Attainability of a Native-like Lexical Processing System in Adult Second Language Acquisition:
A Study of Advanced L2 Chinese Learners[*]

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Considering the differential successes and failures in adult second language acquisition (SLA), many researchers have urged that studies on L2 ultimate attainment should identify the domains in which adult L2 learners are (or are not) able to attain native-like proficiency levels, hence providing a descriptive basis for the learning potential in adult SLA. In particular, both Birdsong (2005) and Sorace (2005) contend that at the L2 end-state, the fundamental difference between native speakers and highly proficient late L2 learners often reside in the processing system, thereby leading to minor quantitative and/or qualitative departures from monolingual norms. To test the above claim, this study explored whether a native-like lexical processing system can be attained by advanced L2 learners who start acquiring Mandarin Chinese as a foreign language long after the onset of puberty. To this end, the study employed the advanced-learner approach, recruiting 23 adult L2 Chinese learners, whose L2 reading skills were comparable to native Chinese speakers, and 23 native speakers of Chinese as controls. Two online reading tasks that aimed to tap into sentence-level Chinese character recognition were administered to the participants. Data revealed that, while the two groups were comparable in terms of their overall Chinese reading ability, both similarities and differences co-existed between them with regard to the underlying lexical processing procedure and the nature of the activated lexical information; nevertheless, these L2 learners were still able to achieve functional equivalence with natives at the performance level. Based upon these findings, implications for L2 end-state lexical processing system will be discussed.

Key words: adult second language acquisition, L2 ultimate attainment, L2 lexical processing, L2 written-word recognition, phonological recoding

1. Introduction

Ever since Penfield & Roberts' (1959) proposal that the brain gradually loses

plasticity and Lenneberg's (1967) formulation of the Critical Period Hypothesis, one of the liveliest debates in second language acquisition (SLA) research concerns whether native-like proficiency is attainable for adult second-language (L2) learners. In pursuing this line of inquiry, SLA researchers have recognized that L2 ultimate attainment should not be seen as a monolith (e.g. Birdsong 2005, 2006, Han 2004a, 2004b, 2004c, 2006, Sorace 2005). An adult L2 learner's language subsystems can end up with differential successes and failures; native-like, near-native, and non-native (divergent, incomplete) competence can all be possible end-states for an adult L2 learner's different language subsystems.

However, in exploring the linguistic domains in which adult L2 learners are (or are not) able to attain native-like proficiency levels, researchers tend to "equate 'language' with 'grammatical competence'" (Hyltenstam & Abrahamsson 2003:576), thereby focusing on the description of L2 end-state grammar (see also Hulstijn 2002, Marinova-Todd 2003). Notably, language proficiency should include, but not be limited to, "grammatical competence." According to Sorace (2005), the fundamental difference between a native speaker's and a non-native speaker's language proficiency may involve under-specification at the level of *knowledge representations* and/or involve *processing* difficulties necessary to utilize the acquired L2 representations online (see also Juffs 2004, Kilborn 1992). In particular, Sorace (2005), in an attempt to address L2 ultimate attainment, contends that at the L2 end-state, the fundamental differences between "native speakers" and "near-native speakers" often reside in processing abilities, rather than in underlying grammatical representation *per se* (see also White & Juffs 1998). Similarly, Birdsong (2006:183) points out:

> With respect to certain language *processing tasks* (e.g. lexical retrieval, parsing strategies, detection of fine acoustic distinctions inherent in syllable stress, consonant voicing and vowel duration, etc.), *native-like* performance is *not* observed [even] among high-proficiency late L2 learners. [emphasis added]

Thus, highly advanced adult L2 learners who have presumably reached the asymptote of their L2 may still be unable to efficiently perform mental operations at native-like levels in accessing, analyzing, and generating the cognitive data required for *certain* linguistic activities, leading to "selective processability effects" (Birdsong 2006,

Brown & Hulme 1992). To fill the gap in the L2 ultimate attainment research, this study drew on the advanced-learner approach to investigate the L2 lexical processing system developed by advanced adult L2 Chinese learners. The underlying assumption of this approach is that advanced L2 learners have reached the upper limit of their L2 development, and that, as such, "the differences from native speakers are presumably limited" (Hyltenstam 1988:70); these limited deviances from the native norm, if any, may provide the best index for L2 ultimate attainment (see Birdsong 1992, Flege, Munro & MacKay 1995, Urponen 2004). In particular, to investigate the ultimate attainment of the L2 lexical processing system, the present study explored whether there exist any processing and/or representational differences between these L2 learners and native speakers in sentence-level written word recognition, and if so, to identify these differences. To the above end, this paper will first review relevant theories and research of written word recognition conducted with native Chinese speakers. Then, the participants, methodology, and research materials used in this empirical study will be described. Next, the paper will report the results of the study. Finally, the paper will discuss theoretical and pedagogical implications based on the derived findings, and conclude with limitations of the study.

1.1 Sentence-level written word recognition

While the recognition of isolated written words involves synchronous access to and/or activation of all possible meaning components associated with a word—a process termed *semantic activation* (Tan, Hoosain & Peng 1995), sentence-level written word recognition involves an *extra* step, a disambiguation or *semantic integration* process, whereby context-based information is utilized to select a contextually-appropriate meaning among the previously activated semantic candidates (Swinney 1979, Tanenhaus & Lucas 1987). At issue is precisely *when* the context-based information starts to affect and constrain sentence-level written word recognition. A substantial amount of research that utilizes online reading techniques to examine the effects of contextual constraints on semantic access has shown that there is an autonomous phase in which readers first access all meanings associated with a word; it is only after the semantic meanings of the word are mostly, if not exhaustively, accessed that context starts to exert its influence on constraining the precise meaning of the word (Onifer & Swinney 1981, Swinney 1979; see also Tan & Perfetti 1999). In this view, the semantic activation process in initial sentence-level word recognition is quite similar, if not identical, to what happens in isolated word recognition, because both may proceed uninfluenced by contextual constraint. If we subscribe to this view, sentence-level written word recognition involves a *repetitive* cycle of a serial *two-stage processing*: the first being (near) context-free

semantic activation and the second being context-sensitive semantic integration. Based upon a sizeable body of neurological research, Pulvermüller (1999) argues that the semantic activation process presumably can be complete as quickly as 150-200ms after the onset of stimuli. On the other hand, findings of Luo (1996) suggest that the semantic integration process presumably takes place 200-300ms after the onset of the stimuli.

1.1.1 Lexical representation and processing procedure involved in the semantic activation process

Using isolated words as stimuli, existing research has mainly focused on the semantic activation process in isolated word recognition. In particular, two issues are often addressed and investigated in these studies. The first issue concerns the use and timing of phonological activation in written word recognition: whether readers translate a written word into its phonological representation—a phenomenon called ***sub-vocalization*** or ***phonological recoding***—when they make sense of the word (see Fox 1991); and, if so, what its timing is. Because a word's meaning(s) can be activated very quickly, usually in less than one-fifth of a second (Perfetti & Tan 1998), the phonological representation of a written word will not be readily available to facilitate or mediate semantic access if it cannot be computed at an early phase of the written word recognition process.

The second issue concerns the nature of phonological recoding. More recently, several empirical studies have attempted to look into the nature of the phonological code activated during the written word recognition process (e.g. Lukatela et al. 2001, Xu et al. 1999). These empirical studies investigate whether phonological recoding, if it occurs, involves a sound code approximate to the stored speech form comprised both of segmental (e.g. consonant and vowel) and suprasegmental information (e.g. stress, tone). Or does phonological recoding simply involve the segmental information?

While the second issue may speak to the underlying *lexical representational information* involved in written word recognition, research on the first issue may shed light on its underlying *lexical processing procedure*. To provide a theoretical framework for the processing procedure and the lexical representation involved in the semantic activation process, research examining phonological recoding performed by native speakers of Chinese will be reviewed in the following sections.

1.1.2 Use of phonological recoding in semantic activation

Studies that explore the use of phonological recoding in activating the semantic code of isolated Chinese single- and/or two-character words usually draw upon the following two experimental paradigms: (1) lexical decision and (2) semantic judgment.

In a lexical decision task, participants are typically presented with a battery of lexical

items (i.e. target words), which consist of both valid words (e.g. *rose*) and pseudo-words that overlap in various lexical dimensions (orthography or phonology) (e.g. *roze*). That a participant's lexical judgment tends to be tricked by a homophonic distractor suggests that the phonological code mediates the meaning retrieval process of written words. Lexical decision tasks are often combined with the priming technique in which participants are primed with a certain stimulus (i.e. the prime word) before the actual lexical decision task has to be performed. If phonology is required to access the lexical semantics of the target word, the brief presentation of a phonological prime word that shares phonological information with the target word would pre-activate the semantic information of the target word, hence facilitating the participants' lexical decisions on the target word.

Using a primed lexical decision task, Cheng (1992) showed that a lexical decision was faster for his adult native Chinese speakers when the target character was preceded by a homophonic prime word than when preceded by a phonologically-dissimilar one. This homophonic priming effect was independent of the manipulated **stimulus onset asynchrony** (SOA)—the time interval between the onset of the prime word and that of the target word (at 50, 500, and 750ms)—and independent of visual similarity between the prime word and the target word. Cheng thus contended that semantic activation of Chinese characters relies mainly upon phonological recoding.

In contrast to Cheng's (1992) finding, other phonological recoding research that also uses lexical decision tasks disconfirms the use of phonological recoding in semantic activation. Zhou, Shu, Bi & Shi (1999) asked adult native Chinese speakers to make lexical decisions on two-character target words preceded by two-character prime words, with an SOA of 100ms. No significant priming effect was found when the target word was preceded by a homophonic prime word, suggesting that there is little or no mediated access from phonology to lexical semantics.

While Zhou et al.'s (1999) claim is based upon the study of two-character Chinese words, Chua's (1999) study provides further evidence using four-character Chinese words as stimuli. Chua (1999) found an interfering homophonic priming effect. However, this interference effect was not present in all cases; it was only evident when the homophone distractors were orthographically similar to the correct target words. Thus, Chua asserted that there was a diminution in the homophone interfering effect—which manifested as a decrease in the relative contribution of phonological activation in semantic access—when there was sufficient and predictable orthographic support.

In contrast, many Chinese phonological recoding studies using semantic judgment tasks offer an entirely different picture. A semantic judgment task typically presents readers with two words, shown either simultaneously or one after the other, and requires participants to decide quickly and accurately whether the second word is semantically

related to the first (e.g. *flower* and *rose*). In Perfetti & Zhang (1995), pairs of single-character words—either semantically related or sharing the same sequence of phonemes—were presented sequentially to adult Chinese-speaking participants at three different SOA conditions (90ms, 140ms, and 310ms). In a parallel task, the participants made judgments about pronunciation sameness. The results showed that the participants were slower and more likely to make errors in rejecting homophones as not being synonyms, and in rejecting synonyms as not being homophones. The interference effect as observed in the homophonic distractor condition seems to support the view that phonological recoding mediates access to the semantic codes of a Chinese character.

Perfetti & Zhang's (1995) findings are later replicated in a series of studies, including Zhang, Perfetti & Yang (1999), Tan & Perfetti (1999), and Xu et al. (1999). In particular, using two-character word pairs as stimuli, Tan & Perfetti (1999) found significant phonological interference effects across all three designated SOA conditions: 0, 71, and 157ms. This discovery thus extended the findings of Perfetti & Zhang (1995), which used one-character Chinese words as stimuli. Tan & Perfetti (1999) therefore maintained that phonological recoding is involved in activating the semantic code of Chinese words, whether the words are comprised of single or multiple characters.

Accordingly, the use of phonological recoding in semantic activation seems to be task-dependent, suggesting that phonological recoding mediates semantic activation only when the lexical meaning(s) of a written word need(s) to be deliberately attended—a task that we often do in reading for meaning. According to Shen & Forster (1999:452), a simple explanation of why a lexical decision is insensitive to phonological priming is:

> Lexical decisions may be triggered by the overall level of activation in a lexical network, rather than the discovery of a lexical representation that matches the input…[consequently] a positive decision might be reached long before the input has in fact been recognized …[a point] when semantic properties are being determined.

In other words, lexical decision tasks may tap into a very early stage of access—a point too early for phonological activation to exert any influence—and hence may not capture the full picture of semantic access.

1.1.3 Timing of phonological recoding in semantic activation

Researchers can determine the relative time course of phonological and semantic activation by observing the stimulus onset asynchronies (SOAs) at which homophonic and semantic priming effects emerge. In a semantic judgment task, Perfetti & Tan (1998) observed that orthographic prime words produced priming effects as early as 43ms

SOA, homophonic priming effects at 57ms SOA, and semantic priming effects at 85ms SOA. These observations led Perfetti and Tan to conclude that Chinese character recognition follows the sequence of orthographic, phonological, and semantic activation (see also Tan, Hoosain & Peng 1995).

Weekes, Chen & Lin (1998) observed that the homophonic priming effect was present in the same SOA conditions in which the semantic priming effect occurred (50ms and 80ms). Based on this finding, Weekes et al. contended that the activation of phonological and semantic information is *coincidental* (or in their term *at-lexical*) during Chinese character recognition and should not be considered as a "post-lexical" event—processing that occurs after the semantic code of a Chinese character is fully accessed (see Perfetti & Zhang 1991, for similar findings).

Taken together, a substantial amount of Chinese phonological recoding studies have shown that in recognizing isolated Chinese characters, phonological recoding is performed by native speakers of Chinese, either preceding full semantic activation or occurring as an event coincidental with full semantic activation.

1.1.4 The nature of the activated phonology in accessing the semantic code of Chinese characters

Being the only study specifically examining the *nature* of the activated phonological code in accessing lexical semantics of Chinese characters, Xu et al. (1999) drew on semantic judgment tasks and attempted to research whether a phonologically similar distractor that shared the segmental units with the target word, but not the suprasegmental information (tone), would interfere as much as a phonologically identical (homophonic) distractor sharing identical segmental and suprasegmental units with the target. According to Xu et al. (1999), if suprasegmental (tonal) information is activated together with segmental information (consonant and vowel) in semantic access, interfering priming effects would be manifested more for homophonic distractor items, because both segmental and suprasegmental information are needed in order to interfere with the participants' semantic judgment. If, on the other hand, it is merely the underlying segmental representation that is involved in the retrieval of lexical semantics, interference should be comparable, regardless of whether the participants were presented with phonological distractors of the same or different tones.

Xu et al. found that interfering priming effects were only observed for exact homophones. This finding led Xu et al. (1999) to argue that suprasegmental descriptions, along with segmental information, are encrypted in the phonological representation that is available to readers during Chinese character recognition. While the issues regarding the use, timing and nature of phonological recoding have been investigated in studies exploring isolated written word recognition (where only the semantic activation process

takes place), these issues have not been explored in sentence-level written word recognition (where semantic activation and integration processes both occur). To fill the gap, the following research questions were explored:

Lexical Representation in Semantic Activation

Q1: Is phonological recoding performed to mediate the semantic activation process? If so, does it involve both segmental and suprasegmental information?

Lexical Processing Procedure in Semantic Activation

Q2: Is phonological recoding performed *before* the semantic code of a Chinese character is fully activated?

Lexical Representation in Semantic Integration

Q3: Is phonological recoding performed to constrain the semantic integration process? If so, does it involve both segmental and suprasegmental information?

Lexical Processing Procedure in Semantic Integration

Q4: Does phonological recoding constrain both the early and late stages of the semantic integration process?

2. The study

Two experiments were designed to address the four research questions. Experiment 1 was designed to address research questions 1 and 2, which sought to gain insight into the semantic activation process. Experiment 2, on the other hand, aimed to address research questions 3 and 4 in order to shed light on the semantic integration process. Each experiment was administered individually to every participant, with a one-week interval between experiments.

2.1 Experiment 1

2.1.1 Participants

Twenty-three advanced adult L2 Chinese learners (ages 35 to 55; mean=37.7 years) and twenty-three native Chinese speakers serving as controls participated in the present study (ages 24 to 28; mean=25.3 years). Two experienced Chinese instructors, who were both native speakers of Mandarin Chinese from Taiwan and majored in Chinese

literature/languages, were invited to nominate excellent learners from their former students. These candidates then went through a battery of screening procedures. The final list of people who took part in the current study all (1) had high self-assessment of their current Chinese proficiency, (2) exhibited native-like or near-native phonological perceptual and production skills, and (3) showed native-like performance in a Chinese Proficiency Test and its reading subtest (see Liu 2007, for more details). In other words, these L2 learners' non-native features, if any, could not be easily perceived, and they were able to achieve functional equivalence with natives both in terms of their Chinese reading and phonological skills.

As far as their language learning background is concerned, the L2 learners were all native speakers of alphabetic languages (English, Italian, Dutch, Spanish, and German). They all started to learn Mandarin Chinese in a four-year intensive Chinese as a foreign language (CFL) instructional setting (between the ages of 17-20; mean=18 years), and their average length of study of Chinese is 19.6 years. In terms of professional qualifications, at the time of the study, eight of the L2 learners were professors teaching Chinese philosophy, religion, anthropology, or literature in universities in the United States. Fourteen were doctoral students working on Chinese history, literature, or art, and the remaining participant was a customer service representative for a reputable information technology (IT) company.

The native controls were born and raised in Taiwan, and spoke Mandarin Chinese as their native language. They all had started learning a foreign language (usually English) before entering college (ranging from 1-2 languages), with an average of 5 hours of classes per week. None of them had been exposed to a long-term intensive second/foreign-language learning environment.

2.1.2 Design and materials

There were 176 trials in Experiment 1. In each trial, the participants were asked to read a sentence in which the prime word appeared as the last lexical item and the target word quickly followed thereafter; to avoid overloading the participants' working memory, each sentence was only composed of seven characters. The participants then judged, as quickly and accurately as possible, whether the prime word—which only briefly appeared on the screen for less than 300 milliseconds (ms)—and target word were related in terms of meaning (yes/no response).

To tap into the semantic activation process, two techniques—one top-down and one bottom-up—were adopted. First, with regard to the top-down technique, all the prime words were embedded as the last lexical items in *semantically-unconstrained* sentences. Here, semantically-unconstrained sentences refer to sentences that are composed of

legal Chinese characters that are meaningful when they stand alone; but the combination of all of these Chinese characters reads like an ancient Chinese quatrain that does not make too much sense at the sentential level.[1] In reading this kind of sentence, the participants would be able to perform semantic activation, accessing possible meanings of each character; but they would not have sufficient contextual information to perform semantic integration, knowing the contextually appropriate meaning of each character. Thus, by embedding prime words in semantically-unconstrained sentences, priming effects, if any, can only be attributed to the activation of a lexical code (e.g. semantic or phonological) en route to semantic activation, rather than to semantic integration, because the semantic integration process is discouraged in such a context. An example is provided below (the English words given under each Chinese character represent the possible meaning(s) of each character):

(1)

悲	行	倚	徑	識	昔	意
sad	walk behavior popular	lean rely on	a path a way	identity recognize knowledge	past former	meaning intention expect

The time interval between the onset of the prime word and the onset of the target word (SOA), on the other hand, was manipulated to tap into the semantic activation process in a bottom-up manner. As noted earlier, the semantic activation process can be completed as early as 150-200ms immediately after the onset of stimuli (Perfetti & Tan 1998, Pulvermüller 1999). Thus, to tap into the semantic activation process, SOA needs to be strictly controlled between 0-200ms. Due to the short SOA, participants would not have sufficient time to perform semantic integration; researchers are therefore able to "lock in" the semantic activation process. In this regard, Experiment 1 adopted the short SOA conditions that have been widely used in relevant written word recognition research (85ms: Perfetti & Tan 1998; 157ms: Tan & Perfetti 1999).

Furthermore, to be able to examine whether phonology—segmental and/or supra-segmental information—had been activated and used to mediate semantic activation, the stimuli were constructed mainly based upon the mediated priming paradigm (see Lesch & Pollatsek 1993). Specifically, sets of four primes and four targets were constructed in the following way: semantic primes (e.g. 儀 /yi2/) were the semantic associates of the target words (e.g. 容 /rong2/; homophonic primes (e.g. 宜, /yi2/) were phonologically identical to the semantic primes (e.g. 儀 /yi2/); phonological primes (意, /yi4/), on the

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[1] An example in English would be "*The serial primes the center of the stake*", where the exact meaning for the words *serial* and *stake* cannot be determined.

other hand, were segmentally but not suprasegmentally similar to the semantic primes; and control primes were unrelated to the semantic primes. (Note that the four primes were not orthographically similar to each other.) The four corresponding target words were semantically associated to different meanings of the semantic prime. Each prime was randomly combined with one of the four target words within a set, as illustrated in Table 1 below. In the semantic priming condition, prime and target words were semantically related, and the correct response in this semantic judgment task was "yes". In all other conditions, prime and target words were unrelated and the correct response was "no".

Table 1: Examples of the Prime-Target Word Pairs Constructed
for the four priming conditions

	Semantic Priming	Homophonic Priming	Phonological Priming	Control
Prime Words	儀	宜	意	洋
	/yi2/	/yi2/	/yi4/	/yang2/
	Ceremony; appearance; equipment	Appropriate; becoming; should	Intention; wish; opinion	Ocean; foreign; vast
Target Words	容	器	式	貌
	Appearance	Equipment	Ceremony	Facial features

In the above manner, 176 prime-target word pairs were constructed and then equally distributed over two SOA conditions: 85ms and 157ms (see Table 2 below).

Table 2: The Distribution of the Prime-Target Pairs in Experiment 1

	Semantic Priming	Homophonic Priming	Phonological Priming	Control Priming	(Sub)total
85ms SOA	22 prime-target pairs	22 prime-target pairs	22 prime-target pairs	22 prime-target pairs	88
157ms SOA	22 prime-target pairs	22 prime-target pairs	22 prime-target pairs	22 prime-target pairs	88
Sub-total	44	44	44	44	176

During the experiment, the 176 semantically-unconstrained sentences (which carried the prime word) and the corresponding target words were presented to each participant in random order; therefore no particular response pattern could be anticipated. The participants had only 200ms or so to decode each Chinese character; the speed with which the experiment proceeded, therefore, made it extremely difficult, if not impossible,

for the participants to develop any meta-cognitive response strategy. To prevent the participants from strategically focusing only on the prime words while disregarding the rest of the sentence (and hence falling prey to the processing mode for isolated written word recognition), the participants had to orally state what they remembered about the sentence immediately after the semantic judgment was made; the oral recall could be the gist of the sentence they just read, an image associated with the sentence, or even characters in the sentence.

2.1.3 Instrument

A Macintosh laptop was used to run all of the experiments. Presentation of the stimuli to the participants, recording of the participants' responses and reaction times were managed by a computer program developed by the researcher, using a Macintosh programming language called AppleScript.[2] The laptop was connected to an external keyboard, which allowed participants to respond to the presented materials, and to an external 20-inch LCD, which presented the stimuli to the participants in black or red against a white background in a 120-point, normal (Kai) font; each Chinese character was approximately 3.5 cm x 3 cm (width x height).

2.1.4 Procedure

Before the experiment began, each participant was given instructions, both in English and in Chinese, on the experimental procedure. Each participant then received five practice trials to familiarize him- or herself with the experimental procedure.

Each trial began with the presentation of a blinking arrow, which signaled the beginning of a new trial and the beginning position of the forthcoming text. The arrow appeared at the leftmost middle area of the LCD for about three seconds. After the offset of the blinking arrow, a sentence composed of seven Chinese characters appeared on the screen. The prime word was embedded as the last character in the sentence. Each character in the sentence, including the prime word, was presented to each participant sequentially—from left to right—with a 200ms interval between the onsets of each character. In other words, each participant had 200ms to decode each character before moving on to the next character.

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[2] "Apple Script" and "PsyScript" are both known for their capability to capture the input signal at the level of millisecond accuracy (see http://www.cfn.upenn.edu/resources/software_compare.htm). They are widely used by many psycholinguists who are Macintosh users in various psycholinguistic studies (such as Brian MacWhinney) (for description of PsyScript, please see http://www.maccs.mq.edu.au/~tim/psyscript/).

Recall that stimulus onset asynchrony (SOA) refers to the lapse between the onset of the prime word and the onset of the target word. The prime word was presented on the screen either for 85ms or for 157ms, depending on the designated SOA condition, and then disappeared from the screen with *all* the characters preceding it. Regardless of differences in the SOA across trials, the target word immediately followed the disappearance of the prime word, stayed on the screen for 200ms, and then disappeared.

For easy identification of the target word, all the characters in the sentence, including the prime word, appeared in black, whereas the target word appeared in red. Each participant was told prior to the experiment that as soon as the red word (i.e. the target word) was shown, s/he had to determine, as quickly and accurately as possible, whether the character preceding the red word (i.e. the prime word) was related to the red word (i.e. the target word) in terms of meaning. The participant was asked to make responses by pressing the 'escape' and 'enter' keys to indicate "no" and "yes," respectively. The response time (measured in milliseconds) for each trial was obtained by measuring the interval between the onset of the target word and the onset of the participant's response. Four seconds were set as the maximum response time for each semantic judgment. After making the semantic judgment, the participant was given another four seconds to orally state what s/he was able to remember about the seven-character sentence s/he just read, after which the computer program automatically initiated the events in the following semantic judgment trial. Thus, the linguistic/cognitive events for a semantic judgment trial proceeded as follows:
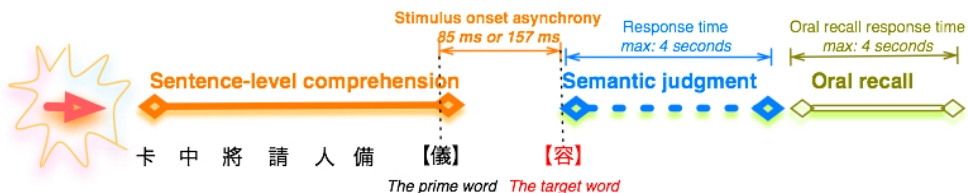
Figure 1: The schematic events in a semantic judgment trial of Experiment 1

2.2 Results

Analyses of the participants' performance data were based on two response variables, accuracy rate and response time. In the present study, the response variables were affected by several fixed (i.e. non-random) factors (native versus non-native status, task type, SOA conditions, priming conditions). Analysis of Variance (ANOVA) models were employed for statistical inference.

2.2.1 Results for the native speakers

The analyses of the native speakers' data showed that there was a significant main effect ($p<0.001$) of priming across the two manipulated SOAs (85ms and 157ms). In particular, Tukey-Kramer multiple comparisons[3] showed that there was a significant difference between the homophonic and control priming conditions, both in terms of **accuracy** ($t(66)=21.57$, $p<0.01$) and **response time** ($t(66)=13.56$, $p<0.01$). The native speakers showed a lower accuracy rate for semantic judgment under the homophonic priming condition than under the control priming condition (80.43 vs. 93.28%, respectively). Similarly, the native speakers averaged longer response times under the homophonic priming condition than under the control priming condition (756 vs. 459ms, respectively). The observation that native speakers' performance was disrupted under the homophonic priming condition suggested the occurrence of an interfering homophonic priming effect (see Table 3 below). Tukey-Kramer multiple comparisons further showed that the observed homophonic priming effect was equally robust, both when the SOA was set at 85ms and at 157ms.

In contrast, both the accuracy and response time data suggested that an interfering phonological priming effect either did not occur or was not robust enough to significantly affect the native speakers' semantic activation process. There was no significant difference between the phonological and control priming conditions, both in terms of **accuracy** and **response time**. In other words, the prime-target pairs under the phonological priming condition did not take longer to reject than the ones under the control priming condition (see Table 3 below).

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[3] The Tukey-Kramer method is a post-hoc statistic tool/option available in many statistic packages (e.g. SPSS, SAS); it can be employed to compare multiple means at the same time (i.e. simultaneous multiple pair-wise comparisons). By performing this post-hoc procedure, we can determine whether the means (derived from different experiment conditions) are significantly different from each other. For more information, see: http://www.uky.edu/ComputingCenter/SSTARS/www/documentation/MultipleComparisons_3.htm

Table 3: Mean Accuracy (%) and Response Time (millisecond) for the Native Speakers under the Homophonic Phonological, and Control Priming Conditions in Experiment 1

		Experiment 1 (The Native Speakers) N=23					
		Mean Response Time (millisecond)			Mean Accuracy Rate (%)		
		Homophonic	**Phonological**	Control	**Homophonic**	**Phonological**	Control
85ms SOA	Mean	770	490	488	80.04	91.90	92.29
	SD	0.13	0.11	0.11	2.65	2.36	2.14
157ms SOA	Mean	743	430	431	80.83	93.87	94.27
	SD	0.1	0.09	0.09	2.73	3.25	3.42
	Mean Total	**756**	**460**	**459**	**80.43**	**92.89**	**93.28**
	SD	0.11	0.11	0.11	2.69	2.98	2.99

With regard to semantic priming, the analysis showed that there was no significant difference in **accuracy** between the semantic and control priming conditions. Despite this finding, there was a significant difference in **response time** between these two priming conditions ($t(66)=3.85$, $p<.01$), with semantic priming associated with shorter overall response times than the control (376 vs. 459ms, respectively). Thus, although a significant semantic priming effect was not evidenced in the accuracy data, it was present in the response time data (see Table 4 below).

Table 4: Mean Accuracy (%) and Response Time (millisecond) for the Native Speakers under the Semantic and Control Priming Conditions in Experiment 1

		Experiment 1 (The Native Speakers) N=23			
		Mean Response Time (millisecond)		Mean Accuracy Rate (%)	
		Semantic	Control	**Semantic**	Control
85ms SOA	Mean	489	488	92.29	92.29
	SD	0.11	0.11	2.14	2.14
157ms SOA	Mean	263	431	94.27	94.27
	SD	0.07	0.09	3.42	3.42
	Mean Total	**376**	**459**	**93.28**	**93.28**
	SD	0.15	0.11	2.99	2.99

Note that the Tukey-Kramer multiple comparisons analysis showed a significant discrepancy between the mean response times between the 85ms and 157ms SOA levels when the priming was semantic (489 vs. 263ms, respectively; $t(66)=7.30$, $p<0.01$). This discrepancy reveals that the semantic priming effect appeared to have been dampened when the SOA was 85ms and intensified when the SOA was 157ms. In the 85ms SOA

condition, the native speakers' mean response time did not differ significantly under the semantic and control conditions. Thus, a facilitative and robust semantic priming effect was captured only 157ms after the prime word was decoded and hence was mainly attributed to the 157ms SOA condition.

2.2.2 Results for the L2 learners

The analyses of the L2 learners' data also showed there was a significant main effect ($p<0.001$) of priming across the two manipulated SOAs (85ms and 157ms). Therefore, Tukey-Kramer multiple comparisons were used to detect significant differences in main effects; both the accuracy data and response data supported the occurrence of an interfering homophone priming effect. Specifically, the analysis showed that there was a significant difference between the homophonic and control priming conditions, both in terms of **accuracy** ($t(66)=13.75$, $p<0.01$) and **response time** ($t(66)=6.30$, $p<0.01$). The L2 learners exhibited longer response times and lower accuracy rates under the homophonic priming condition when compared with the control priming condition (accuracy rate: 78.15% vs. 91.8%, respectively; response time: 1130 vs. 834ms, respectively). Therefore, the homophonic priming effect observed in the L2 learners' performance data essentially replicated the pattern found in the native speakers' data.

However, there was one critical difference between the native speakers and the L2 learners: the L2 learners' performance was also disrupted under the phonological priming condition. Specifically, there was a significant difference between the phonological and the control priming conditions, both in terms of **accuracy** ($t(66)=12.95$, $p<0.01$) and **response time** ($t(66)=5.73$, $p<0.01$). The L2 learners exhibited lower accuracy under the phonological priming condition than under the control priming condition (78.94% vs. 91.8%, respectively). Similarly, the L2 learners needed longer response times for semantic judgment under the phonological priming condition than under the control priming condition (1103 vs. 834ms, respectively). The fact that the prime-target pairs under the phonological priming condition were harder to reject implied that a significant phonological priming effect occurred and disrupted the L2 learners' semantic activation process (see Table 5 below).

Table 5: Mean Accuracy (%) and Response Time (millisecond) for the L2 Learners under the Homophonic, Phonological and Control Priming Conditions in Experiment 1

		Experiment 1 (The L2 learners) N=23					
		Mean Response Time (millisecond)			Mean Accuracy Rate (%)		
		Homophonic	**Phonological**	Control	**Homophonic**	**Phonological**	Control
85ms SOA	Mean	1151	1133	868	77.87	78.85	91.5
	SD	0.23	0.24	0.24	6.62	6.22	2.08
157ms SOA	Mean	1109	1073	801	78.44	79.03	92.09
	SD	0.22	0.23	0.21	6.03	6.56	2.04
	Mean Total	**1130**	**1103**	**834**	**78.15**	**78.94**	**91.8**
	SD	0.23	0.24	0.22	6.27	6.32	2.06

Tukey-Kramer multiple comparisons further showed that the observed phonological priming effect was equally robust between the two manipulated SOAs.

Concerning semantic priming, the analysis revealed a priming pattern quite analogous to what was found for the native speakers. That is, the facilitation under semantic priming only manifested itself in the response time data. No significant difference in **accuracy** was found between the semantic and control priming conditions. Nonetheless, there was a significant difference in **response time** between these two priming conditions ($t(66)=2.16$, $p<.05$); the L2 learners showed shorter response times under the semantic priming condition than under the control priming condition (733 vs. 834ms, respectively). Thus, the significantly shorter response time in judging the prime-target pairs under the semantic priming condition suggested that the semantic priming effect did occur (see Table 6 below).

Table 6: Mean Accuracy (%) and Response Time (millisecond) for the L2 group under the Semantic and Control Priming Conditions in Experiment 1

		Experiment 1 (The L2 Group) N=23			
		Mean Response Time (millisecond)		Mean Accuracy Rate (%)	
		Semantic	Control	**Semantic**	Control
85ms SOA	Mean	860	868	90.91	91.50
	SD	0.23	0.23	1.37	2.08
157ms SOA	Mean	606	801	92.89	92.09
	SD	0.18	0.21	3.01	2.04
	Mean Total	**733**	**834**	**91.90**	**91.80**
	SD	0.24	0.22	2.51	2.06

Note that, analogous to what was found in the native controls' data, a discrepancy was found between the response time means for the 85ms and 157ms SOA levels when the priming was semantic (t(66)=3.83, p<0.01). Specifically, the semantic priming effect appeared to have been dampened when the SOA was 85ms; the L2 learners' response times under the semantic and control priming conditions did not significantly differ from each other (860 vs. 868ms, respectively). Therefore, the observed semantic priming effect was mainly attributed to the 157ms SOA condition.

2.3 Discussion

The observation that all participants' performance was disrupted under the homophonic priming condition suggests that phonological recoding was indeed performed by both the native speakers and the L2 learners in activating the semantic code of a Chinese character. This is consistent with the findings from the research employing isolated Chinese characters as stimuli. However, there was one critical difference between the two participant groups: the L2 learners' performance was also disrupted under the phonological priming condition. According to Xu et al., if suprasegmental (i.e. tonal) information is activated together with segmental information in semantic access, interfering priming effects would be manifested more for homophonic distractor items, because both segmental and suprasegmental (i.e. tonal) information are needed in order to interfere with the participants' semantic judgment. The native speakers' data in Experiment 1 and in Xu et al. (1999) have consistently presented this very priming pattern.

On the other hand, if the tonal information is not actively involved in the semantic access, a phonological distractor prime that shares the segmental but not the tonal information with (the semantic associate of) the target word would suffice to disrupt the participants' semantic judgment. In this case, interfering effect is observed *both* under the homophonic and phonological priming conditions—and this is what we observed in the L2 learners' performance data. Following Xu et al.'s (1999) reasoning, the above priming pattern implicates that the phonological recoding performed by the L2 learners during semantic activation did not seem to include specifications of tonal features commonly used in Chinese spoken word recognition; tonal information is still not readily available to constrain semantic activation. Accordingly, the nature of the phonological recoding performed by the two groups was different during the semantic activation process.

Nevertheless, both the L2 learners and the native speakers had a similar semantic priming pattern; their response times were significantly faster under the semantic priming condition than under the control priming condition. Furthermore, while a robust

facilitative semantic priming effect, i.e. signs of full semantic activation, only appeared 157ms after the prime word was decoded, phonological recoding imposed a pronounced impact on semantic activation 85ms after a Chinese character was decoded. This observation suggests that phonological recoding was performed by all the participants to mediate semantic activation at an *early* locus of lexical processing (i.e. prior to full semantic activation). Collectively, the above findings indicate that the L2 learners probably employed a target-like lexical processing procedure during the semantic activation process, notwithstanding the difference in online lexical representation between the two groups.

It is interesting to note that in the past research on (isolated) Chinese character recognition, it usually takes a native speaker 400ms or longer to perform a semantic judgment task under semantic priming. However, in the 157ms SOA condition of the present study, the native controls' semantic judgments under the semantic priming condition were usually made within 300ms after the prime word was presented (Mean=263ms). This relatively short response time may be attributed to the different kinds of lexical processing systems involved in different processing modes (isolated vs. sentence-level Chinese character recognition). In sentence-level Chinese character recognition, readers tend to process the input for meaning before form, which may lead to a higher level of semantic activation than isolated character recognition, thereby significantly reducing the response time for semantic judgment. This suggests that the semantic activation process in sentence-level Chinese character recognition may not be totally isomorphic with that in isolated character recognition (at least in terms of the efficiency with which the semantic code is accessed).

While Experiment 1 demonstrated differences and similarities between the two groups when they attempted to activate possible meanings of a word, Experiment 2 focused on the semantic integration process.

2.4 Experiment 2

2.4.1 Participants

The same participants continued to take part in Experiment 2, which was administered a week after Experiment 1.

2.4.2 Design and materials

Experiment 2 was mainly based upon the design and materials (prime-target pairs) of the semantic judgment task used in Experiment 1. However, the sentences in which the prime words were embedded only consisted of semantically-constrained Chinese

sentences, which were not only syntactically acceptable, but also contained clear contextual cues disambiguating the exact meaning of each character. An example of a semantically-constrained sentence in Chinese is: "寄包裹得去郵**局**" ("You have to go to the post office to mail a parcel"). Here, 局 is the prime word, which, when standing alone, could mean *situation*, *limitation*, *a set of*, or *bureau*, depending on context. The context of this sentence (e.g. 包裹: *parcel*; 寄: *mail*) helps narrow down the activated meanings of 局, leaving only a single contextually appropriate meaning for 局: *bureau*. 176 semantically-constrained sentences were constructed for the presentation of the prime words used in the present experiment. In addition, unlike Experiment 1, that used only short and median SOAs (85ms and 157ms), Experiment 2 employed only long SOAs that exceeded 200ms in the hope of tapping into early and later semantic integration processes: 243ms and 300ms—the long SOA conditions that have been used in the relevant written word recognition research (e.g. Luo 1996, Perfetti & Zhang 1995, Tan & Perfetti 1997, Zhou & Marslen-Wilson 2000). The 176 prime-target pairs were equally distributed to the two manipulated SOA conditions.

2.4.3 Procedure

The procedure of Experiment 2 remained largely the same as that of Experiment 1, except for the display time of the stimuli. Specifically, in each trial of Experiment 2, instead of presenting each character in a sentence to each subject sequentially with a 200ms interval between the onset of each character, a 250ms interval was adopted so that the participant would have sufficient time to perform semantic integration on the activated semantic code of each character.

Furthermore, due to the use of longer SOAs (243ms and 300ms), the time interval between the onset of the prime word and that of the target word was adjusted in the present experiment. The prime word was presented on the screen either for 243ms or for 300ms, depending on the designated SOA condition, and then disappeared from the screen with *all* the characters preceding it. Regardless of differences in the SOA across trials, the target word immediately followed the disappearance of the prime word, stayed on the screen for 250ms, and then disappeared. Other than the differences noted above, the procedure of the events in each trial of Experiment 2 was identical to the one for Experiment 1.

2.5 Results

2.5.1 Results for the native speakers

The analyses of the native speakers' established that there was a significant main

effect ($p<0.001$) of priming across the two manipulated SOAs (243ms and 300ms). Tukey-Kramer multiple comparisons showed that there was a significant difference between the homophonic and control priming conditions, either in terms of **accuracy** ($t(66)=40.94$, $p<0.01$) or **response time** ($t(66)=20.95$, $p<0.01$). The native speakers had longer response times and lower overall accuracy under the homophonic priming condition than under the control priming condition (Accuracy: 85.08% vs. 99.51%, respectively; response time: 750 vs. 421ms, respectively). The fact that the prime-target pairs under homophonic priming were more difficult to reject was indicative of an interfering homophonic priming effect.

Tukey-Kramer multiple comparisons further showed the observed homophonic priming effect was equally robust between the two manipulated SOAs—a result consistent with Experiment 1.

In contrast to the robust homophonic priming effect, a significant phonological priming effect did not appear either in the accuracy data or in the response time data. The analysis consistently showed that there was no significant difference between the phonological and control priming conditions, both in terms of **accuracy** and **response time** (see Table 7 below).

Table 7: Mean Accuracy (%) and Response Time (millisecond) for the Native Speakers under the Homophonic, Phonological, and Control Priming Conditions in Experiment 2

		Experiment 2 (The Native Speakers) N=23					
		Mean Response Time (millisecond)			Mean Accuracy Rate (%)		
		Homophonic	**Phonological**	Control	**Homophonic**	**Phonological**	Control
243ms SOA	Mean	752	413	417	84.78	99.41	99.41
	SD	0.08	0.08	0.08	2.60	1.57	1.57
300ms SOA	Mean	747	427	426	85.37	99.41	99.60
	SD	0.08	0.07	0.07	1.91	1.57	1.31
	Mean Total	**750**	**420**	**421**	**85.08**	**99.41**	**99.51**
	SD	0.08	0.08	0.07	2.28	1.55	1.43

In terms of semantic priming, although there was no significant difference in **accuracy** between the semantic and control priming conditions, there was a significant difference in **response time** between these two priming conditions ($t(66)=10.80$, $p<0.01$); overall, the native speakers exhibited shorter response times under the semantic priming condition than under the control priming condition (252 vs. 421ms, respectively) (see Table 8 below).

Table 8: Mean Accuracy (%) and Response Time (millisecond) for the Native Speakers of Chinese under the Semantic and Control Priming Conditions in Experiment 2

		Experiment 2 (The Native Speakers) N=23			
		Mean Response Time (millisecond)		Mean Accuracy Rate (%)	
		Semantic	Control	**Semantic**	Control
243ms SOA	Mean	250	417	99.41	99.41
	SD	0.07	0.08	1.57	1.57
300ms SOA	Mean	254	426	99.80	99.60
	SD	0.07	0.07	0.95	1.31
	Mean Total	**252**	**421**	**99.60**	**99.51**
	SD	0.07	0.07	1.29	1.43

Tukey-Kramer multiple comparisons further pointed out that there was no significant difference in mean response time between the two manipulated SOAs when the priming was semantic, suggesting that the observed semantic priming effect was equally robust both when the SOA was set at 243ms and 300ms.

2.5.2 Results for the L2 learners

There was also a significant main effect ($p<0.001$) of priming across the two manipulated SOAs (243ms and 300ms). The analysis exhibited a priming pattern very similar to the one found in the native speakers' data: the L2 learners' semantic integration process was disrupted under the homophonic priming condition. There was a significant difference between the homophonic and control priming conditions, both in terms of **accuracy** ($t(66)=18.01$, $p<0.01$) and **response time** ($t(66)=7.46$, $p<0.01$). The L2 learners required longer response times and made significantly more errors in judging the prime-target pairs under the homophonic priming condition than under the control priming condition (accuracy: 78.35% vs. 96.25%, respectively; response time: 1107 vs. 767ms, respectively). Tukey-Kramer multiple comparisons further showed that the observed homophonic priming effect was equally robust between the two manipulated SOAs.

In contrast to the robust homophonic priming effect, a significant phonological priming effect was not evident in the accuracy and response data. There was no significant difference between the phonological and control priming conditions both in terms of **accuracy** and **response time** (see Table 9 below).

Table 9: Mean Accuracy (%) and Response Time (millisecond) for the L2 group under the Homophonic, Phonological, and Control Priming Conditions in Experiment 2

		Experiment 2 (The L2 learners) N=23					
		Mean Response Time (millisecond)			Mean Accuracy Rate (%)		
		Homophonic	**Phonological**	Control	**Homophonic**	**Phonological**	Control
243ms SOA	Mean	1129	778	776	78.44	95.26	96.05
	SD	0.24	0.23	0.24	8.35	3.49	2.84
300ms SOA	Mean	1084	765	758	78.26	95.65	96.44
	SD	0.22	0.22	0.23	6.85	4.44	3.05
	Mean Total	**1107**	**772**	**767**	**78.35**	**95.46**	**96.25**
	SD	0.23	0.22	0.23	7.55	3.95	2.92

With respect to semantic priming, Tukey-Kramer multiple comparisons showed that there was no significant difference between the semantic and control priming conditions in terms of **accuracy**. Despite this finding, the analysis showed that there was a significant difference in **response time** between these two priming conditions ($t(66)=5.33$, $p<0.01$); the L2 learners took significantly less time to make a semantic judgment under the semantic priming condition than under the control priming condition (524 vs. 767ms), suggesting the occurrence of a significant facilitative semantic priming effect (see Table 10 below).[4]

Table 10: Mean Accuracy (%) and Response Time (millisecond) for the L2 group under the Semantic and Control Priming Conditions in Experiment 2

		Experiment 2 (The L2 Group) N=23			
		Mean Response Time (millisecond)		Mean Accuracy Rate (%)	
		Semantic	Control	**Semantic**	Control
243ms SOA	Mean	527	776	96.44	96.05
	SD	0.19	0.24	2.73	2.84
300ms SOA	Mean	522	758	96.84	96.44
	SD	0.19	0.23	2.89	3.05
	Mean Total	**524**	**767**	**96.64**	**96.25**
	SD	0.18	0.23	2.78	2.92

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[4] The semantic priming effect was observed in the 157ms (Experiment 1), 243ms and 300ms SOA conditions (Experiment 2). However, one may notice that for both of the two participant groups, the semantic priming effect allowed them to exhibit significantly shorter response times under the two SOA conditions in Experiment 2 than under the 157ms SOA condition in Experiment 1. This finding may be attributed to the facilitative role of contextual cues in semantic access (Experiment 2).

Again, Tukey-Kramer multiple comparisons further showed that the observed semantic priming effect was equally robust both when the SOA was set at 243ms and 300ms.

2.6 Discussion

The analyses of the L2 learners' and the native controls' data were quite comparable in Experiment 2. Specifically, both the native speakers' and the L2 learners' semantic judgments were consistently interfered *only* under the homophonic priming condition. Furthermore, this interfering homophonic priming effect consistently appeared and was equally robust in the two manipulated SOAs (243ms and 300ms). This finding indicates that phonological recoding was consistently performed by the two groups to constrain the semantic integration process and that both the segmental and supra-segmental (tonal) information were actively involved in the phonological recoding performed during the semantic integration process. In other words, the nature of the phonological recoding performed during the semantic integration process was identical between the two groups.

It is also interesting to note that both for the L2 learners and the native controls, a robust semantic priming effect appeared in the two SOA conditions under which the homophonic priming effect was evidenced. These findings seem to indicate that phonological representations of Chinese characters were actively involved in early (243ms) and subsequent (300ms) phases of the semantic integration process. Taken together, these results seem to suggest that both groups activate representational knowledge of the same nature and employ the same processing procedure during semantic integration.

3. General discussion and conclusion

Throughout the two experiments, similarities and differences underlying the native speakers' and the L2 learners' Chinese character recognition processes were recorded. Both the segmental and suprasegmental (tonal) information were actively involved in the native speakers' semantic activation process—the early locus of semantic access; however, tonal information did not seem to be effectively engaged in the L2 learners' semantic activation process, although given time tonal information might be available to constrain (and hence facilitate) the L2 learners' semantic integration process—the late locus of semantic access. A possible consequence for this processing "deficiency" (i.e. late temporal availability of tonal information) is that, while the native speakers' phonological recoding performed during the semantic activation process would activate

only lexical meanings associated with the exact sound code of a Chinese character, the phonological recoding performed by the L2 learners in the same process would involve extra, "redundant" lexical meanings associated with other phonologically-similar characters that differ in tone. As a result, they might need more time for semantic activation and semantic integration. This provides *one* possible account for why the L2 learners generally required longer response times to perform semantic judgments than the native speakers in both Experiments 1 and 2.

The fact that the phonological recoding performed by the native speakers was encrypted with tonal features suggests that to acquire a native (or native-like) Chinese character recognition system, one needs to overcome two major hurdles: (1) to successfully acquire the Chinese phonological representation, including both segmental and tonal features and (2) to efficiently utilize the acquired phonological representation online to activate the semantic code of a Chinese character.

Of the two hurdles mentioned above, it appears that the L2 learners had successfully overcome the first hurdle, but not the second. Specifically, as noted earlier, the L2 learners exhibited native-like phonological perceptual skills in the screening tests; this suggests that the L2 learners had successfully acquired the L2 (Chinese) phonological representation, including both segmental and suprasegmental (tonal) features. However, in a task where immediate responses were required (i.e. Experiment 1), tonal information was not quickly activated to mediate the L2 learners' semantic activation process. This finding implies that they did not seem to be able to efficiently utilize the acquired phonological representation in *online* Chinese character recognition. The discrepancy in the L2 learners' differential success in tasks that did and did not require immediate access to the acquired phonological representation suggests that the L2 learners' deficiency is not so much about their "offline phonological representation"; rather, their problem is mainly attributed to their inefficiency in accessing and processing the acquired phonological representation online. In this regard, the L2 learners' non-nativeness has to do with a deficiency in online processing abilities, rather than with offline grammatical representation *per se*—a finding that is in line with the evidence obtained from the brain-imaging studies. Researchers have shown that although there seems to be a congruence of brain areas activated in the L1 and L2 by advanced adult L2 learners, more neuronal activity is involved in L2 versus L1 processing (i.e. more voxels in a given area are being activated). This extra activity could be viewed as evidence that L2 is being processed with more effort than the L1 (Stowe & Sabourin 2005).

Despite this processing deficiency, the L2 learners seemed to employ a processing procedure otherwise identical to the native controls during semantic activation. Because part of the L2 learners' lexical processing system conformed to the target (i.e. processing procedure) and part of it deviated from the target (i.e. differences in online phonological

representational knowledge activated during the semantic activation process), I should argue that differential success and failure may co-exist even within an advanced L2 processing (sub)system (cf. Han 2006), in this case, the lexical processing system. Note that the observed non-target features of the L2 learners' lexical processing system were only perceived in laboratory experimental settings. Outside of the laboratory settings, these L2 learners all appeared to be native-like in recognizing and comprehending Chinese characters (as verified by the Chinese Proficiency Test administered to them during the screening phase). Following Hyltenstam & Abrahamsson's (2000) definition of near-nativeness—"second language proficiency levels that are not identical to native-like levels but that fall short above the limit of perceivable non-nativeness" (p.163; see also Hyltenstam & Abrahamsson 2003)—the L2 learners *may* perform sentence-level Chinese character recognition drawing upon a near-native lexical processing system. Thus, Birdsong's (2006) contention about L2 processing is supported: "With respect to certain language processing tasks (e.g. lexical retrieval)… native-like performance is not observed [even] among high-proficiency late L2 learners" (p.183).

Given that these L2 learners may be able to achieve functional equivalence with natives in terms of overall reading ability (which is verified by the Chinese Proficiency Test conducted during the screening stage), the observed differences between a near-native and a native lexical processing system may appear to be insignificant in the L2 learners' life and endeavors. Nonetheless, the observed processing differences, in particular with the late temporal availability of tonal information in the L2 learners' sentence-level Chinese character recognition, *may* have a significant impact on the amount of lexical information that can be encoded and retained in the learners' working (or long-term) memory. Psycholinguistic studies have shown that phonological rehearsal plays an important role in retaining the decoded (lexical) information in working memory (Baddeley & Hitch 1974). The efficacy of phonological rehearsal is only optimal when the tonal and segmental information of a Chinese character can be efficiently and simultaneously accessed online (Xu et al. 1999). When tonal information cannot be available in the early phase of lexical processing, the efficacy of phonological rehearsal may be impaired.

Recall that at the end of each trial, the participants were required to state what they remembered about the sentence in which the prime word was embedded. While the native speakers were able to recall 85% of the sentences in Experiment 1 and 95% of the sentences in Experiment 2, the L2 learners were only able to perform the sentence recall task for half of the trials in Experiment 1 (Mean=48%) and for 86% of the sentences in Experiment 2. In addition, as noted earlier, in performing the sentence recall task, the participants could report back "anything" about the sentence they just read; it could be a picture/image that came to their mind after reading the sentence or

just the recall of a few characters in the sentence. When the native speakers chose to recall the characters in the lexical strings, the native speakers were able to report back almost all characters they had just read in both Experiments 1 and 2 (verbatim recall). The L2 learners, on the other hand, were only able to report approximately 2-3 characters in Experiment 1, and 5-6 characters in Experiment 2. The above findings collectively suggest that the L2 learners lagged behind the native controls in terms of the amount of lexical information that can be decoded and retained in the Working Memory. Thus, although the captured underlying differences may not affect the L2 learners' online comprehension, they may carry a negative impact on other linguistic/cognitive activities that are crucial for other aspects of language processing.

The above account highlights the importance of establishing/maintaining a strong link between the L2 (Chinese) phonology and the mental lexicon in learning to read an L2 (in this case, Mandarin Chinese). Thus, in addition to imparting specific higher-order reading strategies (e.g. making inferences or predictions) and orthographic features of the Chinese writing system (e.g. strokes and composition of a character), the reading instruction for adult L2 Chinese learners should place higher emphasis on raising learners' phonological awareness, including Chinese syllabic and/or tonal features. In particular, to enhance L2 Chinese learners' phonological awareness, teachers need to bolster the learners' awareness of the Chinese tonal features, particularly when such features are not present in the learners' native language.

I would concede that the evidence presented here deals with a restricted set of task parameters, that is, two semantic judgment tasks, involving reading and priming situations in which each word was presented to the participant briefly. Furthermore, the present study was essentially based upon the data collected over a short time frame. Even though these adult L2 learners were the best that could be found, they might not have been at the end state of their L2 development. Thus, to provide a more reliable, if not better, picture of adult L2 learners' end-state lexical processing system, a longitudinal database is warranted (Birdsong, 2005). Despite the above limitations, this study makes a unique contribution to the existing body of research by exploring the L2 lexical processing—an under-studied dimension of L2 ultimate attainment research. Furthermore, this study investigates the upper limits of L2 lexical processing using a population that is relatively less studied in L2 processing research, advanced adult L2 Chinese learners. As findings relating to the upper limits of adult SLA continue to be produced, SLA researchers will have an increasingly firm empirical foundation from which to develop models of representation, processing, and acquisition for adult SLA.

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成人第二語字彙處理系統之終點成就：
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　　第二語習得的成功與否，往往取決於第二語學習時間點上的差異。接觸第二語的時間越晚，語言學習終點成就的個體差異就越大；即使擁有充分的學習動機並身處在豐富的語料環境中，第二語成人學習者往往和母語使用者存在著質或量上的差異。這些差異不只會浮現在第二語學習者的語言表徵上，也會彰顯在第二語學習者的語言處理上；甚至高程度第二語學習者仍會在這兩個層次上表現出與母語使用者的細微差異。本研究針對一群在語言學習關鍵期後才開始學習中文的高程度第二語學習者，設計了兩個限時閱讀測驗。藉由探討高程度學習者的第二語識字過程，我們得以窺探他們在第二語字彙處理系統的終點成就。本研究發現這些高程度第二語學習者，在識字過程中雖然和母語人士採取同樣的字義理解程序，但在此過程中所激發的字彙心理表徵卻不盡相同；這群高程度學習者無法在字義理解過程中迅速地運用字彙聲調資訊激發字義。本研究認為雖然這個細微差異並不至於影響句子訊息的理解，但對辨識第二語書寫文字字意的速度和精確度，甚至對於閱讀內容的記憶都有負面的影響。

關鍵詞：成人第二語習得，語言學習關鍵期，第二語字彙處理，第二語識字，形音轉換