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The relationship between level of expertise and holistic processing in Chinese character recognition

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by

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Abstract

Evidence from past research suggests that when people process objects in which they are experts, such as faces and Roman letters, they usually engage in holistic processing which is the processing of multiple parts of a stimulus (Bukach, Gauthier, & Tarr, 2006; Wong et al., 2011). However, Hsiao and Cottrell (2009) found the opposite result such that novices used holistic processing in Chinese character recognition while experts did not. The current study explored the correlation between expertise and holistic processing of Chinese characters. We used the composite task to measure holistic processing of Chinese characters from English native-speakers who have learned Chinese, and the basic level advantage task (Wong & Gauthier, 2007) to measure their proficiency in Chinese. We found clear evidence that holistic processing correlates with expertise as shown by a significant positive correlation between the holistic processing of real Chinese characters and the number of years of studying Chinese. This indicates that the longer a participant has studied Chinese, the more holistically s/he processes real Chinese characters. Another significant positive correlation between the holistic processing of Chinese pseudo characters and Chinese character proficiency where smaller scores indicate greater expertise shows that the lower the proficiency in Chinese a participant has, the more holistically s/he processes Chinese pseudo characters. These results not only add more evidence to the argument that holistic processing is associated with expertise but they also support the idea that holistic processing is not unique to face recognition.

Keywords: holistic processing, Chinese character recognition, expertise, composite task, correlation, basic level advantage

Relationship between Level of Expertise and Holistic Processing in Chinese Character Recognition

We are all experts in recognizing certain visual objects because of our habits. One universal example is faces. Moreover, depending on our experiences in languages, we may be experts in different writing systems. English native speakers are experts in recognizing Roman characters that make up English words whereas Chinese native speakers are experts in recognizing Chinese characters. Past research suggests that when people process objects in which they are experts, such as faces, holistic processing is usually involved (Bukach, Gauthier, & Tarr, 2006; Tanaka & Sengco, 1997). Holistic processing is defined as the processing of multiple parts of a stimulus, even when participants are instructed to attend to only one of its specific part. In other words, participants attend to multiple parts of a stimulus obligatorily. For example, when processing a Chinese character that is made up of three identical subparts that mean “wood”, someone who is processing it holistically will report that he is seeing a character that means “forest” rather than seeing three characters that mean “wood”. Researchers continue to find out different factors that may contribute to the presence of holistic processing. Do people use holistic processing on everything for which they are experts or only certain objects? If holistic processing is associated with expertise, like past research has suggested, will a higher level of expertise result in more holistic processing used? This project is an attempt to answer these questions with respect to holistic processing in Chinese character recognition and level of expertise.

Previous research suggests a possible connection between face recognition and word recognition. Brain imaging studies show that word and face recognitions share neighboring neural substrates. McCandliss, Cohen, and Dehaene (2003) found that the Visual Word Form

Area was responsible for visual word recognition whereas Tarr and Gauthier (2000) and many other researchers found that the Fusiform Face Area was responsible for face recognition. Both of these areas are in the Fusiform Gyrus. In addition, a specific event-related potential (ERP) component called N170, which is a measure of brain responses as a result of face recognition (Bentin, Allison, Puce, Perez, & McCarthy, 1996), is also found to be connected to both expert object recognition and expert letter recognition of Roman and Chinese characters (Rossion, Joyce, Cottrell, & Tarr, 2003; Wong, Gauthier, Woroch, Debuse, & Curran, 2005). Moreover, processing inverted faces usually produces a N170 that is delayed (Bentin et al., 1996) and larger in amplitude (Kim, Yoon, & Park, 2004). Wang, Kuo, and Cheng (2011) found the same inversion effect for inverted Chinese characters. Based on these parallel findings between face recognition and Chinese character recognition, it is reasonable to infer that Chinese character recognition also relies on holistic processing.

The reason we chose to specifically study Chinese characters is that comparison between face processing and Roman character processing is more difficult than that between face processing and Chinese character processing since words in Roman characters do not have a homogeneous configuration. Moreover, processing of words in Roman characters relies on identifying the serial order of a set of letters that form combinations of varying length (Wong & Gauthier, 2007). On the other hand, Chinese characters share many similar properties with faces, such as upright orientation and predominantly individual level processing (McCleery et al., 2008). Predominantly individual level processing means that when recognizing a Chinese character, experts tend to first recognize which character it is instead of what font or how many parts it has. Similar to faces, we tend to first recognize who this face belongs to instead of the race of the face or that the face has two eyes. Therefore, Chinese characters make a better comparison with faces.

Holistic processing is defined as the processing of multiple parts of a stimulus, even when participants are instructed to only attend to one specific part of the stimulus. It can be measured using a composite task. In a composite task, stimuli are divided into two halves, left and right, or top and bottom. Participants are presented with two stimuli and only one half of the stimuli will be cued. Participants need to make a judgment on whether the cued half of the first stimulus is the same or different as the cued half of the second stimulus. Given that the left half (or top) is cued, stimuli are congruent-same if both the left (or top) halves and the right (or bottom) halves stay the same. Stimuli are congruent-different if both the left (or top) halves and the right (or bottom) halves change. Stimuli are incongruent-same if the left (or top) halves stay the same while the right (or bottom) halves change. Stimuli are incongruent-different if the left (or top) halves change while the right (or bottom) halves stay the same. Figure 1 illustrates congruent and incongruent trials using Chinese characters divided into left and right halves. Since we tend to process visual objects that we are experts in holistically, if the stimuli are incongruent, we will be less accurate and slower in making the judgment because the irrelevant half of the stimulus interferes with the target half. For example, in an incongruent-same trial where the cued left halves are the same, we want to make a judgment that the cued halves of the two stimuli are the same. However, the right halves that changed and become different interfere with our judgment that the left halves are the same. Therefore, we will be less accurate and slower in making this judgment. This effect is called the congruency effect. However, if the stimuli are misaligned, expertise is disrupted and holistic processing is reduced. The interference is no longer present, and thus the accuracy and response time should not be as impaired.

Therefore, holistic processing should be an interaction between congruency and alignment effects and can be defined in two ways: a) the better performance for congruent aligned than incongruent aligned trials; and b) the larger congruency effect in the aligned than misaligned condition (Wong et al., 2011).

Though expertise is often associated with holistic processing, Hsiao and Cottrell (2009) found controversial results in holistic processing of Chinese characters. In their study, a composite task with stimuli divided into bottom and top halves was used to test the presence of holistic processing. The results showed that only novices used holistic processing in Chinese character recognition while experts did not. Thus, Hsiao and Cottrell (2009) argued that holistic processing is not a marker of expertise. They also found that experts in Chinese characters showed a stronger preference than novices for the left chimeric character when judging whether the left or right chimeric character resembles the original character. With consideration to past research that shows that the left-side bias is also present in face recognition (Brady, Campbell, & Flaherty, 2005), Hsiao and Cottrell argued that instead of holistic processing, the left-side bias may be a general marker for expertise. This finding is unexpected because holistic processing is usually associated with expertise.

However, the findings from Hsiao and Cottrell (2009) may require more careful consideration because firstly, the stimuli were presented simultaneously in the study and secondly, there might be a ceiling effect. Hsiao and Cottrell (2009) used a simultaneous matching task in their study. Past research suggests that people tend to make discriminations faster and more accurately when stimuli were presented simultaneously (Palmer, 1978). Simultaneous presentation may have led to more parts-based processing strategies because it allows participants to perform immediate comparison between the two stimuli. Moreover, the high sensitivity from the study might be a ceiling effect and since Hsiao and Cottrell did not use response time as another measure, just by using sensitivity might not be accurate.

Inspired by Hsiao and Cottrell's study (2009), Wong, Bukach, Yuen, Yang, Leung, and Greenspon conducted two studies: one dealt with Roman characters (2011) and one dealt with Chinese characters (in prep.). The stimuli in the composite task were divided into left and right halves to avoid a top or bottom bias. We first examined holistic processing for Roman characters and found robust holistic processing of words by native English speakers, greater than that shown by bilingual Chinese participants with English as a second language (Wong et al., 2011). In addition, native English speakers, but not Chinese bilinguals, showed more holistic processing for words than nonwords. This is consistent with the argument that holistic processing is associated with expertise.

In the second study (Wong et al., in prep.), we examined holistic processing of Chinese characters split left and right. The results showed that both experts and novices in Chinese showed some holistic processing of Chinese characters, but that only experts showed more holistic processing for real Chinese characters than pseudo Chinese characters (Wong et al., in prep). This finding, again, is consistent with the argument that holistic processing is associated with expertise. Based on the existing results, it is possible that with more expertise one acquires, more holistic processing will be present for character recognition.

The current study studied how holistic processing of Chinese characters changes as people acquire expertise. We conducted this study with native English speakers who have different levels of experience in the Chinese language. We used the composite task to measure their holistic processing and the basic level advantage task (Wong & Gauthier, 2007) to measure their proficiency in Chinese which represented the level of expertise in this study.

The basic level advantage task analyzes the different levels at which people process objects, faces, or in this case, characters. Making a judgment on the basic level involves discrimination two objects in broader categories, for example a "car" versus a "tree," while processing at the subordinate level involves making a finer discrimination between different objects, such as recognizing a "Ferrari" versus a "Range Rover" (Wong & Gauthier, 2007). Wong and Gauthier (2007) found that letter and face perception represent two different types of expertise. Expertise in letter perception leads to improvements mainly on the basic level, such as recognizing that a "K" and a "B" are different letters, while expertise in face perception leads to improvements primarily in the subordinate level categorization. A similar basic level advantage task was used in this study, in which participants were asked to discriminate between different letters on the basic level by answering the question “same letter?” as well as between different styles of letters (handwritten versus typed) on the subordinate level by answering the question “same letter and same font?”. Participants with higher level of expertise should perform better at the basic level than the subordinate level. The stimuli were both Chinese characters and Roman letters. Therefore, both the basic level advantages in Chinese characters and Roman letters were measured.

It was hypothesized that with more expertise participants have in the Chinese language, more holistic processing of Chinese characters would be shown. Specifically, if expertise increases holistic processing of Chinese characters, then years of experience should be positively correlated with holistic processing but the basic level advantage difference (calculation explained in the results section) should be negatively correlated with holistic processing. Moreover, these correlations should be greater for real Chinese characters than for pseudo Chinese characters.

If a relationship between the level of expertise and holistic processing exists, it is a strong evidence to support the argument that expertise is a general marker for holistic processing. If holistic processing appears not to be specific to only face recognition, face recognition is more likely to be domain-general rather than domain-specific. This means that there is not a specific region in the brain that is responsible for and functions independently for face recognition. This study ultimately offers more understanding on the modularity of the brain.

Method

Participants

Fifty-three participants (29 male, 24 female, $M_{age} = 20.2$ years, age range: 18-23 years), all of whom were undergraduate students from the University of Richmond, took part in the study. Researchers made announcements about the study and collected students' email addresses in all of the Chinese classes that were being taught at the University of Richmond. Identical invitation emails for participating in the study were then sent to these students. An advertisement was also made on Spiderbyte, a school-wide electronic communication platform at the University of Richmond. All 53 participants have had some kind of experience in Chinese. With the exception of two Chinese-American participants who did not know to write in Chinese but only knew how to speak in Chinese, all remaining 51 participants have had taken Chinese language classes in the United States or in a Chinese-speaking region, such as China, Taiwan, or Hong Kong. Forty-two participants have English as their first language. Among these 42 participants, ten of them also listed Mandarin Chinese or a Chinese dialect as another first language. The first languages of other participants include German, Korean, Japanese, and Sinhala. Excluding the participants who only knew how to speak in Chinese, participants' average number of years of studying Chinese was 6.77 years and its range was from half a year to 22 years. Each participant was compensated with an amount of $15 for his or her time. Fifty-one participants were right-handed and two were left-handed. All participants had normal or corrected vision when they were doing the tasks.

Procedure

Overview

Participants first did the composite task which measured their holistic processing of Chinese characters. Then, they did the basic level advantage task which measured their proficiency in the Chinese language. Lastly, they filled in the background questionnaire. All participants finished the entire study within one and a half hours.

Composite Task

This task used a 2(word type) x2(alignment) x2(congruency) design to test if holistic processing was present in the recognition of Chinese characters. There were eight conditions and 512 trials in the experiment, totaling to 64 trials per condition (half matching, half nonmatching). The structure of the design of the experiment is summarized in Figure 2. Participants used Macintosh computers with a program called Matlab. The resolution of the computer was set to 300. To match the type of Chinese character that the participants have learned, all stimuli were simplified Chinese characters. There were eight sets of stimuli in this study. Each set contained two left halves and two right halves of a character. These halves could be interchanged to create the four test conditions of real characters. The pseudo characters were formed by taking each real character and swapping the positions of the left and right halves. Figure 3 shows a set of real characters and pseudo character that were used in the study. Each character showed up 16 times in the study and appeared as the study stimulus with the same frequency; each real character also appeared as the test stimulus equally often in the four different conditions. For each participant, four out of eight sets of real characters, as well as the pseudo characters made from the remaining four sets, were used. The choice for real characters and pseudo characters were counterbalanced across participants.

In a trial, the left and right halves of the characters were separated by a vertical line. The task was a match-to-sample task in which a stimulus was shown on the screen, followed by a nonsense mask of which one side was cued to indicate to which side of the stimulus the participant should pay attention. Following the nonsense mask was another stimulus that was either the same as the first stimulus, differed from the original stimulus in just one side, or differed from both sides. Figure 4 shows the sequence of an aligned and a misaligned trial. All stimuli were either a real Chinese character or a pseudo character. The participant had two seconds to indicate if the cued half of the second stimulus was the same or different from that half in the first stimulus. The participant pressed either the number 1 button on the keyboard to indicate the two halves were the same or the number 2 button to indicate the two halves were different. In order to encourage near-perfect accuracy, participants received a three-second pause when they gave an incorrect response. This enabled us to do most of the analysis on reaction time. The composite task took about 45 minutes to one hour to complete. If the characters that were incongruent were processed slower and less accurately than the congruent ones, then it showed that holistic processing was present in character recognition. Holistic processing was measured as the interaction between alignment and congruency in this study.

Basic Level Advantage Task

After finishing the composite task, the participants began the basic level advantage task. This task used a 2 (character type: Roman, Chinese) x 2 (task: subordinate, basic) design to measure participants' proficiency in Chinese. Participants used Macintosh computers with a program called Matlab. The resolution of the computer was set to 300. On each trial, participants were shown two characters simultaneously: either two Roman characters, two Chinese characters, or one of each. They were asked to make a yes/no judgment on whether the two stimuli were in the same category in terms of the subordinate level (e.g. whether they are the same letters and are of the same fonts) or the basic level (e.g. whether they are the same letters).

There were four types of stimuli in this task: handwritten Roman letters, typed Roman letters, handwritten Chinese characters, and typed Chinese characters (See Figure 5). There were 20 stimuli in each type, making a total of 80 stimuli. This task consisted of 320 trials. 160 of them were on the subordinate level and another 160 of them were on the basic level. Within these 160 trials, half of them involved Chinese characters and half Roman letters. Half were "yes" trials and half were "no" trials. For the subordinate-level trials, there were 40 "yes" trials with handwritten characters and 40 "yes" trials with printed characters. 40 of the "no" trials were created by taking the "yes" trials and replacing them with the same character of the other font and the other 40 were created by replacing the "yes" trials with another randomly chosen character of the other font. For the basic-level trials, half of the "yes" trials and half of the "no" trials involved characters of the same font. The "no" trials were formed by duplicating the "yes" trials and replacing one of the characters with one randomly chosen from the same Roman or Chinese character set.

During each trial, a fixation cross appeared at the middle of the screen for 500 ms followed by two stimuli each presented on either side of the fixation. The words "same letter, same font?" and "same letter?" were also shown on the top left corner to let participants know on which level their response should be based. Participants were given three seconds to make a response. They pressed either the number 1 button on the keyboard to indicate yes or the number

2 button to indicate no. The positions (left, right) of the different character types were counterbalanced across trials. There were six blocks in the study, and they alternated with each other with an order counterbalanced across participants. Similar to the composite task, in order to encourage near-perfect accuracy and to conduct most of the analyses on reaction time, participants received a three-second pause when they gave any incorrect response. All participants took about 20 to 25 minutes to finish this task.

Background Questionnaire

After the participants finished the composite task and the basic level advantage task, they were asked to complete a questionnaire. The Appendix shows a copy of this questionnaire. The purpose of this questionnaire was to serve as another measure of participants' proficiency in the Chinese language. This questionnaire was adopted and modified from two published articles. We adopted the background questionnaire from a study by Marcos-Llinas and Garau (2009) and the checklist from a study by Magno et al. (2009). The questionnaire included both open-ended questions and statements that the participants needed to indicate how frequently the statements applied to them. The data from Q3 and Q7 were recorded as variables that represented participants' level of expertise in Chinese. An average score was calculated from the scores of Reading Q2, Q3, Q4, Q5, and Writing Q2 to serve as another variable that represented participants' level of expertise in Chinese. Only the variables of years of experience and years of studying Chinese are reported in this paper, as all other measures from the questionnaire were not found to correlate with holistic processing.

Results

Composite Task

Table 1 shows the sensitivities (A') for all conditions. A' is a non-parametric measure of sensitivity according to the signal detection theory without the assumption of normality or that of equal variances (Stanislaw & Todorov, 1999). It is calculated using the formula below:

$$A' = .5 + \left[sign(H - F) \frac{(H - F)^2 + |H - F|}{4\max(H,F) - 4HF} \right].$$

H and F in the formula represent hit rate and false alarm rate respectively. I focused the analyses of this study on reaction times (RT) because both the composite task and the basic level advantage task were programmed to encourage near-perfect accuracy. The high averaged sensitivity (A' = .9693) shows that this intention was satisfied (For A' of individual conditions, please refer to Table 1).

Holistic processing was measured as the interaction between congruency effect and alignment effect and was calculated as follow: [(aligned_incongruent RT – aligned_congruent RT) – (misaligned_incongruent RT – misaligned_congruent RT)]. This measure indicates how much the interference from the irrelevant part depends on the intact configuration of parts. Table 1 also shows the average RT for correct trials in each condition.

Basic Level Advantage Task

Reaction times (RT) and accuracy are the two measures in this task. Table 2 shows the RT and accuracy for all four conditions: Chinese basic level judgment, Chinese subordinate level judgment, Roman basic level judgment, and Roman subordinate level judgment. Wong and Gauthier (2007) found that experts are better at making judgments on the basic level instead of the subordinate level. Such a difference is called the basic level advantage (BLA). The BLA in RT was calculated by subtracting the basic level performance from the subordinate level performance. To control for the differences in the general ability in performing discrimination tasks, a proportional BLA in RT was calculated as follows: (subordinate level performance – basic level performance) / basic level performance. We expected a larger BLA and proportional BLA in Roman letters than in Chinese characters for the participants in this study because their first language is English. This expectation was met by the higher Roman BLA (Mean = 198.0808) and higher Roman proportional BLA (Mean = 0.3099) than the Chinese BLA (Mean = 186.2458) and Chinese proportional BLA (Mean = 0.2762). Notice that these numbers represent the basic level advantage and thus, a higher number means to there is an advantage on the basic level to a larger extent. Moreover, we also expected a better performance on Roman basic level judgment than on Roman subordinate level judgment. This expectation was also met because the participants showed better performance on Roman basic level judgment (Mean Accuracy = 0.9736; Mean RT = 639.9240) than on the subordinate level judgment (Mean Accuracy = 0.9450; Mean RT = 838.0048). Detailed results can be seen in Table 2 and 3.

We also calculated the BLA difference by subtracting the Chinese BLA from the Roman BLA as well as the proportional BLA difference by subtracting the Chinese proportional BLA from the Roman proportional BLA. When comparing a participant with less experience in Chinese to one with more experience in Chinese, the participant with less experience in Chinese should have a larger BLA difference and a larger proportional BLA difference since s/he is supposed to have a smaller Chinese BLA. Therefore, the larger the BLA difference, the less proficiency the participant has in Chinese. In other words, the smaller the BLA difference, the more expert the participant is in Chinese. In more general terms, the higher proficiency the participant has in both English and Chinese, the smaller the BLA and proportional BLA difference. To the extent that the BLA task is an accurate measure of proficiency, we expected a negative correlation between the BLA difference and the participants' number of years of studying Chinese. However, such a negative correlation was not significant for BLA difference, $r(51) = -.164$, $p = .24$ nor for proportional BLA difference, $r(51) = -.215$, $p = .12$, though both of them were in the correct direction.

To further verify that the BLA task can be an accurate measure of language proficiency, we calculated the basic level performance difference by subtracting the Roman basic level performance from the Chinese basic level performance. This variable shows how much a participant's English is better than Chinese. Assuming that all participants have a similar level of proficiency in English since they are all University of Richmond undergraduate students, a larger difference suggests that the participant has less experience in Chinese. If a participant has a similar proficiency in English and Chinese, the difference should be small. We found a significant negative correlation between the basic level difference and years of experience in Chinese, $r(51) = -.330$, $p = .016$ (See Graph 1). This correlation adds weight to the BLA being an indicator of language proficiency.

Correlation Analyses

A correlation analysis was done on the holistic processing measures and the Chinese proficiency measures. A significant positive correlation was found between the holistic processing of real Chinese characters and the number of years of studying Chinese, $r(51) = .280$, $p = .043$. Graph 2 is a scatter plot that shows this positive correlation. However, there was no correlation found between the BLA difference or the proportional BLA difference and the holistic processing of real Chinese characters. Unexpectedly, a significant positive correlation was found between the holistic processing of pseudo Chinese characters and the BLA difference, $r(51) = .459$, $p = .001$. Graph 3 is a scatter plot that shows this positive correlation. This significant positive correlation was also found between the holistic processing of pseudo Chinese characters indexed by reaction time and the proportional BLA difference, $r(51) = .430$, $p = .001$. Unfortunately, the proficiency measure from the background questionnaire did not correlate with holistic processing of neither real Chinese characters nor pseudo Chinese characters. It is important to note that all these significant correlations still remain reliable when data from the participants who claim Chinese as their first language were omitted.

Discussions

The hypothesis, with more experience in the Chinese language, more holistic processing should be present for real characters, is supported by the significant positive correlation between number of years of studying Chinese and the holistic processing of real Chinese characters indexed by reaction time, though we were not able to find a significant negative correlation between the BLA difference and the holistic processing of real Chinese characters to further support this hypothesis. The other significant finding of the negative correlation between the BLA difference and the holistic processing of pseudo Chinese character was unexpected and potential explanations are offered below.

The significant positive correlation between number of years of studying Chinese and the holistic processing of real Chinese characters suggests that the longer a participant has studied Chinese, the more holistically s/he processes real Chinese characters. In other words, the longer a participant has studied Chinese, the more interference from the irrelevant parts he/she has while recognizing the real character. This finding is in line with the existing literature that argues holistic processing is associated with expertise, including the previous research done on Roman characters by similar researchers in this study (Wong et al., 2011). On the same logic, this finding is inconsistent with the findings from Hsiao and Cottrell (2009), which argues that novice but not experts use holistic processing. Such a difference in Hsiao and Cottrell's study

(2009) may be because of the ceiling effect (A' > .95) that might have incorrectly appeared to be holistic processing for experts, especially when sensitivity was their primary measure; or due to simultaneous presentation, which might encourage a parts-based strategy (Palmer, 1978).

The significant positive correlation between the BLA difference and the holistic processing of pseudo Chinese characters indexed by reaction time suggests that the less proficient a participant is in Chinese, the more holistically he/she processes Chinese pseudo characters. In other words, the more experienced a participant is in Chinese, the less holistically he/she processes pseudo Chinese characters. There are several reasons that we suspect might have contributed to this interesting finding. Firstly, experts' neural system may be fined tuned with experience. Secondly, Bukach, Phillip, and Gauthier (2010) found that antique car experts process only antique cars holistically and modern car experts only process modern car holistically. Even though antique and modern cars share some degree of perceptual features, these two different kinds of expertise do not generalize and thus it shows that holistic processing is highly specific. Applying this finding to the case of Chinese characters, although real characters and pseudo characters share some degree of perceptual features, holistic processing is not involved in both characters because people who are more experienced in Chinese are only experts in real Chinese characters and by no means experts in pseudo Chinese character. Lastly, we also suspect that it is also possible that for reading, higher level processing such as word meaning may contribute to holistic processing. Parts-based processing may predominate early perceptual processing until top-down processes are activated by stored representations of some kind (either lexical or semantic).

We observed some limitations in this study. Firstly, the BLA task might not have been a good measure of language proficiency. Although we found a significant negative correlation between the difference of Roman and Chinese basic level performance and years of experience in Chinese, we also found that some participants with English as their first language did not show a stronger Roman BLA than their Chinese BLA. To compensate for this limitation, we programmed a word/nonword task that asks participants to discriminate between real Chinese characters and pseudo Chinese characters, and data collection is currently ongoing. The word/nonword task may be a better way of measuring a participant's reading experience. Another limitation was that it was hard to find participants with experience in Chinese for more than 8 years but not for the entire lifetime in the Richmond community, especially on the University of Richmond campus. Right now, the data obtained from participants who have been learning Chinese and have had around or less than four years of experience in Chinese or Chinese-Americans who usually grow up with Chinese as a second language. It is indeed difficult to find people who have been learning Chinese for at least five years in an English-speaking country. The third limitation concerned the background questionnaire. It was unexpected that there was no correlation found between the questionnaire measure on reading and writing and holistic processing. It might be because the statements on the questionnaire focused too much on class learning experiences, such as "I read Chinese text outside of class assigned readings," and that the participants who were not taking Chinese classes when they did the experiment found these statements inapplicable and thus gave low ratings.

There are several future directions that are worth exploring. The first one is that this kind of developmental study using varied levels of experience in a language has not been done on Roman letters. It would be appropriate to do such a study in a country that English is a mandatory subject in the curriculum, such as Hong Kong. This can be a longitudinal study that the same group of secondary school students are brought in once a year or half a year to complete the composite task, the BLA task, and a background questionnaire. Another direction is to explore further why novices in Chinese do not process real Chinese characters holistically but do for pseudo Chinese characters. What is special about pseudo characters that cue novices to engage in holistic processing whereas a real character that they might have indeed come across cue them not to is an interesting question.

All in all, these results support the idea that holistic processing is not specific to face recognition. If holistic processing is not specific to face recognition, face recognition is more likely to be domain-general rather than domain-specific. It suggests that there is not a specific brain region responsible for face recognition only. This study offers more understanding on the modularity of the brain.

References

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8*, 551-565. doi:10.1162/jocn.1996.8.6.551

Brady, N., Campbell, M., & Flaherty, M. (2005). Perceptual asymmetries are preserved in memory for highly familiar faces of self and friend. *Brain and Cognition*, *58*, 334-342. doi: 10.1016/j.bandc.2005.01.001,

Bukach, C. M., Phillips, W. S., & Gauthier, I. (2010). Limits of generalization between categories and implications for theories of category specificity. *Attention, Perception, & Psychophysics*, *72*, 1865-1874. doi: 10.3758/APP.72.7.1865

Bukach, C. M., Gauthier, I., & Tarr, M. J. (2006). Beyond faces and modularity: the power of an expertise framework. *Trends in Cognitive Sciences*, *10*, 159-166. doi:10.1016/j.tics.2006.02.004

Hsiao, J. H., & Cottrell, G. W. (2009). Not all visual expertise is holistic, but it may be leftist: The case of Chinese character recognition. *Psychological Science*, *20*, 455-463. doi: 10.1111/j.1467-9280.2009.02315.x

Kim, K. H., Yoon, H. W., & Park, H. W. (2004). Spatiotemporal brain activation pattern during word/picture perception by native Koreans. *Neuroreport*, *15*, 1099-1103. doi: 10.1016/j.neulet.2005.10.101

Magno, C., Filho, M. K., Lajom, J. A., Regodon, J. R., & Bunagan, K. S. (2009). Assessing the level of English language exposure of Taiwanese college students in Taiwan and the Philippines. *Asian EFL Journal*, *11*, 62-73. Retrieved from: http://ssrn.com/abstract=1429345

Marcos-Llinas, M., & Garau, M. J. (2009). Effects of language anxiety on three proficiency-level courses of Spanish as a foreign language. *Foreign Language Annals*, *42*, 94-111. doi: 10.1111/j.1944-9720.2009.01010.x

McCandliss, B. D., Cohen, L., & Dehaene, S. (2003). The visual word form area: Expertise for reading in the fusiform gyrus. *Trends in Cognitive Sciences*, *7*, 293-299. doi: 10.1016/S1364-6613(03)00134-7

McCleery, J. P., Zhang, L., Ge, L., Wang, Z., Christiansen, E.M., Lee, K., & Cottrell, G.W. (2008). The roles of visual expertise and visual input in the face inversion effect: Behavioral and neurocomputational evidence. *Vision Research*, *48*, 703–715. doi:10.1016/j.visres.2007.11.025

Palmer, S. T. (1978). Structural aspects of visual similarity. *Memory & Cognition*, *6*, 91-97. doi: 10.3758/BF03197433

Rossion, B., Joyce, C. A., Cottrell, G. W., & Tarr, M. J. (2003). Early lateralization and orientation tuning for face, word, and object processing in the visual cortex. *NeuroImage*, *20*, 1609-1624. doi: 10.1016/j.neuroimage.2003.07.010

Stanislaw, H. & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers*, *31*, 137-149. doi: 10.3758/BF03207704

Tanaka, J. W., & Sengco, J. A. (1997). Features and their configuration in face recognition. *Memory and Cognition*, *25*, 583-589. doi: 10.3758/BF03207704

Tarr, M. J., & Gauthier, I. (2000). A flexible area for subordinate-level visual processing automatized by expertise. *Natural Neuroscience*, *3*, 764-769. doi: 10.1038/77666

Wang, M.-Y., Kuo, B.-C., & Cheng, S.-K. (2011). Chinese characters elicit face-like N170 inversion effects. *Brain and Cognition*, *77*, 419-431. doi: 10.1016/j.bandc.2011.08.016

Wong, A. C.-N., Gauthier, I. (2007). An analysis of letter expertise in a levels-of-categorization framework. *Visual Cognition*, *15*, 854-879. 10.1080/13506280600948350

Wong, A. C.-N., Gauthier, I., Woroch, B., Debuse, C., & Curran, T. (2005). An early electrophysiological response associated with expertise in letter perception. *Cognitive, Affective, and Behavioral Neuroscience, 5*, 306-318. doi: 10.3758/CABN.5.3.306

Wong, A. C-N., Bukach, C. M., Yuen, W. S., Yang, L, Leung, S., & Greenspon, E. (2011). Holistic processing of words modulated by reading experience. *PLoS ONE*, *6*, e20753. doi: 10.1371/journal.pone.0020753

Wong, A. C-N., Bukach, C. M., Yuen, W. S. Yang, L., Leung, S. & Greenspon, E. (in prep). Holistic processing of Chinese characters.

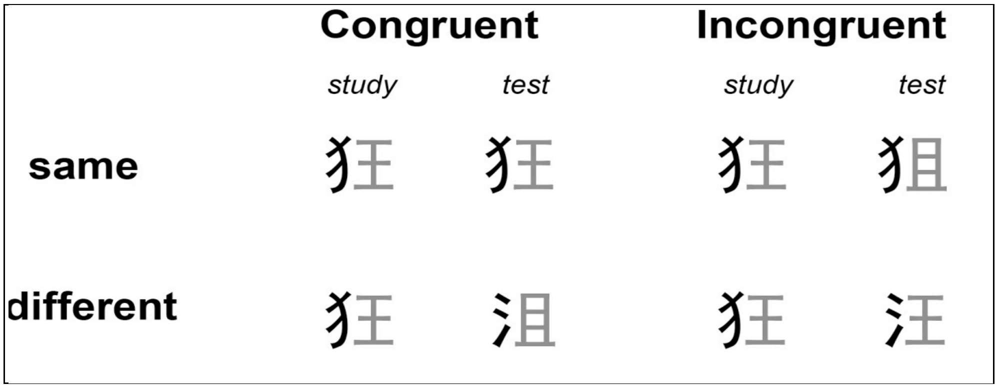


Figure 1. An illustration of congruent and incongruent trials. Given that the left half is cued, stimuli are congruent-same if both the left halves and the right halves stay the same. Stimuli are congruent-different if both the left halves and the right halves change. Stimuli are incongruent-same if the left halves stay the same while the right halves change. Stimuli are incongruent-different if the left halves change while the right halves stay the same.

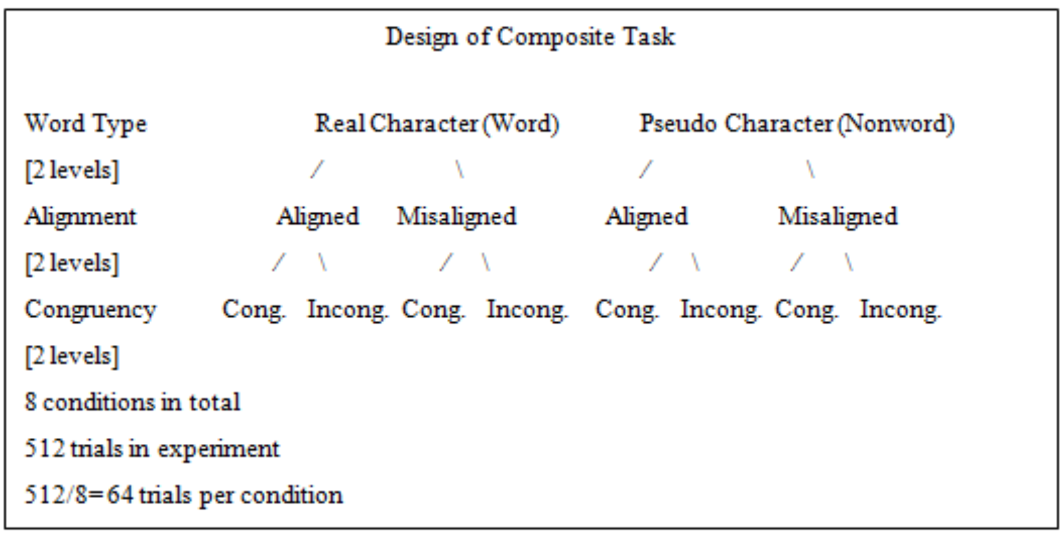


Figure 2. A chart illustrating the structure of the experimental design. There are eight conditions in the study in total: word-aligned-congruent, word-aligned-incongruent, word-misaligned-congruent, word-misaligned-incongruent, nonword-aligned-congruent, nonword-aligned-incongruent, nonword-misaligned-congruent, and nonword-misaligned-incongruent.

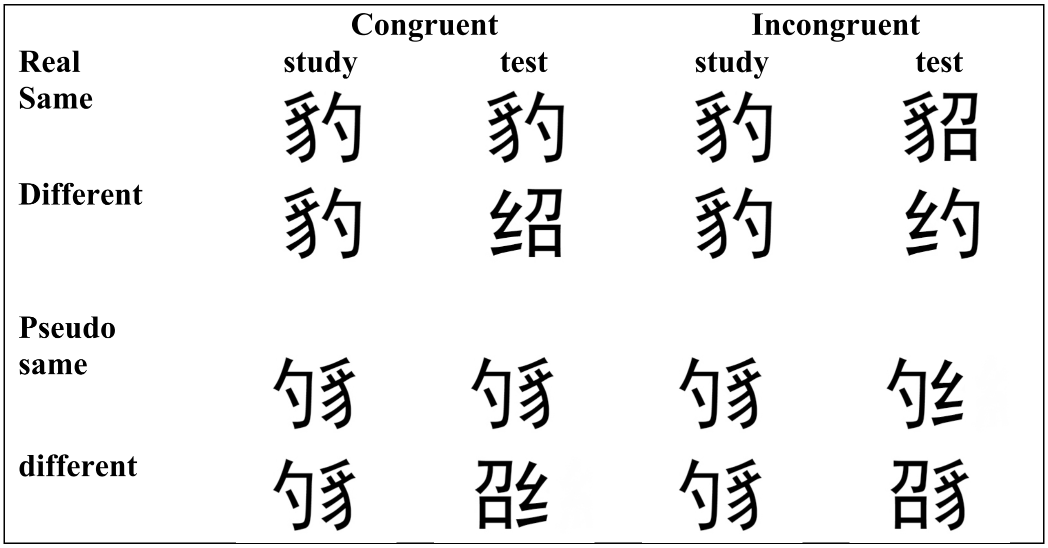


Figure 3. Sets of stimuli of real characters and pseudo characters from the composite task.

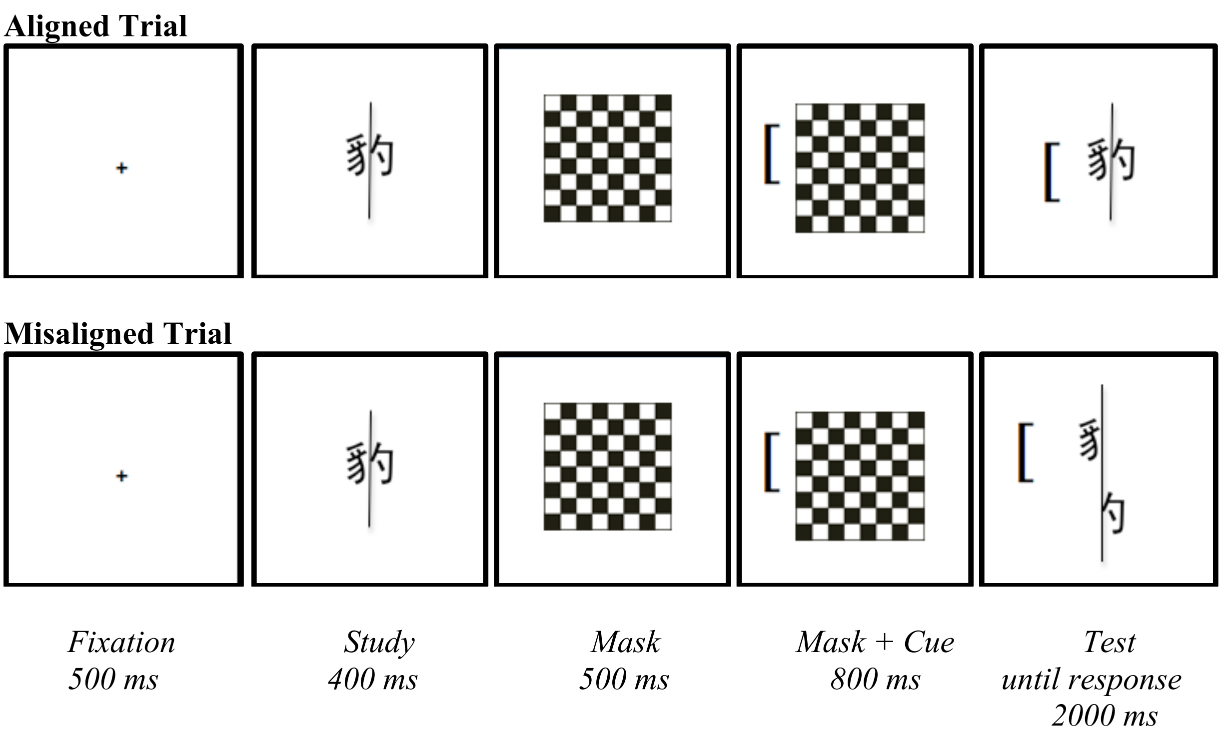


Figure 4. The trial sequence of an aligned and a misaligned trial in the composite task.

Handwritten Roman letters

Typed Roman letters

Handwritten Chinese characters

Typed Chinese characters

Figure 5. Stimuli used in the basic level advantage task.

Table 1. Sensitivity (A') measures and reaction times in the composite task.

Conditions			**A'**	**Reaction Times(ms)**
Real Characters	Aligned	Congruent	0.9765	643.9801
		Incongruent	0.9572	662.3630
	Misaligned	Congruent	0.9737	657.3300
		Incongruent	0.9705	658.2995
Pseudo Characters	Aligned	Congruent	0.9760	629.6263
		Incongruent	0.9683	653.8006
	Misaligned	Congruent	0.9703	644.6604
		Incongruent	0.9616	650.4715

Table 2. Accuracy and reaction times in all conditions of the basic level advantage task.

Conditions		**Accuracy**	**Reaction Times (ms)**
Roman Letters	Basic	0.9736	639.9240
	Subordinate	0.9450	838.0048
Chinese Characters	Basic	0.9649	684.4089
	Subordinate	0.9059	870.6547

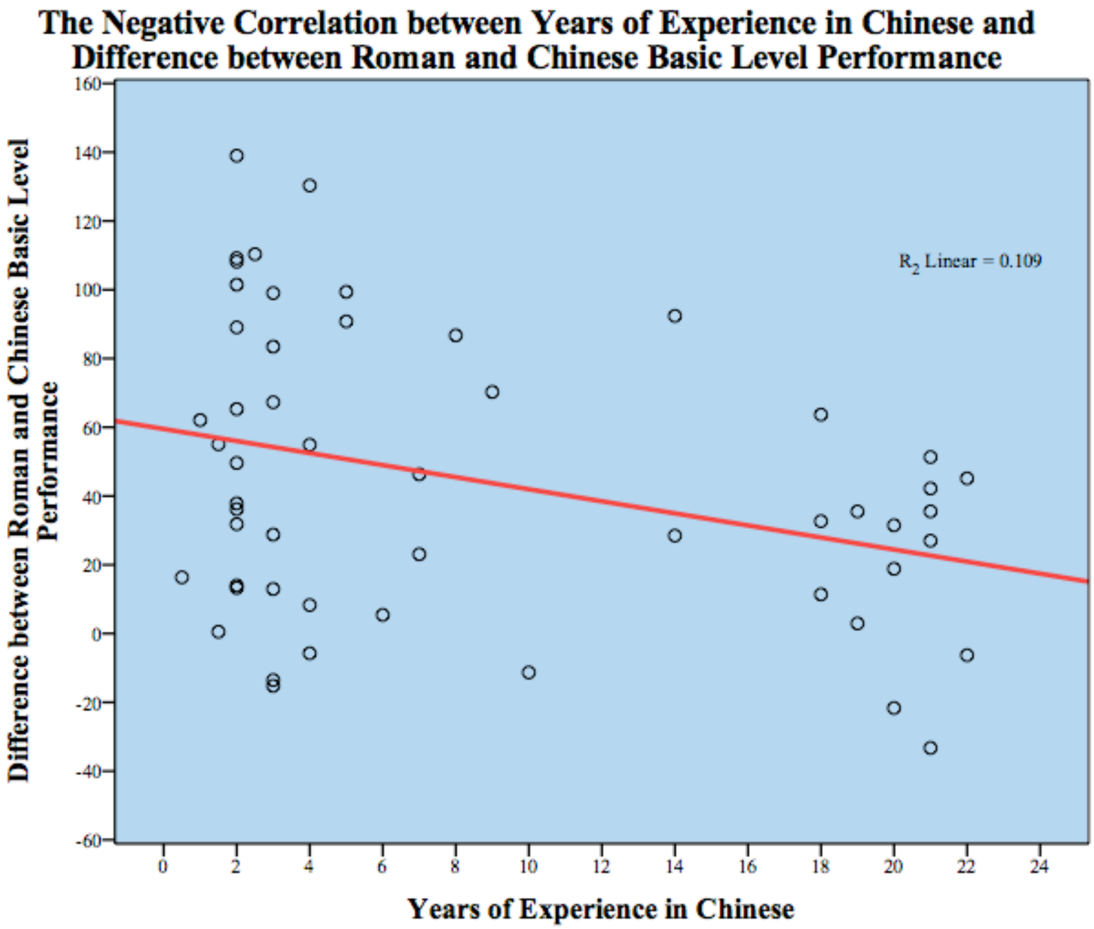
Table 3. Basic Level Advantage in RT and the proportional BLA in RT in the basic level advantage task.

	BLA in RT	**Proportional BLA in RT**
Formula	SL performance – BL performance	(SL performance – BL performance) / BL performance
Roman Letters	198.0808	0.3099
Chinese Characters	186.2458	0.2762

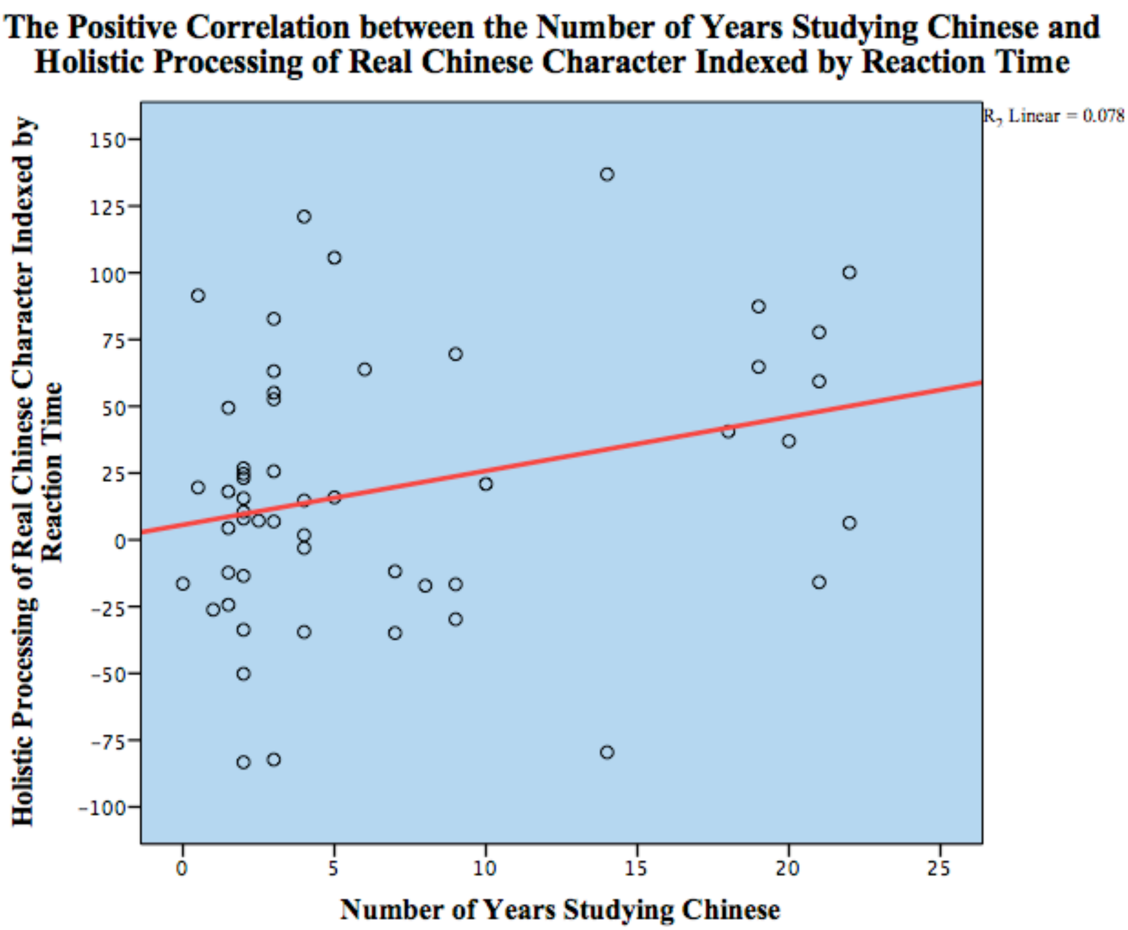
Note: SL = subordinate level; BL = basic level

The more expert is the participant in that language, the bigger the BLA should be.

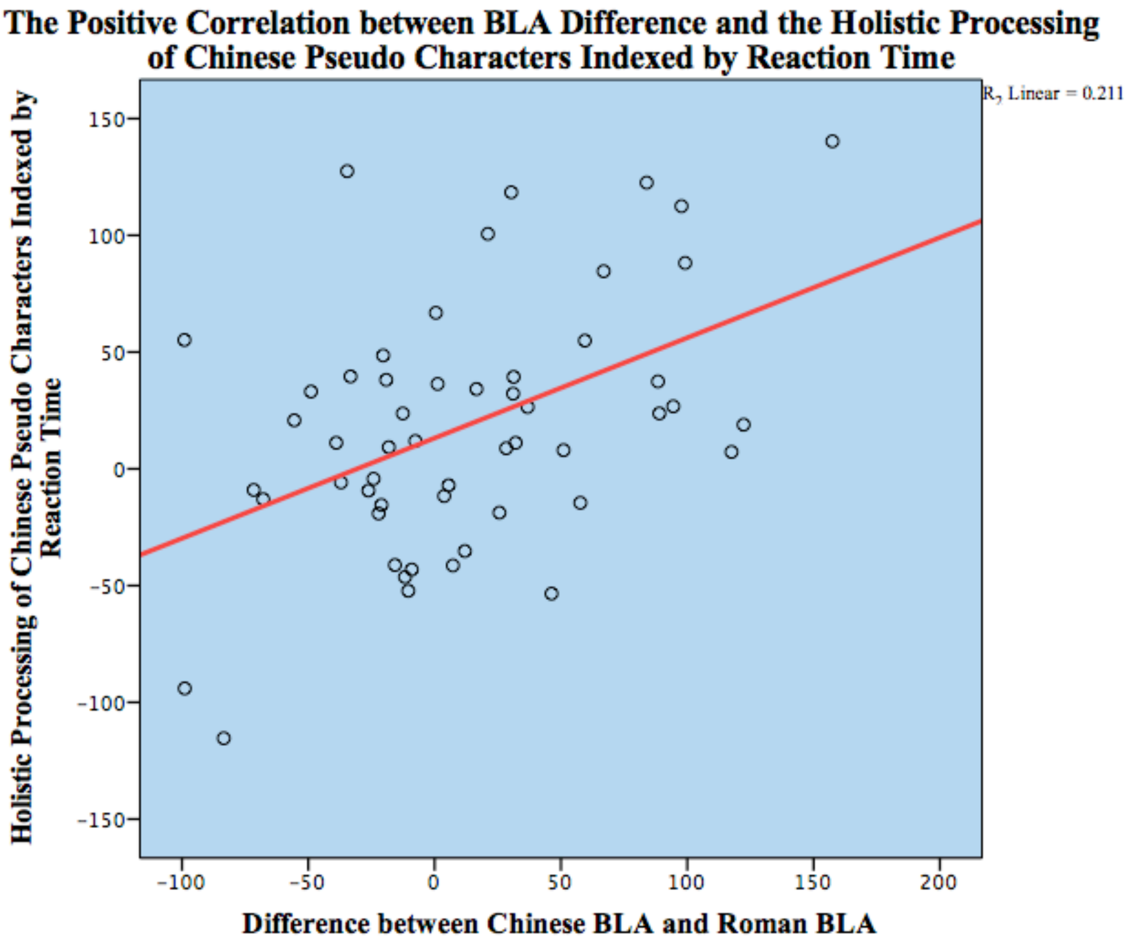
Graph 1. The negative correlation between years of experience in Chinese and the difference between Roman and Chinese Basic Level Performance.



Graph 2. The positive correlation between the holistic processing of real Chinese characters and the number of years of studying Chinese.



Graph 3. The positive correlation between the holistic processing of pseudo Chinese characters and the BLA difference.



Appendix

Questionnaire
Subject Number: ____________________

Background
Q1. Where were you born? ___________________________

Q2. How long have you been living in America? ____years

Q3. What is your native language? (can be more than one if applicable)
____

Education Background
Q1. Chinese Language Instruction Class(es) Being Taken Currently:
(e.g. CHIN 101) ____
Q2. Chinese Language Instruction Class(es) Completed:
High School:
Chinese Level 1 ☐ Chinese Level 2 ☐ Chinese Level 3 ☐
Community College:
Chinese Level 1 ☐ Chinese Level 2 ☐ Chinese Level 3 ☐
University:
CHIN 101 Elementary Chinese ☐ CHIN 102 Elementary Chinese ☐
CHIN 201 Intermediate Chinese ☐ CHIN 202 Intermediate Chinese ☐
CHIN 301 Advanced Intermediate Chinese ☐ CHIN 302 Conversational Chinese ☐
CHIN 311 Insights into Chinese Culture ☐ CHIN 312 Insights into Chinese Culture ☐
CHIN 388 Individual Internship ☐ CHIN 389 Practice Assistantship ☐
CHIN 401 Advanced Chinese I ☐ CHIN 402 Advanced Chinese II ☐
CHIN 406 Summer Undergraduate Research ☐
CHIN 410 Business Chinese ☐
CHIN 495 Independent Study ☐
CHIN 497 Selected Topics ☐
Others:
____
Q3. How long have you studied Chinese for? ____ year(s)

Q4. When did you first start learning Chinese? ____years old

Q5.
a. Did you stop studying Chinese? ____
b. Why? ____
c. For how long? ____
d. How old were you when you took Chinese again? _______________________________________

Q6.
a. Have you ever visited a Chinese speaking country? ______________________________________
b. Where did you go and for how long? ____
c. Was it a study abroad program? ____
d. Have you ever taken classes in other subjects that were taught in Chinese? (e.g. History, Math, Science) If so, how many? ____

Q7. How many hours do you spend studying Chinese? ___________________________ hours/week

Instruction: Read each item and check how often the situation applies to you.

	Always	Often	Sometimes	Rarely	Never
Reading					
1. I read Chinese text outside of class assigned readings.					
2. I look up new words in the Chinese dictionary.					
3. I read books written in Chinese.					
4. I read newspapers written in Chinese.					
5. I read magazines written in Chinese.					
6. I read the class assigned Chinese textbook.					
Speaking					
1. I talk with my friends in Chinese or other Chinese dialects.					
2. I talk with my family in Chinese or other Chinese dialects.					
3. My teacher speaks Chinese in class.					
4. I speak Chinese in class.					
5. I talk to native Chinese speakers in Chinese.					
6. I give presentations in Chinese.					
Writing					
1. I take notes in Chinese in class.					
2. I write things in Chinese to myself and to other people.					
3. I practice writing Chinese characters in class.					
4. I practice writing Chinese characters outside of class.					