact that this region is always active in early character processing means that it has a role in orthographic assembly, with the added activation in atypical character layouts indicative of the added effort required to establish these orthographic lexical representations.

Past research has not directly compared stoke-level perceptual processing with awareness of larger visually-salient character graphic parts. These parts have previously been referred to as "components" and "chunks", though perhaps a more appropriate term is "logographemes", since this term conveys the fact that they are (1) of processing importance and (2) a direct result of the logographic nature of the Chinese writing system. The perceptual learning research of Elze et al. and studies of stroke-level visual processing all indirectly indicate the presence of multiple levels of orthographic analysis during pre-lexical processing, and older evidence from English language

research similarly supports an understanding of perceptual processing as occurring in such stages. The Interactive Activation Model provides a framework for thinking of the visual information of a character as being obtained through the parallel, perceptual processing of orthographic features at stroke, logographeme, and character levels (McClelland & Remulhart, 1981). This model was focused on distinguishing letter and word visual perception in English, yet the authors point out that multi-level perceptual processing likely occurs in other scripts as well. Chinese orthographic awareness could similarly involve perceptual processing above stroke and below character levels. Future ERP and fMRI studies should attempt to piece apart functions of the disparate brain areas involved in character perception, specifying the brain areas linked to various visual orthographic functions just as Tan et al (2005) helped describe the roles of neural regions ties to phonology.

Studies have begun doing this, albeit indirectly. Primarily focused on exploring variations in visual imagery and perception during character reading, Qiu et al (2007) identified the right temporal-occipital junction as involved in stroke searching (not chunking) during visual imagery. It is anticipated that the next decade will bring more pinpointed predictions regarding the visual orthographic functions of the left mid fusiform, the left middle frontal gyrus, the premotor area, the bilateral cuneus, as well as some right hemisphere regions not involved in alphabetic reading.

Neural imaging observations must be backed by on-line studies of the rapid orthographic processing involved in character reading. Repetition blindness (RB) is an effective methodology for testing such early perceptual processes. The fact that the repetition of entire character graphic forms are forgotten immediately after rapid serial visual presentation (of only 57 ms) shows just how quickly orthographic lexical entries are assembled (Yeh & Li, 2004). A follow-up study by these researchers shifts their focus to the *nature* of such rapid assembly through an experimental design trying to reveal component RB. During a rapid serial visual presentation of two characters

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(placed between non-character stimuli), significant RB was found when participants were shown characters sharing a graphic component with exposure durations of 29 or 43 ms (but not 71 ms). Higher error rates when trying to recall a character that shares a logographeme with a previously viewed form is strong evidence that character forms are first visually integrated from strokes into chunks during pre-lexical processing. Added support for this interpretation comes from analysis of the *types* of errors that occurred in recalling the second character (sharing a chunk component), with a component in the second character either omitted or replaced by a different logographeme.

A role for logographemes in pre-lexical processing is also supported by the development of reading abilities in Chinese children. Su & Samuels (2010) varied the number of strokes and radicals present in characters during a lexical recognition task. When children of different ages performed this lexical recognition task (second graders, fourth graders, sixth graders and college students) the only significantly delayed response latency was found for the second graders on characters containing the most strokes. The fact that high stroke count does not delay recognition after grade two, and the fact that number of radicals never effected recognition, suggests neither strokes nor radicals play a major role in the rapid visual assembly of character orthographic form.

Su and Samuels (2010) conclude that there is a brief analytical phase in character reading, which quickly comes to be replaced by more holistic recognition, based on lexical orthography ERP support such stages in the pre-lexical processing of character forms comes from the work of Qiu et al (2007), who found that Chinese readers showed a spread of activation between different brain areas during stroke judgment tasks involving pseudocharacters. Might perceptual assembly extend beyond stroke analysis to something more efficient? ERPs recorded during character (and pseudocharacter) decision tasks for two different fonts showed much larger negative-going ERPs for the more degraded Xing Kai Ti font (Lv & Wang, 2012). The consistency with which

reading this font led to more negative- going ERPs in a 300-500 ms time window suggests that variations in visual complexity involves more than the nature or number of stroke components.

Another experiment that provides indirect evidence for character "chunking" is the fMRI study of Sun et al. (2011) that examined brain regions involved in early character reading when characters were shown with their radical parts spaced out to varying degrees. Early activation of the left middle occipital gyrus and left superior parietal lobule during spaced character reading was very similar to the activation during spaced English word reading (the letters of the English words were spread out). Unlike in English word reading, however, Chinese readers consistently showed strong activation of the bilateral cuneus. Of particular interest is the fact that variations in the spacing of character radicals did not affect the bilateral cuneus activation, while the other early visual processing areas showed non-monotonic patterns that varied with character spacing. The researchers discussed the findings in terms of radical-level processing, yet also acknowledge that the results are evidence for unique visual-spatial processing in Chinese. The early nature of this activation means it is unlikely to involve phonological processing (there is no GPC), and the monotonic activation of the bilateral cuneus can therefore be attributed to perceptual "chunking".

Just as neuroimaging studies try to understand how characters are conceptualized so too have written production tasks attempted to evaluate the development of visual orthographic skills. Empirical examinations of the writing abilities of Chinese children illustrate how their graphic awareness changes over years of study (Shen & Bear, 2000). Younger (grade one) students make mostly phonological spelling errors on a timed writing task, yet a majority of the errors made by older (grade six) students were graphic or semantic errors. Rather than making the same pinyin or homophonic substitution errors as the first graders, older student errors were partial characters or similarly shaped forms as they sped through the timed writing assignment. Writing production

results should be cautiously applied to evaluations of character recognition processes. Given the complexities of the Chinese logographic system, it may not be the case that the same patterns of activation are involved in receptive character recognition and productive character writing. When viewed in conjunction with evidence from the on-line masking, repetition blindness and priming tasks described previously, however, the developmental changes in writing errors reveal that the awareness that L1 Chinese have for their orthography seems to change with reading experience and literacy training. Similar writing-error experiments should be done with L2 Chinese readers.

Could it be the case that explicitly training students to notice character "logographemes" leads to the perceptual learning evident in the visual masking effects found by Elze et al. (2012)? The following research proposal tries to train students with no previous exposure to characters to develop the same sort of orthographic awareness abilities observed in masking effects of their L1 reading condition. Elze et al concluded that character reading experience had a large influence on the orthographic abilities of L1 Chinese readers. In synthesizing past research on functional brain activation in L2 Chinese reading, Perfetti et al. (2007) claimed early differences in L2 processing (compared with L1 reading) disappear during a second semester of formal study, with the neural processing patterns of more experienced L2 readers mirroring those of L1 Chinese. Can training techniques that focus on character orthographic structure help L2 students develop new strategies that allow for efficient assembly and access of lexical level representations? Might it be the case that explicit emphasis of graphic "chunks" helps L2 readers restructure lexical assembly abilities? This proposal tests the idea that chunking is central to orthographic assembly, evaluating whether subconscious, bottom-up orthographic skills can be explicitly taught and can support L2 literacy.

All three of the proposals to follow are motivated by what is considered an "alphocentric" focus on GPC as the way in which novel characters are read. Word recognition in fine-grained,

phonetically transparent orthographies, such as alphabets, does undoubtedly rely heavily on GPC, especially for certain stages of development (Ehri, 2014). Given that these sub-lexical strategies are clearly not available in logographic decoding, research has already helped establish that there is a much more central role for orthographic awareness in Chinese character reading. While this has been consistently found across experimental designs, the most robust research to date is more focused on explaining the relevance of these orthographic abilities to ESL education of Chinese. It is clear from such research that the mental representations of English words is different for L1 Chinese than other ESL readers (Taft , 2002; Akamatsu, 2003; Wang, Koda and Perfetti, 2003).

The study proposals that follow aspire to be part of a new wave of research that *specifies* orthographic subskills and *switches* the direction of L2 research. Based on Andrews' (2008) idea that lexical quality is essential to efficient reading, and Grainger's (2009) outlook that location-specific orthographic processing is essential to all skilled reading, these proposals seek to specify orthographic subskills involved in *accessing* the lexical-level and arriving at sound and meaning. Following the blueprint of Taft et al (2002, 2004), these proposals explore the nature of mental representations readers develop for characters, hoping to uncover insights that can aid pedagogy.

6.0 EXPERIMENT I: EXAMINING CHARACTER PRE-LEXICAL PROCESSING

Participants

All of the participants in this study will be L1 English university students or college graduates, between the ages of 20 and 30 years. None will have had past exposure to logographic languages. Students with proficiency in an alphabetic L2 will be included. Some students may be graduate students while others will be undergraduates. Students will not be omitted that are early bilinguals or who have considerable proficiency in an L2 (that is not Mandarin); such details will be recorded in a survey to be provided at the outset of the experiment. Participants will be literate readers of English without any sort of reading deficits. Given that this research design involves an independent variable with two levels, 96 students will be randomly placed in the conditions, ensuring that each condition has at least thirty participants. Generally speaking, students are to be recruited from the University at Pittsburgh and Carnegie Mellon University communities. In addition to ensuring that all participants included in the data have no prior exposure to character or Chinese language learning, the students will also be asked to refrain from beginning to study Chinese language in the three to four weeks between the initial experiment and delayed posttest.

Materials

Computer software. E-Prime (Psychology Software Inc., Pittsburgh, PA) will be used to design both training and testing conditions. A program developed using this software that has been used in previous University of Pittsburgh research will be used for the stroke construction

condition, while the "chunking" condition is to be developed from scratch. In using E-Prime to develop the "chunk" training and testing regimens, every effort will be made to ensure that the new program mirrors the existing stroke construction condition. The ways in which the two are identical will include the size of the presented characters, the rate at which they are constructed, duration of presentation, and the computer system on which they are presented to the participants.

Characters used in the training. The fifteen characters incorporated into training are all concrete nouns containing exactly three to five graphic "chunks". An example is the character 狗 (dog). Five characters will contain three distinct chunks, five others will contain four chunks, and the final five will all contain five logographic chunks. The number of chunks is controlled in this way to ensure that orthographic complexity does not vary between the experimental conditions. The number of chunks will be determined based on the responses of L1 Chinese assistants to the question "How many distinct graphic parts, regardless of sound or meaning, do you believe are present in this character?" Only characters deemed to have the same number of "chunks" by nine of the ten L1 readers will be included as stimuli in the experiment. All fifteen of these carefully selected character stimuli will be high frequency concrete nouns and that it is therefore assumed all fifteen will represent concepts very familiar to the American university students (such as *dog*).

Questionnaire. A questionnaire will be provided to students at the outset of the study, inquiring into their age, post-secondary academic history, and language proficiencies. Students with any prior exposure to Chinese character reading or ability in a dialect of Chinese language will not be permitted to participate in the study. Students will have already been assumed to have no prior exposure to characters or Chinese language, but the questionnaire serves as a final check. All students that fill out the questionnaire will be put through the experiment, but their data will only be included if the questionnaire verifies that they lack experience with Chinese language.

Computers. Apple personal computers with 18-inch screens will be used to conduct the study with all subjects. The computers were selected for convenience and E-Prime compatibility.

Experimental environment. The training and testing session for experiments 1A and 1B will both be conducted in a quiet room in an academic building. The testing room is unfamiliar to all of the experiment participants, and does not contain any images that could serve as distractors.

Procedures

Upon arriving to begin their session, each participant will first fill out the questionnaire and then be randomly assigned to the "stroke" or "log composition" character training condition, or to a third control condition. This third group will simply be exposed to whole character forms, rather than to forms that are assembled stroke-by-stroke or through chunking. Having completed the questionnaire and been assigned to one of the three training regimens, the experimenter will next read the instructions for their particular training trial to each participant. The instructions shall be read twice, with participants asked if they have questions about the training task after both readings, and reminded to try and remember the structure of the forms that they are shown.

Having been told the nature of the training task, participants in both conditions will next be exposed to the same character stimuli on a computer screen, but will practice studying these novel logographic Chinese character forms in three different ways (based on assigned condition). Participants in all conditions will see all character for exactly thirty seconds during the training, at which time the screen will automatically move on to displaying the next character. Each of the fifteen characters will be shown in exactly four of the thirty-second segments, meaning that total training exposure to each character during training is two minutes and the total time duration of the training is thirty minutes. Characters are shown at random within each block, but the one that ends a given block cannot be first in the next block (characters are never shown consecutively).

Participants in the "stroke" training condition will be shown the fifteen characters being created one stroke at a time. Each stroke-by-stroke creation of a character will take four seconds, at which point the character will remain on the screen for one second. This process will repeat itself six times for each character within each training block. Participants in the "log composition" training condition will instead be shown the three to five logographemes in each character slowly moving together to create the character. The logographic chunks will take four seconds to unify into a character after which they will remain on the screen for one second before the composition process restarts. Students in the control condition will see the character presented holistically for thirty seconds. Once each character has been randomly presented in four thirty-second training trials within the four blocks, training is over and students move on to the lexical decision task. In both training conditions participants tap the computer's space bar each time a character is formed, with this regular involvement used to ensure and evaluate attentional control throughout the task.

Figure 7: Experiment 1a training of the two experimental groups

"Stroke"   "Log composition"

(Appearing one stroke at a time)   (Appearing as parts coming together)
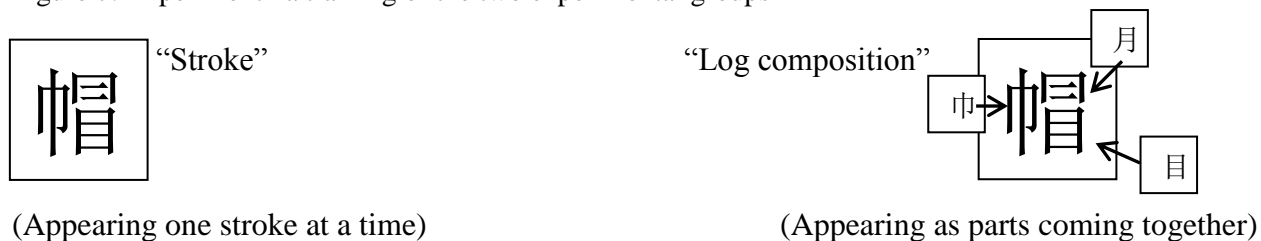
Despite the aforementioned variations in the two training conditions, participants in both conditions will be tested through the exact same lexical decision task. The test for Experiment 1a involves being shown 42 characters and pseudo-characters, 15 of which were the characters that the student was exposed to during the training. The presentation of the 42 characters and pseudo-characters will be randomized and they will be controlled to contain three to five logographemes. Participants will have five seconds to determine whether or not each form is one of the originally presented characters, indicating whether they believe a character is from the training session by

tapping two different keys on the computer's keyboard using their dominant hand. If participants fail to provide a response within the allotted five seconds, the test will move on to the next item.

Experiment 1b will unfold similarly to Experiment 1a, with the exception that this time semantics is to be incorporated into both the training and the lexical decision task. Training will occur as in Experiment 1a, except this time the characters are assembled beside an image that the students have been told represents the meaning of the character. For example, when participants see 狗, an image of a dog will appear next to the character during each of the training trials. All other aspects of the training will unfold in the same way; with all participants placed in the same condition as they were in Experiment 1a ("stroke" and "log composition"). During the reading of instructions prior to the second experiment, the proctor will mention that an image embodying the meaning of each character is to appear next to each character and that this image will be relevant to the following tasks. Participants are also to be reminded that character form is still an important element in the testing that will follow the thirty-minute Experiment 1b training task. A new set of fifteen characters will be used as stimuli in experiment 1b, but with similar structure.

Experiment 1b testing involves the simultaneous presentation of an image and a character form. Participants have five seconds to decide whether a character form is paired with the proper image. Each trial in this second lexical decision task is to include one of four possible situations: a correct pair of a character (from training) with its image, an incorrect pairing of a character and image that were both presented, a character that was not included in the training with an image that was, and pairings in which both character and image were not included. Participants will be told to click one key if they see pairs from the training session, and to hit a different key if the pair was not present during the training trial. It will be emphasized that they are only to select the "affirmation" key when the image and character are paired just as they were during the training.

Figure 8: Experiment 1b training of the two experimental groups

"Stroke"   "Log composition"

帽

巾 → 月 目

(Appearing one stroke at a time)   (Appearing as parts coming together)
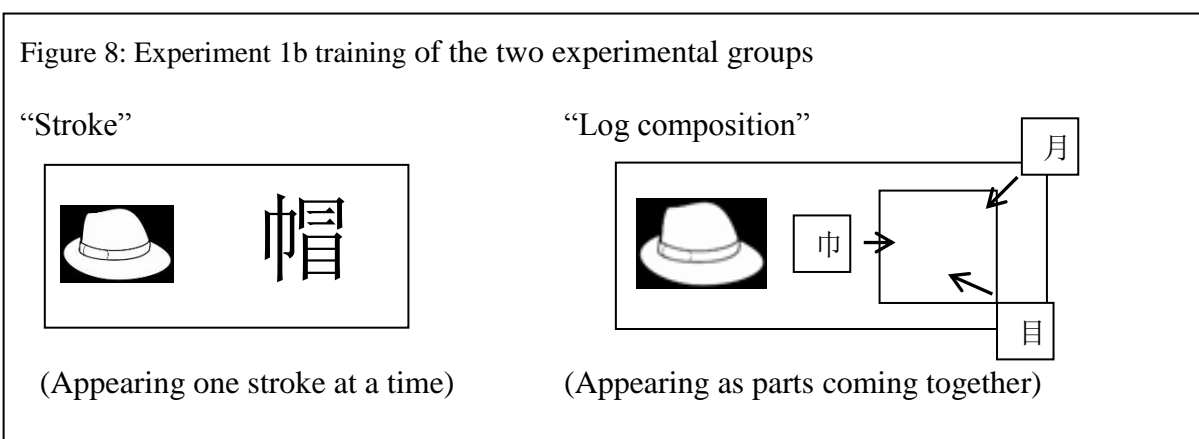
All other aspects of both Experiment 1a and Experiment 1b will be kept constant, such as the size of the characters during both training and testing, as well as the number of logographic chunks contained in all characters presented (equal numbers of three, four and five). Norms will be developed for the number of chunks present in the characters, with characters containing more than five or less than three logographic chunks not utilized in the experiment. As mentioned prior, developing norms will involve ten L1 readers deciding how many visually-salient chunks are in potential character stimuli. Both experimental conditions will require students to decide whether they recall character by tapping one of two keys, with five seconds allotted for each tap response. Should neither key be pressed within the five seconds, an absence of a selection will be recorded.

Between three to four weeks after their original training and testing sessions, participants will return to the same experiment environment and perform the same two lexical decision tasks. These delayed posttests will contain the same character forms and meanings that were involved in the initial trial. There will be no new training provided prior to the posttests, since the goal of the posttest component is to assess whether or not longer-term character recognition is improved through the original training tasks. After the posttest, participants all answer a series of questions to verify that they have not studied Chinese logographs or language in the interim time period.

Hypotheses

The present research specifically involves three separate null and alternative hypotheses. The first null hypothesis is that there will be no difference in character recognition during the lexical decision task of Experiment 1a, regardless of the training group that students belong to. A second null hypothesis is that the same lack of variations will be found in Experiment 1b. These null hypotheses are accompanied by alternative hypotheses that claim there will be advantages in character recall for the "chunk" training condition. Specifically, in Experiment 1a there will be a difference in recognition of character forms, with participants in the "log composition" condition recalling character forms better than those in the "stroke" condition. With regards to Experiment 1b, there will be a difference in ability to make associations between character form and images, with participants in the "log composition" condition linking character forms with related images better than participants in the "stroke" condition. The final null hypothesis extends the previous predictions to the posttest, claiming that students in the "log composition" and "stroke" condition will perform equally well on posttest lexical decision tasks, to be completed three to four weeks after the original training and testing was conducted. Conversely, our alternative hypothesis with regards to the posttest is that the "log composition" condition students will perform significantly better on both of the posttest lexical decision tasks than the "stroke" condition participants. It is generally thought that the "chunk" condition will be superior since it allows students to analyze aspects of character composition that aid in the assembly of orthographic lexical representations. It is also predicted that both experimental conditions will result in improved performance relative to the control condition that simply has the characters presented in their full form during training.

Results

Since this study involves an independent variable (training) with three levels (stroke, log composition, and control) and a dependent variable (performance on character recognition tasks) which will be calculated into an interval dependent variable, a univariate ANOVA test will allow for evaluations of whether the means of the conditions are (statistically) significantly different. Experiment 1a and Experiment 1b will both be statistically evaluated using univariate ANOVAs. For both experiments, the scores on the lexical decision tasks will be evaluated to ensure that the scores in each group are normally distributed and that the variances for the scores of both levels are not widely different, thereby upholding two major assumptions underlying the ANOVA tests. All tests will all have the critical (alpha) value set at .05, with the statistic being calculated for a two-tailed (non-directional) decision. Assuming a degrees of freedom over 90 (the *df* should be at least this large given each training condition will have over thirty participants), a t-value of 2.0 will be required to reject the null hypothesis and assert that there exists evidence of a statistically significant difference in performance of the two training conditions on the lexical decision tasks. It is predicted that the t-values will be greater than 2.0 in both Experiment 1a and Experiment 1b.

This experiment also involves administering both lexical decision tests to all participants a second time through a follow-up posttest. Giving the same sort of tests to the same individuals allows for use of repeated measures ANOVA to assess any significance in the variations between scores on the lexical decision tasks at the two time periods. It is hypothesized that univariate and repeated measures ANOVAs will reveal significant variations in performance between the three training conditions during on the initial lexical decision task, as well as the posttest administered several weeks later after the initial training and testing. It is also anticipated that lexical decision

task scores for students across all three training conditions will be lower on the delayed posttests, because several weeks will have passed since their exposure to the character forms and meanings.

Discussion

This study is focused on evaluating the pre-lexical architecture that leads to activation of lexical constituent representations. Any findings of prominent pre-lexical chunking of characters, when viewed in conjunction with the prior research prefaced in this paper, would suggest there is only *one* single pre-lexical processing pathway that leads to lexical access. This single pathway for the processing of all characters is qualitatively different than in alphabetic languages, as past studies highlighting the centrality of orthographic awareness and an absence fine-grained sound-symbol mappings support. If we can reject the null hypothesis and claim that "chunking" results in better character recognition than stroke-by-stroke presentation, it will indicate that pre-lexical Chinese character processing involves visual-orthographic assembly above the basic stroke unit.

The absence of pre-lexical phonology during character reading represents a fundamental, qualitative difference in form-form mappings between logographic and transparent, fine-grained scripts. Cascaded grapheme-phoneme conversion is utilized in alphabets for novel word reading; words already represented lexically are processed down a different, direct path to orthographic lexical activation. Only this latter processing pathway is available in the early, perceptual stages of Chinese character recognition, regardless of the familiarity of the form being read. The lack of a multi-route path to lexical activation might mean that certain sorts of dyslexia in Chinese could have grave consequences for reading ability, because all vocabulary growth occurs through the same pre-lexical graphic composition process (i.e. chunking). This explains why surface dyslexia is often observed in Chinese children (Ho et al., 2007). The presence of only this single pathway

mean L2 readers should be taught characters in a way that facilitates formation of- and access to- lexical forms, reinforcing assembly of orthographic entries and helping expand L2 vocabulary.

Yet how is the pre-lexical assembly of character graphics organized? The existence of a single route to lexical knowledge makes it even more essential that the nature of this pre-lexical processing pathway be better understood. Having ruled out radicals and phonological knowledge as part of pre-lexical processing, it is inferred that these aspects of characters play a post-lexical, top-down role in reading. The perceptual process through which all characters are assembled into orthographic wholes is crucial to development of literacy for both L1 and L2 readers of Chinese. If in fact characters are initially assembled through the chunking of strokes into larger, visually-salient graphic components, pedagogical practices of language instructors might be modified to reinforce these unique aspects of character pre-lexical processing. Should students in the present study show evidence of significant variations in recall, especially on the posttests, it will indicate that even brief chunk training helps L2 learners develop lexical representations. More consistent exposure to character graphic components will likely lead to more advanced orthographic ability.

There are many ways in which character "chunking" might be incorporated into Chinese language education. Less explicit character pre-lexical training could involve input enhancement, whereby characters are shown in a way that highlights their chunk components. This presentation could be extremely explicit (as in the present study) or could simply mean altering the color or font of the character components. Should an instructor really want to explicitly provide students with an awareness of orthographic structure, students could be asked to assemble characters from the many chunks that appear within characters. While the rapid pre-lexical assembly of chunks into orthographic representation is a largely unconscious process, explicitly teaching students to

recognize and assemble character graphic chunks could help them automatize pre-lexical graphic encoding and acquire the lexical character representations they need to become efficient readers.

The activities mentioned above must also consider an important aspect of instruction that was not factored into the present study: The time it takes to train students in these different ways. Even if it is established that awareness of chunk character components aids literacy development, it does not necessarily follow that the benefits are large enough to warrant spending lots of class time teaching chunk awareness. The ways in which practice with pre-lexical assembly aids word recognition and retention of vocabulary may not be strong enough to take up precious class time.

If in fact training with dynamic "chunk" presentation leads to better character recall than dynamic stroke presentation, such a training effect will provide insight into pre-lexical character processing. Should future studies continue to show that there is no role for radicals or phonology in pre-lexical character recognition, it is also important that such studies not overlook the crucial ways that radicals and phonology *do* support reading. Radicals are most likely incorporated into character recognition when no strong ties exist between orthographic lexical representations and constituent lexical entries, helping readers infer the sound and meaning of unfamiliar characters.

Turning to the role of phonology in character recognition, there is no doubt that lexical-level phonology has a crucial role in Chinese reading. As described in the multi-route description of semantic access provided in the Lexical Constituency Model, access to meaning is sometimes mediated by phonologic lexical activation (Perfetti et al., 2005). Phonology is relevant to reading and, like radicals, plays a vital role in accessing semantics, but phonology and sub-lexical radical access are mediated by orthographic lexical entries and play no part in pre-lexical processing.

Strokes on the other hand certainly have some sort of role in the pre-lexical, visual-spatial assembly of orthographic lexical representations. As the smallest salient component of characters,

stroke processing likely plays some role in character comprehension and production. There exists plenty of evidence suggesting that character writing relies on stroke-by-stroke processing, yet the findings of Yu et al. (2011) and Yan et al. (2012) presented earlier in this paper raise the prospect that strokes may not play as pivotal a role in recognition. To review, Yu et al. (2011) showed that fMRI analysis revealed different areas activated in the early reading of ill-formed characters with one, two, or three neighboring strokes absent. Yan et al. found that characters with only 15% of strokes missing were readable, especially when the strokes were not next to each other, while characters with more absent pieces were incomprehensible. Combined with the predicted results of the present research, such studies suggest that it is chunks of strokes and not stroke-by-stroke analysis that matters most for pre-lexical processing (and character recognition more generally). The Interaction Activity Model (McLelland & Rumelhart, 1981) lends a framework for thinking of strokes and chunks as working together as part of character recognition and lexical access.

Observations of significant variations in recognition of character forms and the ability to make ties to meaning between the "stroke" and "chunk" conditions can only provide preliminary evidence that there is more to pre-lexical processing than stroke assembly. A lack of longitudinal data on the way pedagogical practices affect character comprehension and reading ability should be remedied in future research. Examining the way different literacy pedagogies might influence character recognition over the course of several weeks or months could provide more meaningful evidence for perceptual chunking than has been found in the much briefer exposure times of the present experiment. Future studies, regardless of whether or not they are longitudinal, might also attempt to control participant factors that were not accounted for in the present design. Age and reason for studying Chinese (motivation) might impact the way that students decode characters; both factors should be controlled in the future. The most important areas of individual difference

to control include the visual-spatial abilities and orthographic awareness of L2 readers. Language learners who possess these skills may excel at chunking characters early in L2 Chinese education; other students may need more time and explicit instruction to show such perceptual development.

One factor that cannot be the source of an absence of statistically significant variations in performance is dynamic presentation. The present study controlled for the dynamic presentation of characters by ensuring that both "stroke" and "chunking" conditions created characters while the participants observed. This aspect of the task was carefully controlled because it could be the case that dynamic aspects of character assembly influence character recall. Future research could reproduce the "stroke" and "chunking" training tasks of the present study in ways that are both dynamic (as in the present study) and static (i.e. by varying the color of strokes or chunks within characters). Such a manipulation might lead to a better understanding of whether or not dynamic presentation is superior to showing character forms statically during L2 literacy instruction.

Should the present study fail to show significant variations in character recognition based on the two training conditions, there are several potential explanations for these findings. First, it could be the case that aspects of individual difference in visual-spatial skill have a much stronger impact on pre-lexical (perceptual) aspects of character recognition than variations in training task. Alternatively, the brief nature of the half-hour training sessions in this study could simply not be enough exposure to have any significant effect on recognition and application of character forms. Future studies that incorporate a more longitudinal design and much more training with "stroke" and "chunk" character assembly might produce much more marked (and statistically significant) variations. Finally, given the incredibly rapid nature of pre-lexical character (graphic) assembly, it may be the case that these visual-spatial abilities develop naturally and that explicit instruction cannot enhance or speed up the process of assembling character orthographic representations. As

the work of Perfetti, Xu and Chang (2013) suggests, it may also be the case that the orthographic abilities taught in the training conditions may only serve to support more experienced L2 readers.

The present study has provided a framework for understanding pre-lexical processing of Chinese characters as involving the purely perceptual assembly of chunk parts, with phonology and radicals relegated to later roles in word recognition. Improved character recognition after "chunk" training might also be related to past research that has established orthographic skills as playing a primary and pivotal role in character decoding. Future studies must continue evaluating the nature of this orthographic processing by investigating how visually salient graphic parts are assembled into lexical representations. Pre-lexical graphic processing provides the foundation for character literacy, and should be studied as an aspect of character reading with real ramifications for pedagogy. As L2 Chinese education continues growing in popularity and prominence abroad, it is essential that literacy training emphasize the perceptual abilities underlying lexical assembly.

7.0   CONTRIBUTIONS OF RADICAL COMPONENTS TO CHARACTER READING

7.1   SUB-LEXICAL RADICAL USE AND UNFAMILIAR CHARACTER DECODING

When a pseudoword, such as "zint", is shown to native speakers of English and they are asked to offer a pronunciation for this novel form, speakers are apt to all guess the same "regular" pronunciation. Literate L1 Chinese are also able to predict the pronunciation of pseudocharacters (Weekes, Chen and Lin, 1998). There exist many studies showing that semantic and phonetic radical cues are involved in unfamiliar character reading. Kanji reading studies have shown that literate L1 Japanese readers identify forms faster when the left radical within a kanji character is semantically tied to the overall meaning of the character (Yamada & Takashima, 2001). The cues provided by such semantic radicals are combined with contextual clues to try and help determine the meaning of novel kanji within the context of sentences (Mori & Nagy, 1999). More recent studies focused on Chinese L2 reading provide evidence of the semantic contributions of radicals (Shen & Ke, 2007; Williams, 2013), with MEG and ERP measures helping to identify specific brain regions active during semantic radical processing during Chinese reading (Hsu et al., 2011).

Phonetic radical components have also been shown to be utilized in early word reading of Chinese second language readers, despite the lack of reliability of such sub-lexical phonetic parts (Williams, 2013). Young L1 Chinese readers similarly incorporate sublexical phonetic cues from radicals into their reading (He, Wang and Anderson, 2005). In this study second and fourth grade students were able to make use of the phonological information in bound-phonetic characters just

as well (and sometimes better) than in independent-phonetic characters. Primed naming studies with 3rd and 6th grade L1 readers have similarly shown that both semantic and phonetic cues will prime a target with a related sound or meaning, even when the radical prime is part of a complex character that has an overall meaning or sound unrelated to the target to follow (Wu et al., 1999). These findings suggest that even young L1 children have rapid, automatic access to radical cues.

The use of radical phonetic cues by normal readers has also been compared to the reading abilities of dyslexic L1 Chinese readers. Some Chinese dyslexics cannot make use of the direct semantic route in reading, and therefore must make use of phonetic cues to pronunciation in trying to decipher the written form of characters. The reading ability of such dyslexics depends in large part on the consistency and reliability of the phonetic radicals in the characters they read (Bi et al, 2007). When students with this sort of dyslexia are given targeted training in the ability to recognize and utilize phonetic radicals, their reading abilities improve dramatically (Ho & Ma, 1999). As will be mentioned later in discussing consistency, transparency and other effects that influence the role of radicals in reading (Lin & Collins; Lv et al, 2014), explicitly instructing students to recognize and utilize the sublexical cues of radicals helps *both* dyslexic L1 and non-dyslexic L2 readers develop literacy skills and expand receptive vocabulary (Shen & Ke, 2007).

Some past research has not focused on showing the value of radical phonetic or semantic cues, but instead provides evidence that *both* have an important role to play in dyslexic and non-dyslexic reading. Law & Yeung (2010) provide a detailed account of one dyslexic student who can only read down the semantic path. This student made extensive use of semantic radical cues in character reading, predicting the meaning of novel characters based on their semantic radicals. Whereas this student did not utilize phonetic radicals in reading, these same authors also discuss another dyslexic Chinese reader who, like in Bi et al.'s (2007) study, could only make use of the

non-semantic pathway. Moving away from dyslexic reading, Hsiao (2011) utilized eye-fixation measures to evaluate perceptual processing of common "SP" characters with the phonetic radical on the right side and uncommon "PS" characters with phonetic radicals located on the left side. Experienced oral readers tend to fixate on the right of characters, with such observed reliance on phonetic cues akin to semantic radical preview benefits found in silent reading (Yan et al., 2012).

Having established that radicals influence the visual perception and reading of characters, the next step is to try and define the sort of role they might play as part of character recognition. Despite sometimes existing as characters in their own right, radicals are not always represented as lexical items and therefore should be viewed as a non-lexical support structure that support the reading of unfamiliar or less familiar character forms. Unlike the non-lexical support structure of the GPC mechanism that is utilized in alphabetic reading, radical cues to pronunciation are not at the fine grain size of the phoneme but at the much larger phonological unit of the syllable. Given the absence of consistency with which radical forms map into phonological units, it is important to remember that there is a trade-off between phonetic transparency and morphological richness (Perfetti & Harris 2013). While failing to provide fine-grained phonology, radicals have a unique non-lexical role that is a product of the morphological and orthographic depth of characters.

The past decade has brought a new focus on the importance of morphological awareness in Chinese literacy development (Wu et al, 2009). Studies have shown that morphological skills develop in children from kindergarten through the sixth grade, and that emerging morphological awareness is correlated with literacy growth (Shu et al., 2006; Wu et al., 2009; Tong et al., 2009). Chinese morphological awareness most likely does not involve a lot of derivational morphology (Lam et al., 2012), and most certainly involves types of compounding and homophone awareness that have little relevance to radical awareness (Chen et al., 2013; Hao et al., 2013). The sorts of

morphological awareness tested in the compounding awareness research of Chen et al (2009) and Pasquarella et al. (2013), however, may be connected with the ability to decode bound radicals. One study evaluating the kanji reading of L1 Japanese describes the ways in which these readers decomposed unfamiliar graphic forms and utilized the cues of their semantic radicals; awareness of radicals helps learners arrive at sound and meaning of unfamiliar graphic forms (Mori, 2003).

7.2   RADICAL ACCESS: A MORPHO-ORTHOGRAPHIC ACCOUNT

Decomposition of whole character graphic forms for radical representations is unlikely to involve morphological awareness. There are important variations in the way that semantic and phonological information is extracted from multi-syllabic words and individual characters. In an on-line experiment, when the characters in a multi-syllabic Chinese word are switched around, Chinese children still claim them to be a real word, but when radicals (of right-left SP characters) are switched the same children quickly and reliably reject the validity of such pseudocharacters (Liu et al., 2010). Character order is not important for accessing the meanings of multi-syllabic words, yet analysis of individual characters does not involve the same sort of holistic processing (Li & McBride-Chang, 2014). Segmentation leads to holistic word analysis early in reading; but it is unlikely that the same compounding is also at play in sub-lexical radical processing (Yang et al., 2012). Orthographic and morphological abilities underlying developing radical awareness in L1 and L2 Chinese reading is an area of empirical inquiry ripe for research in the years ahead.

The analytical nature of radical awareness observed in Liu et al (2010) means that radical semantic and phonetic cues can only be accessed *after* orthographic lexical representations have been assembled. The children in this study were able to reliably reject pseudocharacters that used

radicals in "illegal" positions within the character configuration that violated proper placement. At the same time, when shown pseudocharacters that did not violate the radical positioning rules these same children had a hard time denying that they were real characters. These findings mirror the observations of Taft, Zhu and Peng (1999) in that they establish that positional information is an essential part of all radical representations. Priming studies also show how the relation of the radical to the entire orthographic structure of the character is an essential part of these sub-lexical representations, with facilitation shown when the prime and the target shared a radical in similar positions (Ding, Peng and Taft, 2004). The influence of shared radicals in different positions was actually *inhibitory*, with the violation of orthographic *rules* leading to a longer latency before the character could be identified. It is unlikely that the presence or absence of orthographic overlap would have the same effect at the word-level in Chinese. The analysis of radical representations involves orthographic effects and positional specificity because radical access must be mediated by orthographic lexical entries. For this reason, radical activation is best described as *post-lexical* sub-lexical processing. The positional specificity elaborated on above implies that while Yamada & Takashima (2001) were able to effectively show the influence of semantic radicals on reading, they were incorrect in claiming radicals lead to bottom-up activation of the orthographic lexicon.

8.0   THE NATURE OF MORPHO-ORTHOGRAPHIC DECOMPOSITION (MOD)

## 8.1   A SKILLED, TOP DOWN AND INHERENTLY ORTHOGRAPHIC PROCESS

We can conclude from the radical positioning and priming studies of Marcus Taft and his colleagues (1999, 2004) that the decomposition of orthographic lexical representations results in activation of radical components. It has been posited that morphological processing in alphabetic scripts is based on orthographic analysis, with decomposition based on the orthographic salience and not the semantic properties of morphemes (Rastle & Davis, 2008). The authors cite findings from behavioral and neural studies in support of the centrality of orthographic representations in morphological decomposition. Logographic writing systems are more orthographically complex and less phonetically transparent than alphabetic systems, so morphemic segmentation based on orthographic analysis is likely even more relevant to character decoding. No matter the language in question, Rastle & Davis's theory claims words perceived to have the *potential* for morphemic components are *automatically* decoded, regardless of whether or not their graphic parts actually contain semantics. An English example is the word *corner,* which is asserted to be automatically decomposed- in the same way that *darkness* is- despite its lack of morphemes. This same sort of morpho-orthographic decompositional process may very well be involved in character reading.

Rastle & Davis consolidate the findings of many fMRI studies that used masked priming and long-lag repetition priming to examine the brain areas involved in decoding morphemes, and in turn to ascertain whether this decomposition process is in fact morpho-orthographic in nature. Their extensive literature review suggests that the mid fusiform gyrus- as discussed earlier in the portion on character perception- only involves bottom-up visuo-spatial processing. The anterior middle occipital gyrus, however, was much more active for masked priming of *corn* after *corner* than *broth* following *brothel*, despite the fact that neither pair has transparent semantic relations. Prefrontal regions were also found to be active in the priming of *corn* after *corner* (opaque) and *hunt* after *hunter* (transparent), but not *brother - broth*). Frontal regions are also active in radical decoding, suggesting top-down morpho-orthographic access (Hsu et al., 2011; Yang et al., 2011).

The claim that radical access is morpho-orthographic and "semantically blind" (Kinoshita et al., 2012) has not gone unchallenged. A response came in the form of a study which examined the way in which semantic transparency impacts forward masked priming for multi-morphemic prime-target pairs (Feldman, et al., 2014). The strong morphological facilitation affects for more transparent pairs lead the authors to conclude that semantic features are accessed prior to lexical-level *semantics*. This is an important insight showing key contributions of radical awareness to vocabulary growth. Just as the radical priming study (Zhou et al., 2014) discussed earlier offered strong support that radical-level phonological representations are accessed prior to lexical-level phonology, Feldman et al. are showing similar sorts of facilitation effects for semantic radicals. Neither of these findings, however, refutes the assertions of Rastle & Davis because they do not elaborate on the role of lexical-level *orthography*, as seen in the following modified LCM model.

Theoretical views of Rastle & Davis are extended into the modified LCM model below, which posits that radical access is always mediated by orthographic lexical representations. This

theoretical position has not been evaluated empirically through studies of character decoding, yet receives support from lexical decision and transposed-letter effect research in English and Dutch. Orthographically similar primes lead to faster lexical decision *regardless* of semantic relatedness of prime-target (rename-NAME vs. relate-LATE vs. entail-TAIL), but semantically transparent prefixed words (rename-NAME) and suffixed words (viewer-VIEW, rather than corner-CORN) showed slightly stronger priming effects (Diependaele et al., 2009, 2011). These results are taken as evidence that there exist both morpho-orthographic and morpho-semantic stages in decoding, designated as sublexical "decomposition" and "integration" stages below, which are both thought to make unique contributions to unfamiliar graphic form decoding (Dunabeitia et al., 2007, 2011).

Figure 9: Sub-lexical support structure incorporated into the lexical constituency model
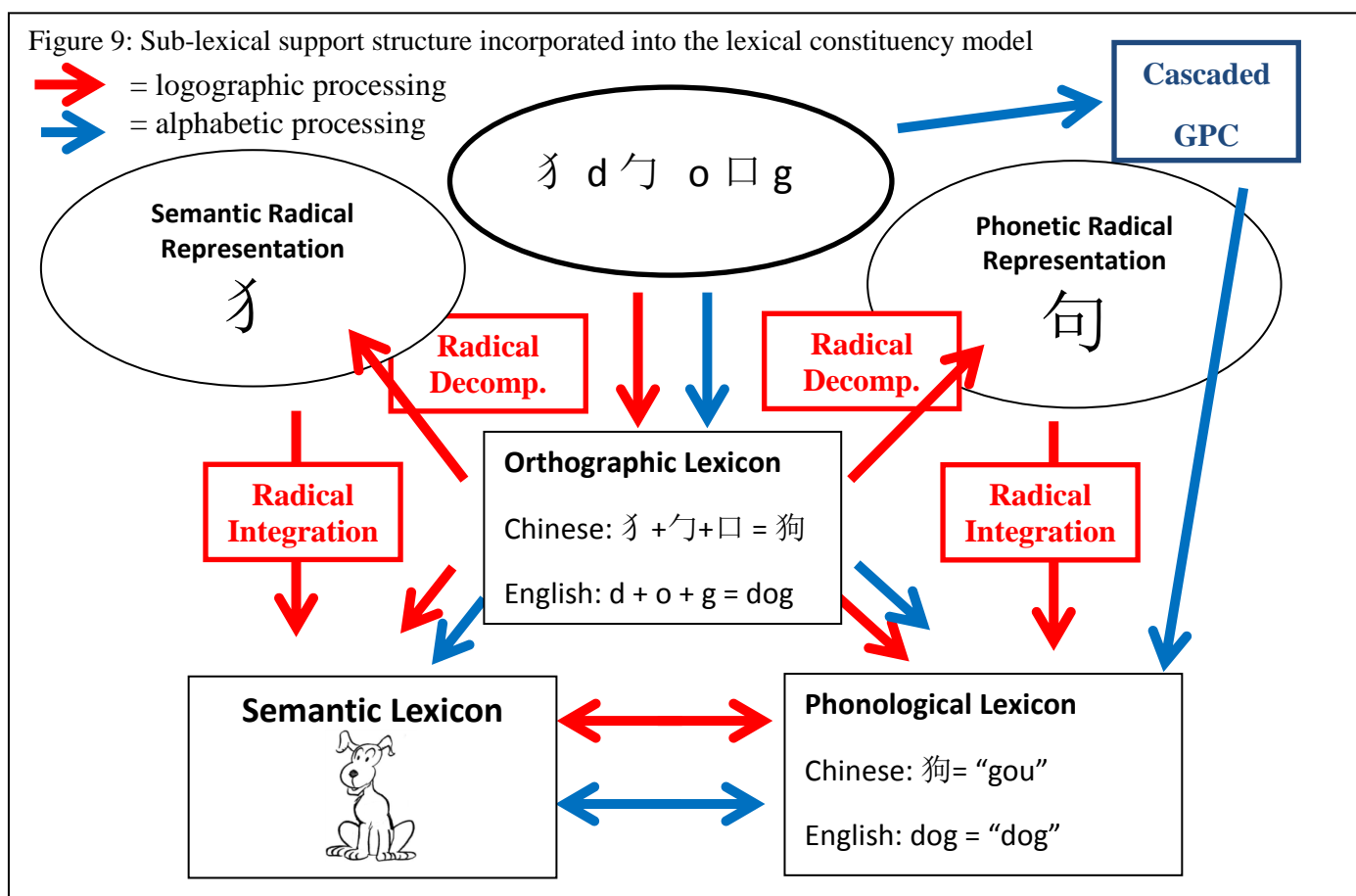
This model- based on the original LCM designed by Perfetti, Liu and Tan (2005) - shows how pre-lexical visual-orthographic assembly leads to orthographic lexical activation. The ability to decompose orthographic wholes into radical components (that carry semantic or phonetic cues) is an orthographic process that does not involve semantic or phonetic feature analysis, supported by research that shows that transposed-letter effects, which are orthographic effects, cannot occur across morpheme boundaries (Dunabeitia et al.., 2007). Radicals mediate access to lexical-level phonology and meaning, leading to the observed homophone interference (Zhou et al., 2014) and semantic transparency (Feldman et al., 2009) effects. Such effects show the role radical semantic and phonetic cues have in the reading of unfamiliar graphic forms, yet this does not change the fact that radical access involves advanced orthographic awareness mediated by lexical activation.

The advanced orthographic processing used to access radical cues is a form of morpho-orthographic decomposition, akin to the process described by Rastle and Davis. This sort of skill should be added to subskills of orthographic awareness, as outlined by Cunningham et al. (2012). According to Cunningham (2012), orthographic awareness needs to be recognized and studied as a distinct reading subskill, distinct from visual-spatial skills or lower-level perceptual processing. The ability to form, store and retrieve word-specific orthographic information has been shown to be tied to reading fluency and comprehension, with many tasks (i.e. orthographic verification and orthographic choice) correlated with L1 English and ESL reading abilities (Cunningham, 2001). Recent, modified dual-route models such as the Bimodal Interactive Activation Model (BIAM) (Diependaele et al., 2010) lend a framework for explaining how phonology is activated quickly in alphabetic decoding and how higher-level orthographic abilities are essential to skilled reading. Strong orthographic neighborhood density effects are found for L1 alphabet readers (Dunabeitia, 2008), suggesting that morpho-orthographic decomposition serves as a skilled decoding strategy.

Figure 10: An overview of BIAM and the related orthographic neighborhood density effects

S = Semantic

O = Orthographic

P = Phonological

V = Visual

A = Auditory

The V-to-O connections and A-to-P connections become more precise with increased neighborhood density in L1 and L2 reading, meaning SAND can be decoded more accurately(and rapidly) than JUDGE.
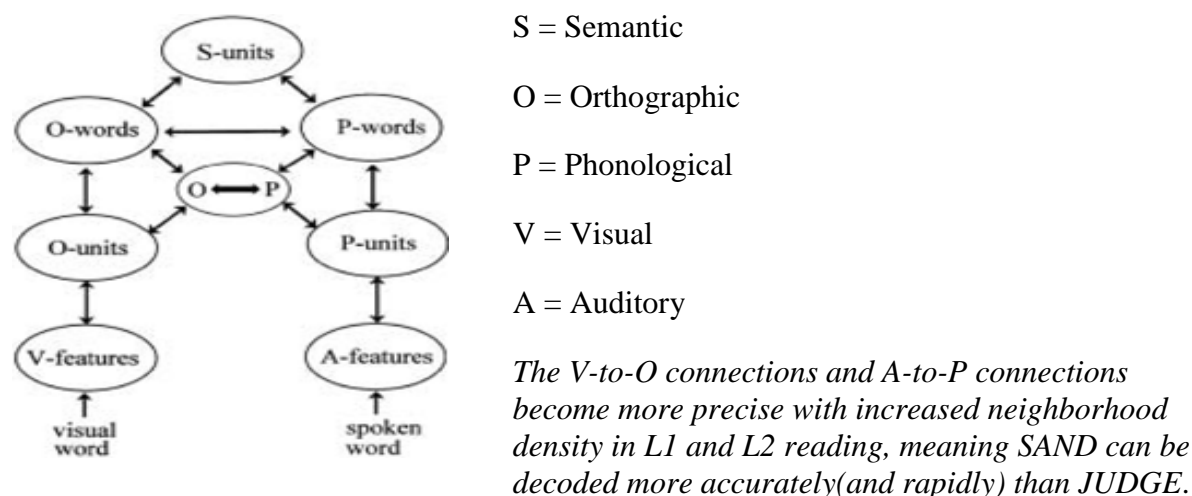
8.2   RADICAL FUNCTIONALITY AND MOD

The nature of access to radical sound and meaning has been shown in studies examining the effect of semantic radical transparency and phonetic radical consistency on character reading (Lee, 2009; Wang & Koda, 2013; Lin & Collins, 2013). Results of character meaning inference tasks not only suggest that radical semantic transparency affects character learning but also sheds light on the primacy of character morpho-orthographic analysis during Chinese character reading. Contextual clues are incorporated into character decoding when morphological analysis is not an option (due to a lack of radical transparency) but when novel characters contain more transparent radicals contextual clues are not used (Wang & Koda, 2013). The diversity and concreteness of semantic radicals also influences their role in reading unfamiliar forms; radicals conveying more concrete concepts and used in more diverse morphological arrangements are more relevant to L2 pseudocharacter reading (Lv et al., 2014). Just as functional salience of semantic radicals affects their relevance to reading, phonetic radical consistency also influences the ways in which skilled readers incorporate the cues into unfamiliar character decoding (Lee, 2009; Lin & Collins, 2012).

The ability of radical features to be incorporated into novel character analysis therefore varies considerably; transparency, regularity, consistency, functional diversity and frequency all influence whether or not radical components can be incorporated into the reading of novel forms. Radicals only occasionally are useful as morphological units, but they also could be incorporated into reading as visually salient graphic units as well. Sub-skills of radical awareness described by Shen & Ke (2007) show the morphological and orthographic properties of radicals are difficult to disentangle. In evaluating the use of radicals in reading by second language students of Chinese, Williams (2013) cannot definitively conclude whether analysis of phonetic radicals by students is part of a process of orthographic disambiguation or the result of strictly phonological procedures. Repetition blindness of radical components during rapid visual presentation could similarly be attributed to morpho-orthographic decoding *or* to visual orthographic encoding (Yeh & Li, 2004).

Despite the fact that most evaluations of radicals are focused on the semantic or phonetic features that they contain, it may very well be the case that their greatest contributions to L1 and L2 Chinese literacy is as visually salient graphic units. Orthographic and morphological abilities develop in a similar time frame in L1 Chinese children (Packard et al., 2006; Tong et al., 2009) and when considered along with the orthographic awareness-based morphological decomposition description of Rastle & Davis these findings seem to show that there are undeniably orthographic abilities developing along with radical awareness. The spelling errors of young Chinese children show their conceptualizations of characters become orthographically and morphologically more complex as they develop more advanced graphemic and semantic strategies (Shen & Bear, 2000). Neural imaging and eye tracking studies in the mold of the pioneering work of Yang et al. (2011) and Wong & Chen (1999) help distinguish the orthographic and morphological contributions of radical parts, showing that both make key contributions to processing at different temporal stages.

8.3 TWO ROLES FOR RADICALS: SEPARATE VISUAL AND SEMANTIC SALIENCE

As experimental designs are developed that can differentiate the pre-lexical orthographic and (later) sub-lexical morphologic analysis of radicals, it could be the case that the earlier, more perceptually-based graphic analysis of character "chunks" is essential to emerging literacy skills. It has been shown experimentally that L2 learners of Chinese rely most heavily on orthographic-based strategies in studying characters (Shen, 2005). Despite the visual orthographic salience of character "chunks", radicals have generally only been evaluated for semantic and phonetic worth. This is a problem given the factors limiting reliance on these decomposition strategies, as well as the visual complexity of the logographic system. Studies of Chinese-English bilingual children show that despite overlap in morphological and phonological abilities between the two languages, the orthographic skills underlying character reading are different (Wang, Yang and Cheng, 2009). It could very well be the case that researchers accustomed to compounding morphology in alphabetic scripts see potential parallels worthy of study in sub-lexical radical components, yet in doing so the research community may be overlooking the pre-lexical perceptual contributions of character logographemes, as well as the phenomenon of perceptual learning that is described by Elze et al (2011) and shown in the repetition blindness (RB) work of Yeh & Li (2004). RB is a good way to study perceptual processing because this sort of on-line experiment measures token individualization, not morphological decomposition or memory retrieval (Wong & Chen, 2009).

The supposition that visual orthographic *assembly* is an essential part of Chinese reading does not mean that the later decoding of orthographic lexical representations for radical support is unimportant. Even in studies providing evidence that subcharacter pronunciation and meaning cues are incorporated into novel character reading, it is acknowledged that such strategies are not always useful (He, Wang and Anderson, 2005). The ability to perceptually assemble characters,

on the other hand, is essential to all character reading and vocabulary growth. Surface dyslexics in the Ho et al (2007) study, for example, all suffered from an early processing impairment that was decidedly orthographic in nature. This pre-lexical orthographic assembly includes visually-salient character components, many of which are radicals in their own right. The goal then is to differentiate between the pre-lexical orthographically constructive and the later morphologically deconstructive skills tied to radical awareness, through an experimental design that sheds light on *how* exactly it is that sub-lexical components contribute to the reading of unfamiliar characters.

The repetition blindness and eye-tracking experimental designs both have the potential to illuminate the perceptual role played by radicals and logographemes in assembly of orthographic representations. It is difficult to develop a way in which the repetition blindness design could be utilized in differentiating the earlier orthographic role of radicals from their later sub-lexical role as semantic/phonetic cues. This is due to the fact that most of the logographic parts forgotten in Yeh & Li's 2004 study were radical representations as well (it is difficult to develop test stimuli that are *real* characters sharing a "chunk" that is not a radical and that will still be real characters when this chunk is removed). Due to this sort of natural limitation of the Chinese writing system, evaluating the natural of Chinese repetition blindness requires the use of pseudocharacter stimuli. If the same sorts of effects found by Yeh & Li are obtained with artificial stimuli that lack radical representations, it will be evidence that the effects found in the original study are attributable to the visual orthographic salience of the radicals and not any aspect of their semantic/phonetic cues.

There are some disadvantages to this sort of modified repetition blindness task. Failure to use real characters may threaten the external validity of the results, as does the fact that repetition blindness tasks in general involve character recognition and recall devoid of any context. It will be important that pseudocharacter repetition blindness tasks be conducted on both L1 readers of

Chinese and L1 English speakers without any character reading experience, in order to establish that the presence of character component blindness after rapid serial presentation is in fact due to perceptual abilities that have been learned by the L1 readers. This sort of extension of repetition blindness research holds potential, but eye-fixation studies may possess more external validity.

One way of comparing the orthographic and semantic/phonetic roles of radicals in a more realistic context is through the eye-fixation paradigm. Building on the experimental procedure of Wong & Chen (1999), it is possible to replace several characters within a section of text and then evaluate the ways in which both L1 and highly proficient L2 readers perform during self-reading. Whereas Wong & Chen manipulated the replacement character so that it was either a homophone or orthographically similar to the proper character, the manipulation in this modified experiment would be to vary the extent to which the new character is orthographically similar to the original. The comparison in this modified experiment is to evaluate the precise nature of the orthographic disturbances that occur when characters are replaced with *pseudocharacter* substitutes that have varying sorts of orthographic overlap. All manipulated characters in this study will be comprised of exactly three orthographic chunks. The in-text replacement will vary from the original graphic form by either, (1) having a wholly different log structure and no common chunks, (2) having the same structure but share no chunk components, (3) have the same structure and share chunks, (4) have the same structure and share a radical, or (5) being a "switch" form with improper positions.

Figure 11: Illustrating how the original research design of Wong & Chen (1999) might be modified:

Original Character: 范

Type of orthographic replacement: Example* (based on real character 范)

(1) No orthographic overlap (in terms of chunks)   融   (nothing in common)
(2) Structural similarity (one above, two below)   最   (only structure in common)
(3) One chunk replaced by artificial chunk   Must create pseudocharacters for this condition
(4) One radical replaced by a different radical   茳   (half of time phonetic, half semantic)
(5) Switch position of original three chunks   Must create pseudocharacters for this condition

*In the actual eye-fixation study all replacements will be pseudocharacters (to control for lexicality)

The "chunk" sharing manipulation could then be sub-divided into conditions that vary the number of chunks shared and the extent to which the unshared chunks differ from the proper chunks that they replaced. Replacement pseudocharacters will share either two or three (of four) component chunks with the characters that they replaced. Orthographic overlap of replacements would be controlled, with half of chunk-sharing replacement pseudocharacters containing novel perceptual parts that are not orthographically similar to those that they replaced, while the other half have a strong likeness (in both stroke number and overall shape) to the logographemes that they are substituting for. The level of orthographic similarity between the original real-character and pseudocharacter replacement chunks will be verified in pre-test trials with native L1 readers of Chinese characters. Ensuring all manipulated and replacement forms have exactly four chunks will be accomplished by developing norms of visual stimuli prior to the study, as such a database does not presently exist. Finally, it is important to note that some of the chunks involved in these manipulations also have identities as phonetic or semantic radicals (which vary in transparency, consistency and regularity, among other factors). These separate identities are to be considered in evaluating the eye-movement behavior of the students, with the additional semantic and phonetic cues of the radical components incorporated into evaluations of the eye-tracking results later on.

It is predicted that the most reliable disruptions in processing (based on measures of both number of fixations and the duration of said fixations) will be observed for pseudocharacters that have different orthographic layouts than the character that they replace. Only slightly longer and more reliable disruptions will be found for replacements characters with similar graphic structure but that do not share chunks in common. We also would predict variations in disruption between characters sharing two versus three chunks with their replacement, with more orthographically similar forms leading to shorter and less consistent disruption to eye movement. It is additionally

hypothesized that there will be no significant variations in the disruptions based on the existence (or lack of) independent radical identities for the chunks being replaced in the target character.

Should it in fact be found that pseudocharacter replacements result in similar disruptions regardless of whether or not replaced (and retained) chunks exist as independent radicals, it will suggest that the graphic salience of radical components is very relevant to reading. There are also some limits to the extensions that can be drawn from this sort of eye-fixation research, however. The fact that readers may be expecting a particular character in the manipulated location means that any findings could have limited applicability to reading of novel character forms. Since the ability to access information from novel forms is essential to developing literacy, it is important that studies look into the role of chunks and radicals in recalling forms that were previously unknown to the reader. Another limitation of the above design is that this eye-tracking research is not easily extended to the reading strategies employed by students of lower proficiency levels. Given these limitations and practical problems accessing the necessary equipment for conducting eye-tracking and repetition blindness research, an alternative character recall design is proposed for evaluating whether explicit instruction of radicals makes them more relevant to recall than chunks. Whereas Experiment 1 sought to establish that perceptual "chunking" occurs in Chinese reading, this second proposal aims to evaluate the relative contributions of perceptual processes and more top-down radical decoding to recall of whole-character orthographic representations.

The importance of this line of empirical enquiry extends beyond theoretical outlooks on radical access. Studies asserting that radicals contribute to character recognition through bottom-up assembly (such Wu et al. (2009) and Zhou et al. (2014) conclude that pedagogies highlighting radical cues support literacy development. If radical access occurs through morpho-orthographic decomposition, as tested in the design below, it might mean reexamining how radicals are taught.

9.0   EXPERIMENT II: RADICAL EFFECTS ON PSEUDO-CHARACTER RECALL

Participants

This study evaluates pseudocharacter recall for L2 character readers of low, intermediate and high proficiency. The low level readers are all undergraduate students enrolled in year one of Chinese at an American university. L2 intermediate readers are all enrolled in the third or fourth year of the Chinese language program at the same university. Advanced L2 Chinese readers will be located through an open search throughout the city, since such highly proficient L2 readers are generally not available within the undergraduate population. All of the readers in this group must have scored at least an eighty on the HSK 6 or comparable reading comprehension test. The highly proficient L2 reading group will not include any heritage language learners who were exposed to character reading prior to high school (nor will the intermediate or beginner groups).
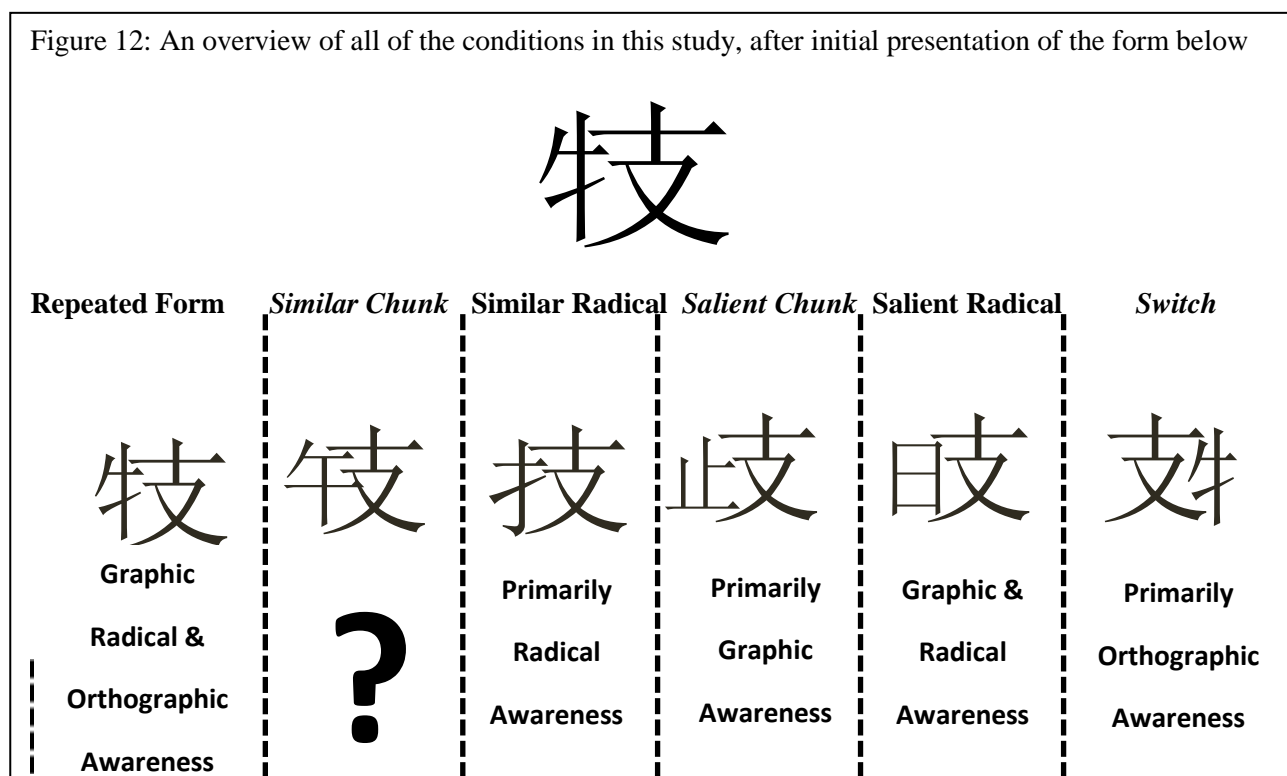
Materials

This study will utilize a laptop with E-Prime software package to present characters to the students during the initial training exposures. A simple sheet of paper with pseudocharacters that may or may not have been previously presented will be used in the recall task of the experiment, with the likeness of these characters to initially presented forms manipulated and evaluated with a Likert scale (as depicted in Figure 5). Orthographic structure of pseudocharacters is carefully controlled, with all forms containing between ten to twelve strokes and three to four "chunks". The structure of pseudocharacters is also controlled so that all manipulated character components (during the subsequent recall task) only reoccur three times across all presented pseudocharacters.

The essential manipulation is the extent to which pseudocharacters on the second (sheet of paper) presentation resemble the characters shown on the initial computer-based presentation. Of the thirty six forms on the sheet of paper six of them will be exact replicas of pseuodocharacter

stimuli from the original computer-based exposures. Six stimuli will share the same two radicals, but placed in invalid positions. Major manipulations are made to the final twenty four characters on the sheet. Twelve resemble pseudocharacters from the original computer presentation, except one radical has been replaced by a different radical. The final twelve stimuli resemble items from the computer-based presentation, except the semantic radical has been replaced by a logographic chunk that does not contain any clear cue to pronunciation or meaning. Half of the items in these radical and chunk replacement conditions contain new components that are graphically similar to the parts they replaced, while the other half of the stimuli do not. Because radicals have position-specific identities, the chunk condition involves replacing forms placed in part of the character structure where they would not be seen as having a semantic or phonetic function. The frequency and consistency of the manipulated sub-character components will be carefully controlled as well; all radicals involved in this experiment are highly frequent, transparent and consistent. Given the complexity of these orthographic manipulations, an overview is provided in the diagram below. It is important to note that all stimuli are pseudocharacters that do not actually exist as characters, even as uncommon ones, so this sort of design is replicable with skilled L1 reading populations.

Figure 12: An overview of all of the conditions in this study, after initial presentation of the form below

牧

Repeated Form	*Similar Chunk*	Similar Radical	*Salient Chunk*	Salient Radical	*Switch*
牧	牮	技	岐	旼	斴
Graphic Radical & Orthographic Awareness	?	Primarily Radical Awareness	Primarily Graphic Awareness	Graphic & Radical Awareness	Primarily Orthographic Awareness

Procedure

This study begins with participants shown thirty six different pseudocharacter forms on a computer screen. These forms are to be individually presented on the screen six separate times. Each form begins in a random location and moves slowly across the screen to a box, taking 2-4 seconds to move inside the box. Participants are told to press the space bar when the character is inside the box, to ensure that they are paying attention. The presentation order is randomized so that the sequence in which the thirty six pseudocharacters appear varies between each of the six sets. Viewing these forms six times for six seconds will take 15 minutes for students to complete.

A five minute interview between participant and experimenter will follow the computer-based viewing described above. During this interview the experimenter will use English to ask a series of questions about their attitudes towards Chinese class specifically and Chinese language more generally. The questions will not directly deal with any aspects of written Chinese and are instead designed to get students to stop thinking about the pseudocharacters that they have seen. All of the responses students provide to these questions will be written down by the experimenter.

After the five minute session is over, participants will be provided a sheet of paper with thirty six pseudocharacters written on one side of the paper. Of the thirty six items exactly six are the same as during the previous computer viewing. The rest vary from the originally presented characters in the ways described previously. The participants are instructed to rate the likelihood that each of these forms was present during the computer-based portion of the experiment using a 6-point Likert scale (1 means that it certainly was not present and 6 indicates it certainly was). Participants will simply circle one of the numbers 1-6 provided below each character (see Figure 13), based on their level of certainty that the forms were present in the initial showing. They will have five minutes to complete this task, having been notified of this time constraint at the outset.

Hypotheses

It is anticipated that there will be variations in both the number and nature of mistakenly recalled pseudocharacters based on the Chinese character reading background of the participants. For all language levels it is predicted that reoccurring forms will be recognized as repetitions and be given higher Likert scores than pseudocharacters that replaced a radical or a logographeme, or have the two components switched with the original pseudocharacters presented on the computer. It is also hypothesized that these switch condition characters with the same components in illegal positions will be given extremely low Likert-scale scores by advanced readers and increasingly higher scores by the intermediate and beginner level L2 learners. Turning to the other conditions, which include the replacement of either a radical or a logographeme with a graphically similar or dissimilar "chunk", it is predicted that the existence of both orthographic and semantic identities will lead the changes made during radical replacement more salient and will lead the L1 readers to give lower Likert scores to radical replacements compared with logographeme replacements. These variations in mistaken recall of logographeme and radical replacement pseudocharacters will only exist for more advanced readers when the replacements are graphically similar to the "chunks" they replaced; graphically dissimilar ('salient') replacements will be given lower Likert scores by advanced readers regardless of whether replacing radical or logographeme. The errors of lower level readers will be both more numerous and more diverse, with a general progression from orthographic, to radical, to perceptual-graphic awareness development, as illustrated below.

Figure 13: Overview of hypotheses of Experiment II

- Hypothesis 1: *Repeated forms* given the highest Likert scores.
- Hypothesis 2: *Similar chunks* given the second highest Likert scores.
- Hypothesis 3: *Switch* forms given the lowest Likert scores.
- Hypothesis 4: *Salient radicals* given the second lowest Likert scores.
- Hypothesis 5: Radical awareness more developed than graphic awareness in less experienced readers, and this will lead to higher Likert scores for *salient chunks* than for *similar radicals*.

支
1 2 3 4 5 6
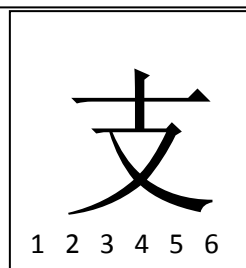
Results

Multivariate analysis will be used to evaluate whether the variations in Likert rankings of recall for the six replacement conditions differ from one another in statistically significant ways. It is predicted that the most statistically significant variations in Likert scores between dependent conditions will be found for advanced readers. Less proficient readers will develop orthographic awareness first, with radical awareness developing second and graphic awareness developing last.

Discussion

The focus of this second study was to piece apart the visual orthographic and semantic or phonologic contributions of radicals. Should the results show graphic similarity to be predictive of mistaken character recognition, irrespective of whether components are represented as radicals, it will suggest radicals are valuable largely for existing as perceptually-salient *orthographic* parts. The ways in which radicals contribute semantic and phonetic cues during character recognition has been researched previously (Lin & Collins, 2013; Lv et al., 2014) but past research has failed to focus on the bottom-up orthographic relevance of radicals. The lexical constituency model and dual-route hypothesis have both helped establish that the orthographic and semantic lexicons are directly connected during Chinese character recognition, which in turn means that developing the ability to efficiently assemble orthographic entries is an essential, early skill in character reading. Proposal 1 tests the claim that explicit training with chunking helps Chinese L2 students learn to perceptually assemble orthographic entries, perhaps through similar strategies as L1 readers. The findings of this follow up experiment build upon this claim by evaluating whether such chunking strategies lead to similar rates of mistaken recognition for pseudocharacters that share radical and non-radical (logogographeme) components. It is not phonetic or semantic information of radicals but their visual-spatial salience that is most centrally involved in unfamiliar logographic reading.

Whereas the proposed adaptations to the eye-fixation study of Wong & Chen allows for differentiating between pre-lexical logographeme consolidation and later radical decomposition, this mistaken recognition experiment instead seeks to separate the semantic and phonetic cues of radicals from their orthographic salience and relevance for character recognition. If, as predicted, pseudocharacters that swap logographemes with the initially presented characters are mistakenly identified as often as those that have radicals replaced from the originally presented forms, it will mean that it is visual orthographic salience (not the semantic or phonetic information) of radicals that is most centrally involved to the recognition and retrieval of orthographic form. Such results, if they in fact occur, should not be taken as evidence that radical semantic and phonetic cues are not useful in some instances of unfamiliar character reading. Instead, the importance of graphic similarity to character identification- regardless of wither such visual orthographic overlap is the result of radicals or other subcharacter logographemes- suggests all visually-salient components play an critical role in character recall. Orthographic assembly is central to accessing the lexical level and is crucial to character recognition. Understanding this sub-lexical system requires more research investigating the *pre-lexical* contributions of logographic parts for perceptual learning.

9.1   EXPERIMENT III: EVALUATING RADICAL ROLES USING ON-LINE TASK

This second proposal suffers from several limitations. As an off-line, recall-based design, the study is not able to ascertain and evaluate a time course for activation of chunks and radicals. The second proposal also cannot be used with L1 character readers, not only due to likely ceiling effects that would result (they would perform extremely well) but also because their orthographic awareness has developed to the point that misplaced chunks may be as salient as the radical parts. The advanced perceptual and visual orthographic abilities of L1 readers are adept at recognizing when all visually-salient chunks (not just radical parts) appear in unusual or "illegal" positions.

In order to pinpoint the time-course of "chunk" and radical component processing, and to compare the character processing of L1 and L2 readers, the on-line lexical decision task below is briefly put forth as a third and final research design that is intended to evaluate the relative roles of visuo-spatial chunks and semantic radicals in orthographic assembly and awareness. Whereas the first proposal establishes the relevance of pre-lexical, perceptual chunking to lexical access and the second study shows the complementary contributions of chunk and radical identities to character recognition, this third experiment examines the time-course of graphic and semantic component contributions. On-line designs that can vary the presentation times of character forms provide a window into the time it takes for chunks and radicals to be accessed and integrated into whole orthographic lexical representations of both character and realistic pseudocharacter forms.

Participants

All participants in this study will either be undergraduate students from China enrolled in an American university or undergraduate students at the same university enrolled in year three of the school's Chinese language program. The non-Chinese students have only studied Mandarin in their present university program; any additional Chinese language studies will disqualify them.

Materials

This study will utilize E-Prime software to flash pseudocharacters onto a computer screen. In addition to E-Prime software, the PC laptop used in this study will also contain a video game similar to Tetris; requiring players to try and sort block shapes in a way that consolidates space.

The pseudocharacters flashed onto the computer screen over the course of the experiment will fall into three categories. Some will be actual characters that are commonly occurring words (that the L2 students have studied), while the other two conditions involve pseudocharacters with either a radical *or* a (non-radical) chunk replaced from what would otherwise be a real character.

Procedures

The experiment begins when the participant arrives and sits down at the PC laptop. They are told that they will be evaluated on their ability to play a video game while being distracted by Chinese characters. They are also informed that the experiment involves calculating a score tied to their performance on the video game. The characters will pop up on the screen as distractors, which they must decide are real characters or not real characters (by pressing two different keys on the keyboard) before they can continue along with the game. Crucially, all of the participants are informed that they receive bonus points when they are able to correctly identify characters, so that while not the primary focus correctly identifying characters helps their overall game score.

The students start playing the Tetris-like game, which is intended to grasp their attention and does so by presenting shapes that must be sorted into a growing wall. Thirty seconds in they are confronted by their first character or pseudocharacter form. For thirty minutes these participants play this game, racking up points based on the ability to neatly fit the shapes into the growing wall. New character and pseudocharacter forms are flashed every fifteen to twenty-five seconds throughout the thirty-minutes. Each form is flashed for 25, 50 or 100 ms on the screen, at which point it vanishes and is replaced by a "Y" and "N", indicating that the left key should be pressed if it was an actual character and the right key should be pressed if the form was not real. Participants are not told whether or not each guess they make is correct or not, so as to not affect their mood or motivation throughout the session. Participants must make a decision on presented forms within a 300 ms time frame. Once they have made a decision on each character, they will resume playing the Tetris-like game until the thirty minute period is complete. Students are told that goal of the activity is to accrue points (both by building the wall well and recognizing forms), so it is hoped and anticipated that the participants will make quick and intuitive lexical decisions.

Hypotheses

For the fastest presentation time (25 ms) there will be no significant variations between the frequency with which the radical and chunk replacement pseudocharacters are thought to be real or fake. For the slowest presentation time (100 ms) the radicals will be effectively decoded for semantic cues, and as a result rarely be mistakenly selected due to their increased saliency. In other words, bottom-up (perceptual) processing will have a singular effect on lexical decision for the shortest presentation times, while longer durations allows *both* graphic and semantic saliency to influence lexical decision, leading to greater saliency and significantly less mistaken selection of radical replacements in the 100 ms condition (but not at 25 ms, and only marginally at 50 ms).

Discussion

This final proposal mimics the recall study that precedes it in evaluating the relative roles of sub-component graphic and semantic salience. This on-line design allows for comparisons of the time-course of "chunk" and radical processing, something that was not afforded by the recall design of Experiment II. The on-line nature of this task not only allows for direct observations of perceptual learning among the more advanced character readers, but also allows for comparisons of L1 and highly proficient L2 readers. Since previous research suggests orthographic awareness varies between alphabetic and logographic reading (Wang, Yang and Cheng, 2009), it is time to begin specifying the sub-skills underlying the development of orthographic awareness in both L1 and L2 Chinese reading. There exists a lot of research into the different aspects of morphological awareness relevant to character literacy development. In order to paint a fuller picture of Chinese character recognition and literacy development, it is important that orthographic abilities also be specified and evaluated for relevance to reading research and pedagogical practices. By showing that semantic cues have relevance later in processing, the dual roles of radicals will be evidenced.

10.0   GENERAL DISCUSSION

In describing the ways in which the inconsistency of symbol-sound mappings in English have led to overly "anglocentric" outlooks on reading, Share (2008) reconceives of the dual route model as not mutually exclusive routes for "regular" and "irregular" word reading, but instead as developmentally starting with decoding of sub-lexical units (into phonemes or larger grain sizes), and then gradually shifting to the syllable-level, threshold-based access of familiar graphic forms. The orthographic depth hypothesis of Katz and Frost (1992) claimed that consistency of form-form mappings was the main factor that determined whether readers relied on the phonological (nonlexical) pathway or the orthographic (lexical) pathway. The more recent insights of Share, when viewed in conjunction with the grain size theory of Ziegler and Goswami, help highlight that the size of the phonological units accessible from print (grain size) is an important factor for determining relative reliance on nonlexical and lexical routes. The inconsistency of form-form mappings in Chinese (evident in widespread homophony within the logographic system) means the decoded phonological units cannot reliably mediate meaning access (Perfetti & Harris, 2013).

This paper has put forth the view of a similar relationship between the grain size of form mappings and the nature of pre-lexical processing (lexical access) during *character* recognition. It is anticipated that results of Experiment I will help highlight the fact that the course grain size of characters means that pre-lexical processing of character forms must be of the threshold-based *orthographic* or *lexical* type described by Katz and Frost; it cannot involve phonology because there are no fine-grained mappings to link graphemes to onsets, rimes or any other sub-syllabic phonological unit of the language. Should results be as expected for Experiment I, it will suggest that characters are subconsciously "chunked" into perceptually salient parts and then assembled into orthographic wholes, which in turn initiate the direct and indirect lexical routes of the LCM.

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While the above summary is a reconceived outlook on the orthographic depth hypothesis, Experiments II and III illustrate how this theory fails to provide an effective explanation for the way that radical cues are incorporated into unfamiliar character reading. Even Share (2008) in his call for less "anglocentric" research seems satisfied to presume that pre-lexical processing invariably involves phonology, and that radical components exemplify this idea within character reading. The proposals provided here can hopefully help establish that radical cues are processed through the top-down decomposition of orthographic lexical entries. The benefits of this nuanced decomposition for unfamiliar character decoding helps explain why orthographic awareness is so essential and unique in logographic reading, as suggested by the research reviewed in this paper.

The "trade-off" that occurs as a result of phonological grain size and orthographic depth between writing systems has generally been seen as a rather straightforward inverse relationship between phonological awareness and morphological awareness (Perfetti & Harris, 2013). While this is a key observation that has been arrived at after much cross-linguistic research, it is critical that variations in orthographic awareness between writing systems also be systematically studied. Empirical investigations of orthographic awareness (including evaluations of character reading) can potentially help inform general linguistic theory and also improve Chinese literacy training. Widespread acceptance of subconscious orthographic decomposition can help explain the lack of universality for transposed-letter (TL) effects found by Frost (2012). The absence of TL effects in morphologically rich scripts may not be due to bottom-up processing variations, but instead represent rapid, top-down decomposition of orthography; akin to radical access in Chinese and descriptions of orthographic abilities by Rastle & Davis (2008) and Grainger & Holcomb (2009).

This paper posits that the radicals and perceptual chunks of characters play an important role in consolidation of orthographic lexical entries. An early, purely perceptual role for radicals

does not come at expense to the semantic and phonetic cues that they also occasionally provide, but instead operates as an additional function of the sub-character components. It is possible that the perceptual relevance of radical parts has been previously overlooked for a number of reasons. Pre-lexical processing of "chunks" into orthographic wholes is an unconscious ability that skilled character readers are generally unaware they possess. This perceptual assembly results from the visual orthographic complexity of the Chinese writing system; there is no comparable pre-lexical process for the reading of unfamiliar forms in non-logographic writing systems. The fact that this process is unconscious and unique to logographic scripts has perhaps left it relatively unstudied.

The description of perceptual "chunk" assembly as subconscious should not be taken to mean that this pre-lexical process is solely tied to visual-spatial skills. There may be connections between graphic assembly and visual-spatial abilities (see Lobier et al., 2012), yet there are also major differences between them. While visual-spatial skills are thought to be relatively static and to vary greatly between language learners, the consistency with which Chinese L1 and advanced L2 readers of Chinese recall novel character forms seems to suggest that the orthographic skills involved in "chunk" assembly are *learned* through character exposure and reading experiences. If these are linguistic abilities developed with literacy, it is possible that pedagogical practices emphasizing the graphic structure of characters can speed up literacy development in L2 readers. Evidence for the view that advanced orthographic skills are involved in reading comes not only from inquiries into character reading (Li et al., 2012), but also English (Cunningham et al., 2012; Grainger et al., 2006). Even if it is the case, as posited in this paper, that developing orthographic awareness is crucial to emerging character literacy (in both L1 and L2 populations), visuo-spatial abilities (as described in Baddeley's (2003) visuo-spatial sketchpad) must be carefully controlled in future studies evaluating the relevance of orthographic abilities to emerging character literacy.

Much of the morphological awareness literature (discussed previously) makes it clear that morphological skills develops differently in L1 character readers than they do in older L2 readers. Decomposition of multi-character Chinese words into (derivational or compounded) morphemes involves a later, lexical stage of processing. Orthographic assembly and decomposition, on the other hand, are rapid and may not be influenced by age and previous language learning factors to the same extent as morphological abilities. Such a supposition requires research, but it is possible that orthographic awareness develops similarly for L1 and L2 readers. If orthographic awareness develops similarly for all readers, it would mean new pedagogies that work for L2 students might also be effectively employed in teaching character first language literacy in Chinese classrooms.

The rich orthographic information of characters can perhaps be efficiently and effectively introduced during literacy training through a strong focus on sub-character "chunk" components. Characters can be introduced and accentuated with "chunks" different colors, or alternatively can be presented dynamically assembled from "chunks" (as was done in proposal one). Other pedagogical practices involve providing students with cutout "chunks" and challenging them to construct their own character forms, either from memory or with support materials. Orthographic awareness of character structure can also be encouraged by tasking students with locating errors in character graphic form, with "chunks" removed or replaced from certain characters within real paragraphs of text. These strategies can help students develop orthographic skills, enabling them to effectively assemble lexical representations, recognize characters, expand their vocabulary and begin to integrate radical cues as a decoding strategy. An overview of efforts at developing these types of orthographic abilities can be found in an analysis of four primary schools in Hong Kong (Tse et al., 2007). These schools have succeeded in teaching Chinese literacy through pedagogies that emphasize word recognition and the orthographic structure and of the logographic system.

Figure 14: Some potential methods of introducing character chunks to language students

犭→ 勹/口   犭勹   犭勹

Character composition   Mistake identification   Manipulated presentation
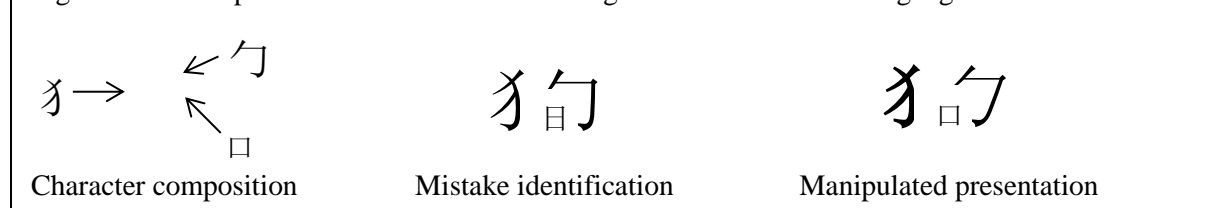
Just as explicit instruction in phonological recoding (GPC) has been shown to help Chinese ESL students develop a new sub-lexical route for unfamiliar word reading (Grainger et al., 2012) and support literacy development (Ehri, 2014), pedagogies focused on orthographic abilities may be particularly helpful for L2 readers coming from an alphabetic background (Feng et al., 2009).

Character perception research is intended to complement more commonly studied aspects of character recognition, such as the contributions of morphological and phonological awareness. This paper has emphasized the fact that these other important abilities are significantly correlated across languages. The fact that compound awareness (a type of morphological awareness) is tied to reading ability in both Chinese and English shows the way that these skills can be emphasized in literacy instruction regardless of the language of study. Herein lies one reason that it is crucial that character literacy training try and incorporate "chunk" components and perceptual strategies: these abilities have not been cultivated in the L1 reading of most L2 character readers. Chinese is unfairly stigmatized as harder than other languages to learn, in part because literacy development is deemed more difficult to acquire. If the special structure of this orthography are explicitly and efficiently taught through pedagogies rooted in research, Chinese foreign language learning will grow to be less stigmatized and more popular of a choice in both secondary schools and colleges. Orthographic awareness is relevant to the reading of familiar forms in alphabetic writing systems (Ziegler et al, 2014), but in Chinese coarse-grained orthographic coding is critical for unfamiliar reading as well as skilled reading. Pedagogies that teach orthographic structure are badly needed.

Should the sort of experimental designs proposed in this paper in fact show that character orthographic abilities- independent of radical identity or stroke order- exist, the next step will be to longitudinally evaluate the efficacy of training orthographic awareness as part of L2 literacy development. In-class evaluations of pedagogies teaching "chunks" can complement the studies outlined in this paper. The richest insights will come when findings from controlled research and classroom observations are integrated. Through such integrative approaches that combine on-line experiments and practical pedagogies, it will be possible to better understand how orthographic awareness contributes to character recognition, vocabulary growth and literacy development. It is possible- perhaps even likely- that the strategies outlined in this section will be most beneficial to intermediate L2 readers who already have lexical-level character representations. This prediction is based on the recent research of Xu, Perfetti and Chang (2014), which showed that pedagogies focused on training character writing improved the reading proficiency of second-year college students, but not students in their first year of Chinese foreign language study. In line with these findings it might be worthwhile to test out designs similar to Proposal 1 with more advanced L2 populations, to see if explicit orthographic structure training might be more beneficial to students at particular proficiency levels. In line with the ideas of Sally Andrews (2008) on lexical quality, it is likely the case that an ability to automatically and efficiently retrieve representations of word form and meaning are essential to more general text comprehension abilities, even in L2 reading.

Expanding empirical evaluations to different L2 populations is therefore one final future direction, that combined with a new wave of on-line, longitudinal and brain imaging research can help in evaluating the relevance of orthographic awareness to character recognition. Just as GPC is an essential pre-lexical skill that aids in alphabetic decoding (and literacy development), these proposals point out the centrality of logographic chunks and orthographic awareness in Chinese.

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10.1   LIMITATIONS

Many of the studies establishing the centrality of orthographic awareness and lower-level skills to character reading are based on L1 experiments. Character recognition research involving eye-tracking, repetition blindness, masking and priming tasks must be replicated with L2 readers. L2 character readers may not be able to transfer some orthographic abilities from their L1 (likely less so if their L1 is a relatively transparent alphabet) reading experience means that L2 students likely can incorporate conceptual knowledge and "higher-level" abilities into their reading. Many otherwise insightful descriptions of orthographic awareness and L2 word recognition (such as the work of Nassaji, 2014) fail to take this into account, and this paper is guilty of the same oversight. Future research must not only compare various L2 populations learning characters to one another, but must also compare L2 learners and their decoding strategies with those of young L1 readers.

One final limitation is the lack of an effective system for categorizing, differentiating and describing the orthographic structure of characters. Most research to date has relied upon radical placement or stroke number to evaluate the orthographic structural complexity of characters, and it is time that a more pragmatic and scientific system be developed for describing character form. An effort to develop such a system might begin by having a large number of highly literate L1 Chinese categorize characters in terms of the number of perceptual components that they believe to be found within commonly occurring characters. Further steps can then be taken to investigate how many perceptual parts L1 readers perceive to be found in uncommon and pseudocharacters.

10.2 CONCLUSIONS

Chinese pre-lexical processing is purely visual-orthographic in nature, with radicals and other chunks possessing a perceptual-orthographic role that is essential to all lexical access in Chinese.

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