Project summary.

This project concerns the recognition and psycholinguistic processing of Chinese characters in reading. Specifically, it examines how readers make use of the information from the phonological and semantic character components of characters, and the influence of various linguistic factors on processing times.

Some writing systems are considered shallow orthographies, in which graphemes and phonemes correspond very regularly and consistently (e.g., German, Serbian), while others like English are known as deep orthographies, where the correspondences are more irregular and complex. Logographic systems like Chinese are deep orthographies, and are unique because the script contains a mixture of phonological and semantic components, varying greatly in their correspondence to the words represented. This has led to much debate over whether reading processes in Chinese are primarily phonological or semantic. The research addresses the debate in psycholinguistic studies as to whether the process of reading and recognizing Chinese words and characters is primarily phonological, or primarily semantic and orthographic, in nature.

This study will show how a standard psycholinguistic model of word recognition, originally developed for alphabetic languages, can apply to a more complex writing system such as Chinese. Within the model, Chinese lexical recognition can be regarded as both semantic and phonological, functioning in parallel, with the most salient route for recognizing a given character being one of these, depending on various linguistic factors. Semantic components are processed as orthographic units (Zhou & Marslen-Wilson, 1999), while phonetic components are processed as phonological information, as in alphabetic scripts. The results will show how semantic and phonetic component information is processed, and how various linguistic factors affect the processing of these cues. Specific similarities and differences in reading Chinese and alphabetic scripts can be quantified and characterized with the same psycholinguistic mechanisms. The proposed studies also introduce considerable methodological improvements over past studies.

The design is based reaction time studies of character and word recognition in Chinese, English, and other languages, but with much improved controls for linguistic factors; the use of multiple linguistic covariates applies greater precision (e.g., as in Balota et al., 2004) to Chinese studies. These controls, using better sample sizes, and the use of principled, quantifiable semantic controls for the first time in the field, represent significant methodological improvements, and greater statistical power and reliability, over past studies.
This research will also bear upon studies of writing systems. By investigating how and the
degree to which readers make use of the semantic and phonological information in the script, a
cognitive linguistic theory of writing systems will be developed from exemplar and schema theory in
cognitive psychology. This will provide a cognitive and psycholinguistic basis underlying both
alphabetic scripts (phonological and syllabic) and logographic scripts, treating glyphs of various
writing systems as exemplar based representations. These may be phonological exemplars (as in
alphabetic scripts) linking glyphs to phonemes, as more complex exemplars linking glyph
combinations to morphemes and phonemes (in deep orthographies as in English), or as composite
exemplars (as in Chinese), linking glyphs to phonological, lexical, and semantic content.

The empirical results of this research, and the resulting cognitive linguistic extensions, can in
turn yield pedagogical applications in teaching Chinese as a first language or second language,
specifically, on reading and writing instruction of Chinese characters. Given the advantages of
explicit knowledge of phonological and radical patterns for Chinese children learning to write (Shu &
Anderson, 1999), this research can elucidate the cognitive mechanisms involved in learning to write
Chinese, or for adults learning Chinese as a second language.

Project description.

Chinese characters contain at least one basic semantic component, or radical (used for
dictionary look-up), and possibly one or more additional non-radical semantic components (NRCs);
these often provide some cue about the whole-character meaning. Most characters also contain a
phonetic indicator, which provides an approximate cue to the pronunciation of the character
(DeFrancis, 1984).

The non-alphabetic nature of Chinese script raises questions as to (1) how readers of a script
with indirect semantic and phonological information recognize words, and (2) how standard
psycholinguistic models of word recognition and processing could apply to Chinese. In studies of
Chinese, some take the strong phonological view that only phonetic information is used early and
predominantly in the process of lexical recognition, and present experimental evidence for this view
from (e.g., Perfetti & Tan, 1998; Perfetti & Zhang, 1991; Tan & Perfetti, 1999). Others take the strong
semantic view that only semantic information is used early and predominantly, with experimental
results supporting their claims (e.g., Wu & Chen, 2000; Wu & Chou, 2000; Chen & Shu 2001; Zhou &
Marslen-Wilson, 1999). The framework adopted here is the dual route model (Coltheart et al., 2001;
Coltheart & Rastle, 1994), which posits that readers recognize words via direct orthographic
recognition and via phonological information; both streams of information work in parallel, and
interact with other linguistic factors.

Previous disparate results are likely due to a lack of sufficient controls; also, small stimulus
sets were used, with small and unrepresentative numbers of radicals. Lexical factors, e.g., frequency
(of a word or character in the language), and phonological factors such as syllable frequency,
phonological regularity and consistency (relatedness of the phonetic indicator to character
pronunciation, and how this relatedness varies across characters) were often not properly controlled
for. Also, no studies have tried to adequately quantify and control for relevant semantic variables,
such as the semantic iconicity or transparency of radicals, the varying degrees of semantic
relatedness between radicals and character meanings (semantic regularity), and the variability of
radicals across different characters (semantic consistency).
Research hypotheses.

The following hypotheses will be addressed:

1. Various linguistic variables affect processing times and usefulness of semantic and phonetic information in characters, i.e., lexical, phonological and semantic factors.

2. Both semantic and phonological information of characters are used early in lexical recognition, with the relative degree and usefulness of each depending on such lexical, semantic, and phonological effects.

3. Semantic components will contribute to lexical access equally well, whether they serve as radicals or non-radical components (previous studies have only examined radicals).

4. Multiple semantic components in a character should lead to faster processing time than for one semantic component, if transparent and related to character meaning; otherwise, opaque or less related components should slow processing times.

Methods.

Population and sample (survey and lab experiments).

Some subjects will fill out character semantics surveys (below), the results of which will lead to semantic indices, which will then be used as control variables for the laboratory experiments (below). Traditional Chinese characters will be used; thus, adult native Chinese speakers from Taiwan and Hong Kong, where traditional characters are used, will be recruited at UIUC.

Survey instrumentation.

A paper survey is being used to obtain native speakers’ ratings of the semantic transparency of radicals, and the semantic relatedness of radicals to characters. Subjects rate a set of radicals according to iconicity or transparency (e.g., iconic 手 ‘hand’ cf. more opaque 非 ‘evil’). In the main section, subjects rate characters for how related their meanings are to their radicals. 3130 characters were randomly assigned to ten survey forms – the 3000 most frequent characters, commonly used by educated adults, plus another 130 to better represent some less common radicals. Radicals and characters are rated on a 7-point Likert scale.

Survey collection and procedures.

Each survey takes 20-30 minutes. 40 surveys have been administered so far, and about 160 more will be administered, for a total of 20 raters for each survey form (in accordance with recommendations from a statistics professor and HLM expert for 20 observations per item, given the complexity of the design with 214 radical groups and 3200 characters).

Survey analysis.
Each set of characters with the same radical constitutes a radical family, but some radical families are large, consisting of hundreds of characters, while some are small, with only a few characters. Also, subjects may complete one to five surveys, and random and fixed effects are included. Thus, an HLM analysis is used to examine the effects of different linguistic variables on the ratings, and to partial out individual variation in Likert-scale semantic judgments. The following variables will be tested.

<table>
<thead>
<tr>
<th>Variable type</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>random effect, covariate</td>
<td>individual rater</td>
</tr>
<tr>
<td>categorical independent variable</td>
<td>radical group (characters with same radical as a group), for all 214 Chinese radicals</td>
</tr>
<tr>
<td>numerical covariates</td>
<td>radical and character frequencies, number of strokes, number of components (in character), syllable frequency</td>
</tr>
<tr>
<td>dependent variable</td>
<td>transparency / relatedness rating</td>
</tr>
</tbody>
</table>

Then all the survey ratings for radicals and characters are to be score-normalized (subtracting off each rater’s mean rating and standard deviation) to derive several semantic indices, which will serve as covariates and inform the design of the lab experiments.

Survey justification.

The procedure is modeled after the development of semantic indices for English with Likert-scale surveys, e.g., Toglia and Battig (1978). This is necessary for Chinese, since not attempting to quantify semantic features of characters is a significant shortcoming of past studies. The analysis will lead to four semantic indices for use as controls in the lab experiments below: radical transparency, radical semantic regularity and consistency, and individual radical relatedness ratings for each character. This represents a considerable methodological improvement over previous experiments, and greater statistical power. Analysis of data collected so far have yielded a preliminary set of semantic indices.

Laboratory experiments:

Instrumentation and procedures.

The laboratory studies, like those those for English and other languages, use a standard masked priming paradigm: a prime that is semantically, orthographically, or phonologically similar or dissimilar to the target is presented for a duration of under 50 milliseconds, which subjects do not consciously detect; after a mask (e.g., a # hash mark to prevent the image from remaining on the retina), a target item is presented (Johnston & Castles, 2003; Kinoshita, 2003). Subjects respond by naming the word or character (naming task), or by pressing a button to indicate whether the word or character is a real word or character (versus a pseudo-word or pseudo-character control) – a lexical / character decision task (CDT). Response times and error rates are recorded and measured as the dependent variables. To test semantic processing of characters, a semantic prime (NRC / radical) is
used to prime the target character, followed by a CDT (semantic priming); in phonological priming, a phonetic component or homophone prime with a naming task is used to test phonological activation (Balota et al., 2004). The E-Prime software package in the Educational Psychology Psycholinguistics Lab (1424 Beckman, under Prof. Kiel Christianson) will be used.

In these experiments, the number of items per cell is higher (usually 10-20 prime-target pairs per cell) than a standard ANOVA design, to better represent the 214 radicals, as one shortcoming of previous studies is the limited sample size, usually a small number of radicals represented. The experiments below, with 10-20 target items (characters) per cell for approximately 120 characters representing 100-120 radicals, will provide a more representative sampling – an important consideration, given the semantic variation among the radicals. With data collected from 36 subjects (a typical number in the field) on each experiment, sufficient statistical power is expected for all the variables and covariates to be included in the statistical models, even for follow-up analyses of particular subsets of the data. This also meets the general requirement of 30 observations per cell for hierarchical and multivariate regression analyses. Effect size statistics, $R^2$ and adjusted $R^2$ values, and power statistics will be reported.

**Data collection and analysis.**

Data analysis will involve ANCOVAs and hierarchical regression in SPSS and SAS. Expt. 1 will test the predictiveness of the semantic indices from the survey results for semantic priming effects, by comparing priming for high and low transparency radicals, and high and low semantic consistency. With different prime types, the effects of the number and types of semantic components (NRCs, radicals) will be compared in Expt. 2, and the effects of phonological relatedness between different parts of syllables of phonetic indicators and characters will be compared in Expt. 3. The relative contributions of semantic and phonetic components, and the time course of phonological and semantic activation will be compared in Expt. 4 by means of different timing periods in stimulus presentations (stimulus onset asynchrony, SOA; Kinoshita, 2003).

Some shorter experiments will be run together in one setting, thus saving considerable time and money; also, the target and filler items for one experiment serve as fillers relative to another experiment when run concurrently. The experiments are summarized below.

Experiment 1 examines the effects of semantic transparency of character forms in character recognition by means of semantic priming. The semantic radicals of characters may be semantically transparent, i.e., iconic, visually related to their meaning, or non-transparent. A given radical may also vary in semantic relatedness across characters, with some radicals being consistently related to the meanings of its various characters, and others being more inconsistent in characters in which it occurs. Such effects have not been experimentally examined, but if found to be significant, such effects would cast doubts on previous Chinese priming experiments in which these factors were not controlled for. To this end, target characters were primed with semantic radicals, a visually dissimilar synonym not sharing the same radical as the target, and an unrelated control symbol as a baseline condition. If semantic radicals do contribute to early semantic activation, then the radical should have stronger priming effects than a synonym semantic prime. While a significant priming effect for synonyms compared to the baseline would indicate early semantic processing, a stronger effect for radical primes would implicate radicals themselves as a semantic contributor to character
recognition. A 3 (prime: radical, synonym, control) × 2 (radical transparency: high, low) × 2 (radical consistency: high, low) designed is used, with 60 targets (15 per cell, high and low transparency by high and low consistency), counterbalanced by prime type across three list conditions. 15 targets of each transparency by consistency combination are used for a representative sample of different radicals and target characters ranging from high to low frequency.

Experiment 2 investigates a group of characters with no phonetic components, composed instead of multiple semantic components. These are problematic for phonology-dominance views, since no phonetic cues are present, but semantic-dominance views have offered no explanation for how multiple semantic components are processed compared to characters with a single semantic component. For this experiment, characters with two semantic components (bisemantic) are chosen, as those with three or more are rare. Bisemantics consist of a dictionary radical, and an additional non-radical semantic component (NRC).

The following table summarizes the experimental runs, combined stimuli and filler items for each session, subjects, and projected costs when run concurrently.

<table>
<thead>
<tr>
<th>Expt.</th>
<th>purpose</th>
<th>procedure &amp; task</th>
<th>design</th>
<th>design variables</th>
<th># targets (t) &amp; fillers (f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expt. 1</td>
<td>effects of semantic transparency on semantic priming</td>
<td>semantic priming + character decision</td>
<td>3 × 2 × 3</td>
<td>prime (radical, synonym, control), transparency (high, low), consistency (high, low)</td>
<td>60 targets 180 fillers</td>
</tr>
<tr>
<td>Expt. 2</td>
<td>radicals cf. non-radicals</td>
<td>semantic priming + character decision</td>
<td>3-way</td>
<td>prime (radical, non-radical, control),</td>
<td>90 targets 270 fillers</td>
</tr>
<tr>
<td>Expt. 3</td>
<td>separate effects of phonological regularity, between onsets &amp; rimes</td>
<td>phonological priming + naming</td>
<td>3 × 4 × 3</td>
<td>prime (phonetic, homophone, control), onset consistency (same, similar, dissimilar), rime consistency (same tone, same segments, similar, dissimilar)</td>
<td>120 targets 360 fillers</td>
</tr>
<tr>
<td>Expt. 4</td>
<td>comparison of time course of semantic &amp; phonological activation</td>
<td>phonological &amp; semantic priming + character decision (4A), naming (4B)</td>
<td>3 × 2 × 3</td>
<td>prime (phonetic, semantic, control), target type (phonetic-radical char., phonetic-radical-NRC triplet), SOA (timing=40ms, 60ms, 80ms)</td>
<td>120 targets 360 fillers</td>
</tr>
</tbody>
</table>
The following variables will be examined in the experiments. The number and types of lexical, semantic, and phonological covariates used accord with previous experiments, and all have been shown to be relevant to both semantic and phonological priming (Balota et al., 2004).

<table>
<thead>
<tr>
<th>Variable type</th>
<th>Relevant expts.</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>lexical covariates (numerical variables)</td>
<td>all expts.</td>
<td>character frequency, component frequency, radical position (e.g., left or bottom of character)</td>
</tr>
<tr>
<td>semantic indices (numerical)</td>
<td>Expt. 1 (as dependent variables); Expts. 2, 3, 4 (as covariates)</td>
<td>radical transparency, radical regularity, radical consistency, radical-character relatedness</td>
</tr>
<tr>
<td>phonological covariates (numerical)</td>
<td>all expts.</td>
<td>syllable frequency, phonological regularity, phonological consistency</td>
</tr>
<tr>
<td>phonological syllable types (categorical variables)</td>
<td>Expt. 3</td>
<td>onset (initial consonant) and rime (rest of syllable) relatedness (between phonetic and character pronunciation)</td>
</tr>
<tr>
<td>dependent variables</td>
<td>all expts.</td>
<td>reaction times (naming, character decision); error rates</td>
</tr>
</tbody>
</table>

**Justification.**

This study will show how a standard psycholinguistic model of word recognition, originally developed for alphabetic languages, can apply to a more complex writing system such as Chinese. As such, it can inform linguists and psychologists about the nature of lexical processing in deep orthographic systems, and specifically, how lexical recognition in a logographic script compares to alphabetic systems. The design is based reaction time studies of character and word recognition in Chinese, English, and other languages, but with much improved controls for linguistic factors; the use of multiple linguistic covariates applies greater precision (e.g., as in Balota et al., 2004) to Chinese studies. These controls, using better sample sizes, and the use of principled, quantifiable semantic controls for the first time in the field, represent significant methodological improvements, and greater statistical power and reliability, over past studies.