Learning Vocabulary in Chinese as a Foreign Language:

Effects of Explicit Instruction and Semantic Cue Reliability

Susan Dunlap, Charles A. Perfetti, and Ying Liu

University of Pittsburgh

Sue-mei Wu

Carnegie Mellon University

Abstract

Does providing reliable semantic information help second language learners acquire new words? Two experiments investigated whether adult learners of Chinese benefited from explicit instruction of semantic information when learning new characters. We manipulated whether semantic subcomponents were reliable cues to word meanings and whether the semantic information was taught explicitly or implicitly. We found a main effect of cue reliability, with better learning for characters with related semantic radicals, and an advantage of explicit instruction for long-term retention. Our results suggest that learners can benefit from being taught the connection between semantic subcomponents of characters and the meanings of words, and they can apply this knowledge when learning new vocabulary items.

Learning Vocabulary in Chinese as a Second Language:

Effects of Explicit Instruction and Semantic Cue Reliability

Adult learners of a second language generally benefit more from explicit instruction than implicit instruction (e.g., de Graaff, 1997; Ellis, 1994; Ellis, 2005; Norris & Ortega, 2000; Ullman, 2001). When learning complex grammar structures in a foreign language, adults benefit more from being explicitly told the grammatical rule than from having to infer a rule through implicit exposure to many exemplars (Reber, 1989; Reber, Kassin, Lewis, & Cantor, 1980). But most aspects of reading and language seem to have exceptions to the rules. For example, in English, sound-spelling correspondences are highly variable. In Spanish, gender markings of determiners do not always match the final vowel of the noun. In Chinese, certain characters have different pronunciations and meanings depending on the sentence context. When there are irregularities or exceptions such as these, would explicit instruction of rules still be beneficial to the learner?

Many words in Chinese have semantic radicals, or orthographic subcomponents that provide information about the meanings of the characters. Previous research has shown that learners of Chinese as a foreign language do not detect the presence of helpful cues in the orthographic forms unless such relationships are taught explicitly (e.g., Taft & Chung, 1999; Zhang, in preparation). In one study, native speakers of Australian English, who had no knowledge of Chinese languages, were presented with 24 Chinese character-meaning pairs to learn. Participants who were told about semantic radicals early in their training remembered more items on an immediate post-test than those who were provided the information late in training or not at all (Taft & Chung, 1999). In another study, native speakers of American English who were learning Chinese as a second language studied Chinese noun classifiers while receiving different types of explicit feedback. Results showed that learners benefited most from having attention drawn to the relationships between form and meaning (i.e., focus on form), even if it was via minimal hints (Zhang, in preparation). These results suggest that if a learner of Chinese as a second language is explicitly taught how to use relevant cues, especially early in their curriculum, it should benefit vocabulary acquisition.

However, explicit instruction might not always be superior for all aspects of language learning. Studies of complex grammatical systems have shown that, when instructed to memorize items (implicit learning condition), participants learned underlying grammatical structures better than those who were instructed to figure out the rule (explicit learning condition). Essentially, the people in the explicit learning condition spent cognitive effort trying to determine the underlying pattern, and often came up with incorrect guesses (Reber, 1989; Reber, Kassin, Lewis, & Cantor, 1980). So, once a misconception is in place, it will lead to future errors in learning.

It is not clear, yet, whether explicit or implicit instruction would be better for teaching the meanings of Chinese characters. On the one hand, students can benefit from being explicitly taught the nature of the writing system, with focus on location and reliability of semantic and phonetic components. On the other hand, students might become distracted or overwhelmed by all the exceptions or irregularities inherent in the writing system. Semantic cues in Chinese are not always reliable predictors of word meaning (Hanley, 2005; Shu, Chen, Anderson, Wu, & Xuan, 2003), it may actually be more confusing for a beginning learner to be taught inconsistent form-meaning relationships.

The aim of this study was to determine how reliability of cues can affect vocabulary learning in a new language. The written form of Chinese contains a high percentage of compound characters, which are single, one-syllable words made up of semantic and phonetic components. [1] These radicals often provide clues to the character's meaning and pronunciation. However, a reader cannot rely solely on using these components to decode new words in Chinese. Therefore, we wanted to ascertain whether it was helpful to teach the sometimes ambiguous relationship between sublexical forms and whole word meanings.

In two experiments, adult learners of introductory Chinese as a second language studied the form, pronunciation, and meaning of new Chinese compound characters. In order to determine if providing semantic cues helped learners acquire new vocabulary items, we varied whether the semantic radicals were reliable or unreliable cues to character meaning, and whether their relationship was taught explicitly or not. We predicted main effects of reliability and explicitness, such that learners learns items with related semantic radicals better than items with unrelated semantic radicals, and that students would perform better on items studied in the explicit condition compared to the implicit condition.

Experiment 1 Method

Participants

Participants were 8 right-handed students (4 female, 4 male) from Carnegie Mellon University, ages 18-25 (M = 20.0, SD = 2.3) who were studying introductory Chinese as a second language in a classroom setting. Six participants spoke English as a first language; one student's first language was Korean; one student's first language was Thai. All participants were paid for their completion of the study.

[1] Note: Although the majority of Chinese compound characters are phonetic compounds which have both phonetic and semantic radical components, there exist a few compounds with no phonetic radicals.

Materials

Our stimuli comprised 40 Chinese characters not previously learned in the students' curriculum (see Appendix A for the complete list of items). Characters were all compound characters with a semantic radical on the left and a phonetic radical on the right. We did not systematically manipulate the phonetic radicals; rather we focused on varying the semantic radicals in this study. In the semantic radical position, ten of the items had the grain radical, ten had the silk radical, ten had the worm radical, and ten had the money radical. For the silk and worm radical items, the meaning of the whole character was always related to the meaning of the semantic radical. These were the reliable cue items. For the money and grain radical items, the meaning of the characters was related in meaning to the semantic radical for only half of the items. These were the unreliable cue items.

Training items were counterbalanced such that learners saw one set of each radical type (reliable/unreliable) in each training condition (implicit/explicit). Also, each radical type (grain, silk, worm, money) was seen equally across the two training condition.

Design

Experiment 1 used a 2 x 2 design. Reliability of semantic radicals (reliable, unreliable and type of instruction (implicit, explicit) were within-subjects variables. Dependent variables were accuracy and response times on lexical decision, naming, and semantic relatedness judgment tasks, and accuracy on the follow-up transfer test.

Procedure

Participants studied materials for two hours using a web-based format accessed from their home computer or from a campus computer lab. The following day, they came to the lab and were tested individually by an experimenter who spoke both English and Chinese. Three weeks after testing, 6 of the 8 participants completed a brief follow-up study on-line, which tested their retention and transfer of knowledge about the semantic radicals.

The online tutorial phase consisted of studying 40 Chinese characters. Participants logged on to the web page and saw a table with all 40 characters to be learned, as well as instructions on how to maneuver through the site. When a learner clicked on any character in the table, the bottom half of the screen would provide the pronunciation and translation for that character, as shown in Figure 1. The English translation was always present on the screen. If the participants clicked on the pinyin word on the screen (e.g., wén), the would hear a male native Chinese speaker pronouncing the word. In the explicit instruction condition, participants received additional information about the item when they moved their mouse over the character. The radical on the left side of the character turned red and a message appeared in the box above (see Figure 2), giving the meaning of the radical and how it was related or unrelated to the meaning of the character.

Immediately after completing the online studying, participants completed a review quiz of the 40 training items while still online. Students saw each Chinese character, one at a time, and had to type in the pinyin (including tone) and the English translation (one or two words). This was done to ensure they had sufficiently learned the target items to a criterion of at least 80 percent accuracy. However, data from the online review quiz are not reported here.

The lab testing procedures were completed in the same order for each participant. First, they had 10 minutes to review the 40 characters. This was followed immediately by lexical decision, naming, and semantic relatedness judgment tasks, and then debriefing and payment.

Lexical decision task. Participants saw 40 real characters and 40 pseudocharacters one at a time at the center of a computer screen. Their task was to respond as quickly and accurately as possible by pressing a yes button if the item was a real Chinese word, and a no button if it was not real. All real characters were those that they had studied in the online tutorial. All pseudocharacters were made of legal radicals in illegal positions or combinations. Accuracy and response times were recorded on the computer using E-Prime software (Psychology Software Tools, Inc.). A trial began with a blank screen for 500 ms, followed by a fixation cross for 500 ms, then another blank screen for 500 ms. Then the item appeared until the participant made a yes or no response. No accuracy or response time feedback was provided to the participant. Order of presentation of the 80 stimuli was randomized for each person. Everyone received a practice session with 7 items (5 high frequency real words they would have learned in the first semester of their introductory Chinese class, and 2 pseudocharacters) prior to actual testing.

Naming task. Participants saw each of the 40 target characters on a computer screen one at a time. The task was to give the Chinese pronunciation of the character as quickly and accurately as possible. Response times were recorded by a voice key microphone. Pronunciations were recorded by the experimenter and later coded for accuracy. Each trial began with a fixation cross for 500 ms, followed by a blank screen for 500 ms, then the target item appeared until the participant made a response. No accuracy or response time feedback was provided to the participant. The experimenter advanced to the next trial manually when ready. Order of presentation of the 40 stimuli was randomized for each participant. Everyone received a practice session with 5 items (high frequency words learned in first semester) before beginning the testing.

Semantic relatedness judgment task. On the computer screen, participants saw an English word in all capital letters, such as GRAIN or FURNITURE, followed by one of the 40 Chinese target words. Their task was to decide if the English word and the Chinese character were related in meaning. Items would be considered related if they were synonyms or were members of the same category, or if one was a categorical member of the other. By this definition, the English word “person” and the Chinese character 朋友 (“friend”) would be related. The English word “metal” and the Chinese character 象 (“elephant”) would not be related. Each trial began with a blank screen for 500 ms, followed by a fixation cross for 500 ms, then another blank screen for 500 ms. Then the English word appeared for 1000 ms, followed by a blank screen for 500 ms, then the Chinese target item appeared until the participant made a yes or no response. No accuracy or response time feedback was given. Order of presentation of the 40 stimulus pairs was randomized for each participant. Everyone received a practice session with 5 pairs of known items before beginning the testing.

Follow-up test. Approximately three weeks after testing, participants completed an online multiple choice translation test. The test items were 20 Chinese characters (5 items each x 4 previously learned radicals) not previously seen in either the training session or the first semester curriculum. Participants were instructed to choose from three English words the item they thought was the correct meaning of each Chinese character. For example, given the Chinese character for wheat, which contains the grain radical, the options were: telephone, medal, and wheat. Students would need to have remembered the meaning of the semantic radical (grain) and apply it to a new character to guess the right meaning (wheat). No accuracy feedback was provided to the participants. This test aimed to measure long-term retention of semantic radical information as well as transfer of knowledge to new characters.

Experiment 1 Results

Lexical Decision

Accuracy. Overall, participants reached a mean accuracy of 87.97% (*SD* = 7.93) on the lexical decision task. Among the target (real) items, we found a main effect of reliability such that participants responded more accurately to characters with related semantic radicals (*M* = 95.83, *SD* = 5.23) than to characters with unrelated semantic radicals (*M* = 90.28, *SD* = 5.12), $t(14) = 2.15$, $p < .05$. There was no significant effect of instruction, and no interaction between reliability and instruction (all *p*-values > .05).

Response time. Response time data were analyzed for correct responses only. Responses faster than 300 ms or slower than 6000 ms were considered outliers and removed. Then, based on the mean of the trimmed response times, responses two standard deviations above or below this mean were removed, and new means were calculated. Results of a *t*-test on the adjusted means showed that participants did not respond to real characters (*M* = 1993 ms, *SD* = 882) any faster than to pseudocharacters (*M* = 2127, *SD* = 857), $p > .05$.

Naming

Accuracy. Scoring for naming accuracy was done on a six-point scale. Participants received a score of 5 on an item if they pronounced the onset, rhyme, and tone correctly. For correct onset and rhyme with incorrect tone, they received a 4. For correct rhyme and tone but not onset, they received a 3. For correct onset only, they received a 2. For correct rhyme only, they received a 1. Participants received a 0 on an item if they gave no response or if their response was totally incorrect. Items for which there was a microphone failure were not included in analyses. Overall, participants scored an average of 3.63 (*SD* = 0.93) on the naming task. We found no main effects of reliability or instruction, and no interaction (all *p*-values > .05).

Response time. Response times were analyzed for items on which the participant scored a 4 or a 5 as described above (correct trials). Responses faster than 300 ms or slower than 6000 ms were removed. Then based on the mean of the trimmed response times, responses two standard deviations above and below this mean were removed, and new means were calculated. Results of *t*-tests on the adjusted means showed no significant main effects of reliability or instruction, and no interaction (all *p*-values > .05).

Semantic Relatedness Judgment

Accuracy. Overall, participants reached a mean accuracy of 80.63% (SD = 8.74) on the semantic relatedness judgment task. We found a main effect of reliability such that participants responded more accurately to characters with related semantic radicals (M = 91.39, SD = 2.46) than to characters with unrelated semantic radicals (M = 67.78, SD = 6.24), $t(14) = 9.96$, $p < .05$. There was no significant effect of instruction, and no interaction between reliability and instruction (all *p*-values > .05).

Response time. Response time data were analyzed for correct responses only. Responses faster than 300 ms or slower than 6000 ms were considered outliers and removed. Then, based on the mean of the trimmed response times, responses two standard deviations above and below this mean were removed and new means were calculated. Results of *t*-tests on the adjusted means showed no significant main effects of reliability or instruction, and no interaction (all *p*-values > .05).

Follow-up Test

Accuracy. Overall, participants reached a mean accuracy of 70.83 (SD = 9.22) on the follow-up test. We found no main effects of reliability or instruction, and no interaction (all *p*-values > .05).

Experiment 1 Discussion

The results of Experiment 1 showed that participants exhibited increased accuracy for items with related semantic radicals, relative to items with unrelated semantic radicals, in the lexical decision and semantic category judgment tasks. Reliability of cues had no additional effect on transfer items. And we found no additional benefit of explicit instruction.

Providing semantic cues promoted retention of target characters and aided in transferring knowledge to new characters on a follow-up test. The single-block within-subjects design of this experiment did not allow us to rule out the possibility that students applied the strategy they learned on explicitly trained items to items in the implicit condition, thus washing out effects of training condition. In Experiment 2, we used a block design to delineate effects of receiving implicit training or explicit training first.

Providing students with the possibility to access additional cues did not necessarily mean they used them all. Ad hoc analyses of the training session log files showed that students did not always move their mouse over the characters in the explicit condition. In Experiment 2, we made it more obvious that the students were to click on the character to get the explicit information whenever possible.

Another limitation of Experiment 1 was the use of the semantic relatedness judgments. In the task, participants had to access the English meaning of the Chinese character, then decide if it was semantically related to the previously seen English word. Students did have to know the meaning of the character to perform well on the task, but there could have been other sources of variability in the data. Answers on the task were often subjective, and answers would vary depending on how closely or distantly related the two items were. Therefore, it may not have been tapping knowledge of semantic radicals directly.

Again, Experiment 1 showed that reliable semantic radicals yielded better performance in lexical decision and semantic categorization tasks. However, instructional method (explicit vs. implicit) did not show any effect, due to the limitation of the within-subject design of this experiment. Thus, a second experiment was conducted to continue investigating the following research question: Does providing reliable semantic information help second language learners acquire new words? We manipulated explicitness of instruction and reliability of semantic cues. We predicted a main effect of reliability, with an advantage for items with related semantic radicals, and a main effect of instruction, such that explicit instruction would lead to greater learning than implicit instruction.

Experiment 2 Method

Participants

Participants were ten students from Carnegie Mellon University, who were studying introductory Chinese as a second language in a predominantly online setting. All students participated for course credit.

Materials

Stimuli comprised 28 Chinese characters from the students' online curriculum. Characters were all compound characters with semantic radicals from one of the following categories: female, heart, mouth, motion, silk, speech, or sun. Within each category, there were some items that were related to the meaning of the semantic radical, and some that were not (see Appendix B for the complete list of items). Because we used items available in the existing curriculum, we could not systematically vary reliability across semantic radical categories, as was done in Experiment 1.

Training conditions were counterbalanced such that half of the participants received the first set of items in the explicit condition and the second set of items in the implicit condition, and vice versa.

Design

Experiment 2 used a 2 x 2 design. Reliability of semantic radicals (related, unrelated to character meaning) was a within-subjects variable; type of instruction (implicit, explicit) was a blocked and counterbalanced within-subjects variable. The dependent variable was accuracy on immediate translation tests (trained items) and on pre-test, mid-test, and post-test multiple-choice items (trained and transfer items). Response times were not measured because (a) no significant differences were found for response times in any of the tasks in Experiment 1, and (b) all training and testing was done via a web interface, limiting precise and meaningful temporal resolution.

Procedure

Participants accessed the experiment online using a web-based format from their home or a campus computer lab. Each student completed a pre-test, a training session and quiz, a mid-test, another training session and quiz, and a post-test.

In the pre-test, students were presented with 48 Chinese characters, one at a time, and had to choose the English meaning from one of four options. The mid-test and post-test were identical to the pre-test.

In each training session, participants studied 14 items. When they clicked on any character in the table, the bottom half of the screen would provide the pronunciation and translation for that character, as shown in Figure 3. The pinyin pronunciation and English translation was always present on the screen. In the explicit instruction condition, the participants received additional information about the item when they clicked on the character. The semantic radical of the character turned red and a message appeared in the box above (see Figure 4), giving the meaning of the radical and how it was related or unrelated to the meaning of the character. At the end of each 14-item training block, students were quizzed on the meanings of the items they had studied. They saw one character at a time and had to type in the English translation.

Experiment 2 Results

Translation Quiz Accuracy

Overall, participants scored a mean accuracy of 83.1 (*SD* = 18.0) on the two 14-item translation quizzes. We found a marginally significant effect of reliability, such that participants were more accurate in translating items with related semantic radicals (*M* = 86.8, *SD* = 19.7) than items with unrelated semantic radicals (*M* = 77.0, *SD* = 13.4), $t(25) = 1.39$, $p = .08$. We also found a significant main effect of instruction, such that implicit instruction (*M* = 89.7, *SD* = 12.9) led to higher scores on the translation quiz than explicit instruction (*M* = 75.0, *SD* = 20.6), $t(25) = 2.27$, $p < .05$. When students made errors translating items studied in the explicit condition, they often gave the meaning of the semantic radical rather than the meaning of the whole character. There was no significant interaction between reliability and instruction, $p > .05$.

Accuracy on the Pre-test, Mid-test, and Post-test

Mean accuracy scores on the multiple choice tests given throughout the semester are shown in Figure 6. We found a main effect of reliability: Students had higher accuracy scores on the mid-test and post-test for items with related semantic radicals (*M* = 96.50, *SD* = 5.60) than for items with unrelated semantic radicals (*M* = 82.14, *SD* = 11.45), $t(18) = 3.56$, $p < .05$. We also found a significant effect of training, such that students had higher accuracy scores on the mid-test and post-test for items learned in the explicit condition (*M* = 92.15, *SD* = 1.15) than items learned in the implicit condition (M = 86.50, SD = 7.59), $t(18) = 2.33$, $p < .05$. As can be seen in Figure 6, there were no significant gains in either implicit training block. Also, there was no significant interaction between reliability and training condition, $p > .05$.

Experiment 2 Discussion

In the translation tasks done immediately after studying, students did better in the implicit training condition than the explicit training condition. It seems that explicit instruction caused some initial confusion, as evidenced by the students' tendency to give the meaning of the semantic radical as their response, which was counted as incorrect. However, in the retention and transfer tests, explicit instruction was clearly superior to implicit instruction. After students were trained in the explicit condition, their scores on trained items increased, regardless of cue reliability. It is worth noting that baseline scores for related items were higher than unrelated and transfer items for both sets of students. Nonetheless, students still showed significant improvements on these items only after explicit training, not after implicit training. There was no effect of training on transfer items. Unlike in Experiment 1, the students in Experiment 2 did not learn that semantic radicals can have some consistency across characters. This could be due to the fact that stimuli were not organized systematically by radical or by reliability during training in the second experiment.

General Discussion

Does providing explicit instruction of reliable semantic information help second language learners acquire new words? Our results show that explicit instruction did help learners acquire new vocabulary in Chinese, and that learning was better for Chinese characters with semantic radicals that are related to the meaning of the whole word.

In Experiment 1, reliability of semantic radical cues helped with short-term (1-2 days) retention. Furthermore, students were able to transfer knowledge of a "semantic radical strategy" to determining the meaning of new items (3 weeks after training), even when the semantic radical was not always a reliable predictor of a character's meaning during study sessions. In Experiment 2, explicit instruction of semantic radicals initially interfered with short-term retention (1-3 days) but helped with long-term retention (4+ days) of trained items. However, these students did not seem to be adopting a "semantic radical strategy" in determining the meanings of new characters (1-15 weeks after training), as was found in the first experiment.

Our results show that students do not necessarily pick up on the sublexical cues provided in a new language's writing system (e.g., Taft & Chung, 1999). However, once this connection is made explicit for them, students can use it as a strategy for remembering vocabulary and decoding new words—even if this sometimes leads to incorrect guesses on new or recently learned items. Teachers of Chinese as a foreign language can use this unique characteristic of the language to tailor instruction of new words. In order to help their students learn, instructors can illuminate connections between orthographic subcomponents and whole word meanings. Instructors of other languages can apply this same principal to the specific characteristics of the writing systems they teach. If there are semantic or phonological cues within a language's orthographic forms, these can be taught to help student learn to read better in the new writing system.

Native speakers of alphabetic languages, such as English or Korean, cannot apply alphabetic principals to learning Chinese characters. Therefore, they must apply a new decoding strategy and accommodate to the new writing system (e.g., Perfetti & Dunlap, 2007; Perfetti et al., 2007). Explicitly showing them the connections between linguistic subcomponents and whole word meanings and pronunciations provides an effective new decoding strategy for these learners.

Is explicit instruction of rules sufficient for helping students achieve transfer to new items? Our finding suggest that this is not necessarily so. Transfer involves extraction of rules or patterns and application to new exemplars. In implicit learning, this process takes more time and exposure to numerous examples (e.g., Reber, 1989, Reber et al., 1980). One semester of foreign language instruction is probably not enough to promoter implicit learning of useful sublexical information. In explicit instruction, attention should be drawn to rules and patterns, not merely to stimulus features. Also, we must consider possible sources of confusion. In Chinese, the presence, position, and validity of semantic radicals can vary greatly. So, for example, it is not enough just to tell students to look on the left-hand side of a compound character. In fact, doing so would probably cause more confusion than robust learning. Nevertheless, we contend that learners do benefit from being explicitly taught the connection between semantic subcomponents of words and the meanings of words, and that they can adopt this strategy in learning new vocabulary.

References

de Graaff, R. (1997). The eXperanto experiment: Effects of explicit instruction on second language acquisition. *Studies in Second Language Acquisition, 19,* 249-276.

Ellis, N. C. (Ed.) (1994). *Implicit and explicit learning of languages.* London: Academic Press.

Ellis, N. C. (2005). At the interface: Dynamic interactions of explicit and implicit language knowledge. *Studies in Second Language Acquisition, 27*, 305-352. doi: 10+10170S027226310505014X

Hanley, J. R. (2005). Learning to read Chinese. In C. Hulme & M. Snowling (Eds.), *The science of reading: A handbook* (pp 272-289). Oxford: Blackwell Publishing.

Norris, J., & Ortega, L. (2000). Effectiveness of L2 instruction: A research synthesis and quantitative meta-analysis. *Language Learning*, *50*, 417-528.

Perfetti, C. A., & Dunlap, S. (2007). Learning to read: General principles and writing system variations. In K. Koda & A. Zehler (Eds.), *Learning to read across languages*. Hillsdale, NJ: Lawrence Erlbaum.

Perfetti, C. A., Liu, Y., Fiez, J., Nelson, J., Bolger, D. J., & Tan, L. (2007). Reading in two writing systems: Accommodation and assimilation of the brain's reading network. *Bilingualism: Language and Cognition, 10*(2), 131-146. doi:10.1017/S1366728907002891

Reber, A. S. (1989). Implicit and tacit knowledge. *Journal of Experimental Psychology: General*, *118*, 219-235.

Reber, A. S., Kassin, S. M., Lewis, S., & Cantor, G. W. (1980). On the relationship between implicit and explicit modes in the learning of a complex rule structure. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *6*(5), 492-502.

Shu, H., Chen, X., Anderson, R. C., Wu, N. N., & Xuan, Y. (2003). Properties of school Chinese: Implication for learning to read. *Child Development*, *74*, 27-47.

Taft, M., & Chung, K. (1999). Using radicals in teaching Chinese characters to second language learners. *Psychologia*, *42*, 243-251.

Ullman, M. T. (2001). The declarative/procedural model of lexicon and grammar. *Journal of Psycholinguistic Research*, *30*, 37-69.

Zhang, Y. (in preparation). *Which feedback to provide? An examination of corrective, reflective, and rule-based feedback in Chinese classifier acquisition in a CALL environment*. Unpublished Master's thesis. Carnegie Mellon University.

Figure 1: Training Format in Implicit Condition, Experiment 1

<table>
<tr><td colspan="2"></td></tr>
<tr><td>蚊</td><td>Pronunciation:
wén</td></tr>
<tr><td colspan="2">Meaning: MOSQUITO; two-winged insect that sucks blood</td></tr>
</table>

Figure 2: Training Format in Explicit Condition, Experiment 1

The highlighted radical means worm, insect, or bug. A mosquito is a type of insect.	
蚊	Pronunciation: wén
Meaning: MOSQUITO; two-winged insect that sucks blood	

Figure 3. Training Format in Implicit Condition, Experiment 2

早	zǎo
MORNING; early	

Figure 4. Training format in Explicit Condition, Experiment 2

The highlighted radical means sun or day. Morning is a part of the day.	
早	zǎo
MORNING; early	

Figure 5: Format of Experiment 2 Pre-test, Mid-test, and Post-test Items

Example item from curriculum:

早

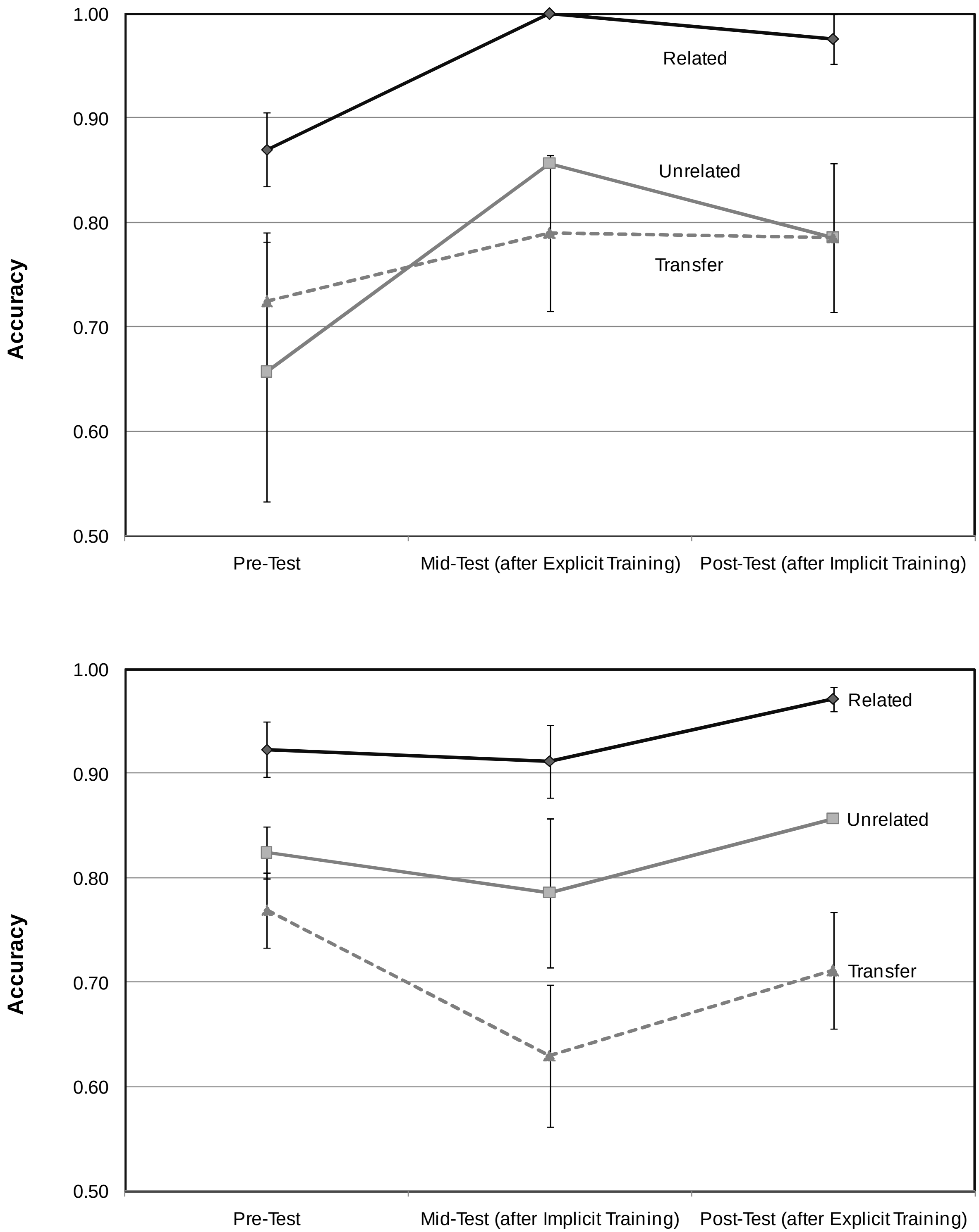
a. morning
b. chicken
c. brother
d. chew

Example transfer item with same semantic radical:

晶

a. drive
b. brilliant
c. cow
d. three

Figure 6: Mean Accuracy for Trained (Related and Unrelated) and Transfer Items on the Pre-Test, Mid-Test, and Post-Test



Appendix A

Experiment 1 Stimuli

Items with the Grain Radical	Pinyin	Definition	Elaboration
稻	dào	GRAIN; a small, dry, one-seeded piece of a cereal grass	The highlighted radical means grain. It provides the meaning for this character.
秧	yāng	SEEDLING; young plant grown from a seed	The highlighted radical means grain. Grain grows from a seedling.
稼	jià	SOW; to plant seeds	The highlighted radical means grain. Sowing is the first step to grow grain.
稈	gǎn	STALK; the stem of a plant	The highlighted radical means grain. Grain grows on a stalk.
種	zhòng	GROW; to raise or allow something to develop	The highlighted radical means grain. Grain is one of the first things grown by humans.
稍	shāo	BIT; a small amount or degree	The highlighted radical means grain. It is not directly related with bit.
積	jī	ACCUMULATE; to amass, gather up, increase	The highlighted radical means grain. It is not directly related with accumulate.
稱	chēng	CALL; to say; to label	The highlighted radical means grain. It is not directly related with call.
税	shuì	TAX; required financial contribution to government	The highlighted radical means grain. It is not directly related with tax.
秘	mì	SECRET; concealed knowledge	The highlighted radical means grain. It is not directly related with secret.

Items with the Silk Radical	Pinyin	Definition	Elaboration
紡	fǎng	SPIN; to draw out and twist fiber into thread	The highlighted radical means silk. It is normally spun into thread.
繡	xiù	EMBROIDER; to decorate with needlework	The highlighted radical means silk. Embroidery is often done with silk materials.
纏	chán	TANGLE; intertwine or snarl	The highlighted radical means silk. It can easily get tangled.
線	xiàn	THREAD; thin strand of fiber	The highlighted radical means silk. Thread can be spun from silk.
編	biān	BRAID; make by braiding or interlacing	The highlighted radical means silk. Braiding was normally done with silk in ancient times.
綢	chóu	SILK; fabric made by silk	The highlighted radical means silk. It provides a direct meaning for this character.
緞	duàn	SATIN; a smooth, glossy fabric	The highlighted radical means silk. Satin is very similar to silk.
絹	juàn	HANDKERCHIEF; small square piece of cloth used for wiping the nose or mouth	The highlighted radical means silk. A handkerchief can be made of silk.
纖	xiān	FIBER; natural or synthetic filament that can be turned into thread	The highlighted radical means silk. It is a widely used natural fiber.
綿	mián	COTTON; plant fiber used to make textiles	The highlighted radical means silk. Cotton is also a natural fiber like silk.

Items with the Insect Radical	Pinyin	Definition	Elaboration
蛾	é	MOTH; insect with powdery body and wings	The highlighted radical means worm, insect, or bug. A miller moth is a type of insect.
蝶	dié	BUTTERFLY; insect with four big colorful wings	The highlighted radical means worm, insect, or bug. A butterfly is a type of insect.
蝗	huáng	LOCUST; grasshopper that eats vegetation and crops	The highlighted radical means worm, insect, or bug. A locust is a type of insect.
蜘	zhī	SPIDER; eight-legged arachnid	The highlighted radical means worm, insect, or bug. A spider is a type of bug.
蜂	fēng	BEE; stinging insect, makes honey	The highlighted radical means worm, insect, or bug. A bee is a type of bug.
蛹	yǒng	PUPA; nonfeeding stage between larva and adulthood in metamorphosis in cocoon of certain insects	The highlighted radical means worm, insect, or bug. A pupa is a type of insect and physically resembles a worm.
蚊	wén	MOSQUITO; two-winged insect that sucks blood	The highlighted radical means worm, insect, or bug. A mosquito is a type of insect.
蟻	yǐ	ANT; social insect that lives in colonies	The highlighted radical means worm, insect, or bug. An ant is a type of insect.
蝎	xiē	SCORPION; arachnid with venomous tail that usually lives in warm, dry regions	The highlighted radical means worm, insect, or bug. A scorpion’s tale physically resembles a worm.
蝸	wō	SNAIL; mollusk with spirally coiled shell	The highlighted radical means worm, insect, or bug. A snail looks like a worm and is also slimy.

Items with the Money Radical	Pinyin	Definition	Elaboration
財	cái	WEALTH; accumulation of money or assets	The highlighted radical means money. Wealth is an abundance of money.
贖	shú	REDEEM; exchange or buy back for money	The highlighted radical means money. Redeem can mean to pay off or to turn into cash.
賺	zhuàn	GAIN; win something through one's effort	The highlighted radical means money. Money is something that can be gained.
貯	zhù	STORE; keep or lay aside for future use	The highlighted radical means money. One reason for storing things is to save money.
賬	zhàng	ACCOUNT; statement of recent transactions and the resulting balance	The highlighted radical means money. An account in normally used to track money flow.
貼	tiē	ATTACH; to affix	The highlighted radical means money. It is not directly related with attach.
贍	shàn	SUPPORT; to take care of an old person	The highlighted radical means money. It is not directly related with support.
敗	bài	LOSE; fail to win	The highlighted radical means money. It is not directly related with lose.
贓	zāng	STOLEN GOODS	The highlighted radical means money. It is not directly related with stolen goods.
則	zé	CRITERION; standard, norm, rule	The highlighted radical means money. It is not directly related with criterion.

Appendix B

Experiment 2 Stimuli

Radical	Item	Pinyin	Definition	Elaboration
Female	姓	xìng	SURNAME; one's family name	The highlighted radical means female. Ancient Chinese is a maternal side society.
	好	hǎo	GOOD; nice; fine; excellent	The highlighted radical means female. It is not directly related to good.
	姐	jiě	SISTER; one's elder sister; a general term for women, usually young	The highlighted radical means female. One’s elder sister must be a female.
	媽	mā	MOTHER; a woman servant	The highlighted radical means female. One’s mother must be female.
	她	tā	SHE; her	The highlighted radical means female. She is also female.
Heart	您	nín	YOU; a polite from of 你 “you”	The highlighted radical means heart or mind. 您，is normally used to address one’s elders or those with a higher social status. With “heart” to show respect.
	意	yì	IDEA; thought; meaning	The highlighted radical means heart or mind. Idea comes from mind.
	想	xiǎng	THINK; to consider; to suppose; to hope; to expect	The highlighted radical means heart or mind. People use mind to think of things.
Mouth	咱	zán	I; me	The highlighted radical means mouth. It is not directly related to “I” or “me”.
	哪	nǎ	WHERE; which (an interrogative particle)	The highlighted radical means mouth. With “mouth” to indicate it is related to questions.
	吃	chī	EAT; to sustain	The highlighted radical means mouth. We eat something with our mouth.

Motion	這	zhè	THIS; such	The highlighted radical means move or motion. It is not directly related to this.
	還	hái	hái: ALSO; still; yet	The highlighted radical means move or motion. It is not directly related to also.
	過	guò	PASS; to get to; to transfer	The highlighted radical means move or motion. One has to move in order to pass.
	運	yùn	MOVE; to transport; to ship; to revolve	The highlighted radical means move or motion. It provides the meaning for this character.
Silk	給	gĕi	GIVE; allow; let	The highlighted radical means silk. It is not directly related to give.
	紹	shào	CONTINUE	The highlighted radical means silk. Something continues as silk or thread extends.
	網	wǎng	NET	The highlighted radical means silk. Net is often a piece of woven silk or thread.
Speech	語	yǔ	LANGUAGE; a word; a sentence; an expression; a saying	The highlighted radical means speech or speak. It provides the meaning for this character.
	誰	shéi	WHO; anyone; someone	The highlighted radical means speech or speak. It is not directly related to “who”.
	說	shuō	SPEAK; to talk; to utter; to say; to explain; to clarify	The highlighted radical means speech or speak. It provides the meaning for this character.
	謝	xiè	THANK; to decline / to fade / to wither	The highlighted radical means speech or speak. Use words and speech to thank others.
	課	kè	LESSON; course; class	The highlighted radical means speech or speak. There are some words or speech in classes.
	話	huà	SPEECH; talk; conversation; words; sayings	The highlighted radical means speech or speak. It provides the meaning for this character.

Sun	明	míng	BRIGHT; clear; understandable	The highlighted radical means sun or day. It is bright with sunlight.
	晚	wǎn	EVENING; night; late; sunset	The highlighted radical means sun or day. Evening is a part of the day.
	時	shí	TIME; hour; period	The highlighted radical means sun or day. Time is a measurement of the day.
	早	zǎo	MORNING; early	The highlighted radical means sun or day. Morning is a part of the day.

Acknowledgments

This work was completed with funding from the National Science Foundation through Pittsburgh Science of Learning Center (PSLC), grant #SBE-03544200. The authors wish to acknowledge the invaluable contributions of Zi Gusheng, Dayne Grove, and the Elementary Chinese teachers and students at Carnegie Mellon University.