Effects of English Capitals On Reading Performance of Chinese Learners:

Evidence from Eye Tracking

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***Abstract*—Native English speakers need more time to recognize capital letters in reading, yet the influence of capitals upon Chinese learners' reading performance is seldom studied. We conducted an eye tracker experiment to explore the cognitive features of Chinese learners in reading texts containing capital letters. Effect of English proficiency on capital letter reading is also studied. The results showed that capitals significantly increase the cognitive load in Chinese learners' reading process, complicate their cognitive processing, and lower their reading efficiency. The perception of capital letters of Chinese learners is found to be an isolated event and may influence the word superiority effect. English majors, who possess relatively stronger English logical thinking capability than non-English majors, face the same difficulty as the non-English majors do if no practice of capital letter reading have been done.**

Keywords-Captical letter; Reading; Congition; Eyemovements

I. INTRODUCTION

Capital letter (upper-case letter) is the unique type form in English language. All letters in a word or just the first letter could be capitalized in writing or printing. Capitals in English have both grammatical and rhetoric functions. The pronoun *I*, the first letter of a sentence, the first letter of a proper noun, abbreviations and acronyms must be capitalized. Titles, headlines, headings, logos, public signs, etc. are often capitalized for emphasis.

Conclusions on the influence of capitals upon the reading performance of English natives were quite consistent that all capitals slowed up the reading and increase interest and effort [1, 2, 3, 4]. Tinker and Paterson [4] were among the first ones to observe more fixations with fewer words perceived per fixation in reading all capitals through eye tracking experiments. The difference in shape between upper and lower case letters were considered to contribute to the poorer legibility of upper-case letters [5, 6, 7]. Lower-case letters included ascenders and /or descenders, and form clusters of letters, often a whole word (e.g. cat, dog, pig) while upper-case letters formed the shape of a horizontal rectangle (e.g. CAT, DOG, PIG), and people tended to remember alternating shapes better than square shapes [8].

Chinese characters are in square form but little study has connected Chinese learners' character reading ability with their reading performance of English capitals. Yet Chinese characters are logograms, which has not variation in type form. So English capitals have a higher possibility to be a difficulty in English learning. That is why we would like to explore and compare the cognitive features of Chinese learners when they are reading English upper and lower case letters.

For Chinese learners, rules about capitals usually are the contents in grammar learning. Although studies on their reading performance of English capitals were relatively few, the results were quite the same that Chinese learners considered capitals were very difficult to read and the reading time on capital words were significantly longer than lower-case words [9, 10]. Chen [11], by conducting tests on recognizing all capital words and phrases, commented that English major students had shown a marked accuracy rate than non-English major students. Usually we take English majors as having higher foreign language proficiency and non-English majors having normal one. Chen's result seemed to prove a positive correlation between English language proficiency and the reading performance of capitals. However, on reading longer sentences with all letters capitalized, both English majors and non-English majors showed very low recognizing accuracy. Also, using tests to measure reading accuracy might be greatly affected by how many words the subjects know and tests cannot describe the cognitive features of Chinese learners in reading capitals. Mistakes and interferences took place in reading may come from heavy cognitive load [12, 13, 14]; but we see little research about cognitive load in capital letters reading in China via eye movement measures like reading time, fixation count, saccade count, etc. experiments. These measures can offer a more direct and objective view of processing difficulty and proficiency in reading both from spatial and temporal dimensions. In China, most eye tracking experiments were conducted to explore the reading performance of Chinese language.

The aim of our experiment was to get six eye movement measures when Chinese learners are reading materials containing English capitals so as to analyze their cognitive features in capital letter reading. Two questions were going to be answered: (1) Does capital letters affect Chinese learners' the cognitive load, cognitive processing, and reading proficiency in reading and how; (2) Does English language proficiency influence the reading performance of capital letters and how.

II. METHODS

This study was 3 ('Text condition': word, phrase and sentence reading) × 3 ('Text type': the All-letter-capital, All-initial-capital and Normal texts) × 2 ('Subject group': English and non-English majors) factors mix designing.

A. Participants

A total of 46 college students from Nanjing University of Science and Technology (a major university in China, hereinafter NJUST), none of whom had participated in the pretest or the pilot experiment, were recruited in the eye-movement experiment for payment. They were all sophomores and aged between 18 and 22. Among them, 22 were English majors and were all female participants. The other 24 were non-English majors, 16 males and 8 females. In NJUST, female students in the English major greatly outnumber male students; while in other non-English majors, male students greatly outnumber female students. We cannot find an equal number of participants for both genders. For convenience, for English major, we choose all female participants and for non-English major, we try to include as many as female participants. Having learned English for more than ten years, all of them passed *Syllabus for College English Test-Band Four* (CET-4 for short). They were all native speakers of Mandarin with normal or corrected-to-normal vision, and had no history of neurological or language impairments. All of them provided informed consents. They were not informed of the purpose of the experiment, and had no previous exposure to similar experimental items. A total of 43 participants were successfully eye-tracked including 21 English majors and 22 non-English majors and their data be analyzed.

B. Materials

Experimental materials in this study were classified into 3 text types and 3 text conditions, altogether 9 presenting modes as shown in TABLE I. Text conditions include word, phrase and sentence. Text types include: (1) normal text which has no capital letter in word and phrase, but has the first letter in sentence capitalized; (2) all-capital text in which every letter is capitalized; (3) all-initial-capital text in which the first letter of each word is capitalized. A total 18 words, 12 phrases and 9 sentences were selected after preparation and pretest.

For words and phrases, subjects' familiarity and length were controlled. Firstly, these words came from the 2016 edition of CET-4 and a total of 6,127 words were left after the removing of unsuitable words. Secondly, the command statement '=LEN( )' in EXCEL was adopted to calculate how many letters each word contained, and words with six letters had the largest number, totaling 891. Thirdly, Online English Dictionary from Collins was used to decide the frequency of each word. As words with frequency 1 and 2 were very likely to go beyond subjects' vocabulary, words for the pretest were randomly chosen from words with frequency 3, 4 and 5. Finally, 16 words with frequency 3, 12 words with frequency 4 and 12 words with frequency 5 were included in the pretest.

Phrases came from *Nucleus College English: Reading and Writing Course 1 and 2*, the textbooks for the course College English in NJUST. Altogether 227 phrases were selected from these two books. Secondly, the number of characters in each phrase was calculated with the command statement '=LEN( )' in EXCEL, and words with 11 characters had the largest number of 27. Thirdly, the number of spaces in these 27 phrases was counted, with one space in 11 phrases and two spaces in 16 phrases. Finally, ten phrases with one space and ten phrases with two spaces were randomly chosen for the pretest.

For sentences, besides familiarity and length, idiomaticity and diversity were also taken into consideration. In consideration of the screen size of the display computer, it was decided that sentences with 28 characters fit this experiment best. Since all sentences were completed sentences containing spaces and punctuation, the 28 characters mentioned here included spaces and punctuation. Firstly, these sentences came from expressions for communication in *Nucleus College English: Listening and Speaking Course 2*. Four topics were adopted, and ten sentences were made for each topic, totaling 40. Secondly, two foreign teachers from School of Foreign Studies in NJUST respectively judged whether these sentences were idiomatic expressions. Eight sentences that were or might be Chinglish were removed. Thirdly, considering the diversity of expressions, we chose 20 sentences from those 32 sentences left.

In the pretest, 80 multiple-choice questions were made for these 40 words, 20 phrases and 20 sentences. The pretest was finished by 29 English majors from Nanjing Agricultural University and 26 non-English majors from NJUST. A total of 49 valid questionnaires were collected. After calculating the accuracy rate for each question, 18 words, 12 phrases and 9 sentences were chosen as experimental materials with the lowest accuracy rate of 95.92%. Hence, it was guaranteed that subjects had no difficulty in recognizing and understanding these materials.

TABLE I. NINE PRESENTING MODES AND SAMPLES

Text Type	Text Condition	Sample
All-captial	word	INTEND
	phrase	ON OCCASION
	sentence	NO, BUT THANKS FOR OFFERING.
All-initial-captial	word	Intend
	phrase	On Occasion
	sentence	No, But Thanks For Offering.
Normal	word	intend
	phrase	on occasion
	sentence	No, but thanks for offering.

C. Apparatus

All experiments were conducted in a sound-attenuated booth in the Language Cognition and Speech Science Lab of School of Foreign Studies in NJUST. The laboratory was equipped with one EyeLink 1000 Plus eye tracker, produced by SR Research Ltd. Eye movements of all subjects were monitored from their right eyes in the Remote Mode supported by the eye tracker. During the experiment, a display computer and a host computer were working at the same time. The display computer was used to present experimental materials, and the host computer was used to run the experimental program. The monitor had a refresh frequency of 75 Hz and a resolution ratio of 1024 × 768. A headrest was used to stabilize subjects' heads and to minimize the interference caused by their body movements.

D. Procedure

The entire experiment for one subject included the practice experiment and the formal experiment. Comprised of three words, three phrases and three sentences, the practice experiment was conducted to let the subject acquire a general understanding. All those materials presented in the practice experiment would not appear in the formal experiment. The formal experiment would be conducted if the subject provided stable eye movements. Before every formal experiment started, a nine-point calibration was performed. After that, each trial started with a one-point calibration in the middle of the screen. The subject was instructed to read the materials silently at his/her normal speed of reading. All materials were displayed in single lines on the screen. After reading each material, the subject needed to answer a multiple-choice question with two choices about the Chinese meaning of the material. No feedback would be given to him/her. Then, the subject needed to press the SPACE button on the keyboard to go on to the next material. The entire experiment took approximately 20 minutes for each subject.

The rate of accuracy in answering those multiple-choice questions was over 92%, as the lowest accuracy rates of English and non-English majors were 92.31% and 94.87% respectively. These accuracy rates were well above the chance level, implying that the subjects carefully read and basically understood the experimental materials.

E. Analysis

Data files were exported and sorted out by EXCEL for statistical analyses. The software utilized for processing the data was SPSS (Version 25.0 for Windows). In consideration of the fact that 21 English majors and 22 non-English majors provided valid samples, the data could be assumed to be normally distributed. Prior to analysis, a part of fixations, which were shorter than 80 ms or longer than 1,200 ms, were excluded from analysis according to Rayner and Pollatsek [15]. As a result, about 1.83% of the data were deleted.

These eye-movement data were processed with a multivariate analysis of variance, followed by Bonferroni adjusted post-hoc tests. Five measures were calculated and analyzed, including Fixation Count/FC, Progressive Saccade Count/PSC, Regressive Saccade Count/RSC, Mean Saccade Amplitude/MSC(only for sentences) and Total Time/TT.

a) FC: Fixation count is the number of times when eyes fixate on a specific area. The number of fixations is a convincing indicator of the cognitive load [16]. According to Henderson and Ferreira [17], reading a difficult text causes the reader to generate significantly more fixations than reading an easy text. Besides, with the same text, skilled readers generate significantly fewer fixations than average readers [18].

b) TFD: Total fixation duration is closely related to the cognitive load, and readers generate longer fixations when the cognitive load becomes heavier [19]. If the text becomes more difficult, the reader's fixations will become longer [20]. Also, total fixation duration of skilled readers is shorter than that of average readers when they read the same text [21]. Although *TFD* and *TC* can both reflect cognitvie load, since the two are frequently-used measurements in eyemovement experiments, we finally decide to include both in our analysis.

c) PSC: According to Rayner [22], the reader does not acquire information during saccades, and a new region of the text is presented after every saccade. Though new information is not obtained during saccades, cognitive processing does continue during most saccades [23, 24].

d) RSC: Regressive saccades, also called regressions, serve the purpose of rereading a specific part of the text [25]. The number of regressive saccades reveals the reader's cognitive reprocessing of previous information. It has been shown to be a good indicator of the reading efficiency [26, 27, 28]. With the text becoming more difficult, the reader makes more regressions (Rayner, 1998). Besides, skilled readers tend to generate significantly fewer regressions than average readers [21].

e) MSA: Mean saccade amplitude is the mean value of angular distances that eyes travel during saccades. Mean saccade amplitude concerns the reader's cognitive processing and reading efficiency [16]. Longer saccades show that the reader can acquire more information from fixations before saccades, and that he/she can read the text faster and more efficiently [24, 29]. As the text gets more difficult, the reader's saccades get shorter [20]. Saccades of skilled readers are longer than those of average readers [21]. However, it is not suitable to analyze word or phrase reading with mean saccade amplitude, because words and phrases are not long enough for readers to generate long saccades. Therefore, in this study, mean saccade amplitude is only adopted to analyze sentence reading.

f) TT: Total reading time refers to the sum of all fixations and saccades during reading. In other words, it is the sum of time spent in reading a specific text. It is different from total fixation duration mentioned above. In this study, the measurement of total reading time starts when the subject presses the SPACE button to read the text, and ends when he/she presses the SPACE button again to answer the multiple-choice question. Total reading time is an important measure to reflect the reading efficiency.

Repeated measures ANOVAs were applied to analyze the FC, TFD, PSC, RSC, MSA, and TT with two with-in subjects factors—Text condition (three levels: word, phrase, sentence), Text type (three levels: All-capitals, All-initial-capitals, Normal) and a between-subject factor—Subject group (two levels: English major and Non-English major).

III. RESULTS

The results in TABLE II. show that the main effects of 'Text condition' ($F(12, 3278) = 285.542$, $p < .001$), 'Text type' ($F(12, 3278) = 19.481$, $p < .001$) and 'Subject group' ($F(6, 1639) = 39.521$, $p < .001$) are all significant on the six measures. Nevertheless, there is no significant three-way 'Text condition × Text type × Subject group' interaction.

TABLE II. RESULTS OF GENERAL LINEAR MODEL WITH THE EFFECTS OF 'TEXT CONDITION', 'TEXT TYPE' AND 'SUBJECT GROUP'. ITEMS IN BOLD INDICATE SIGNIFICANT FINDINGS.

Effect	df1	df2	F	*p*
(Intercept)	6	1639	3580.533	**<.001*** **
Text condition	12	3278	285.542	**<.001*** **
Text type	12	3278	19.481	**<.001*** **
Subject group	6	1639	39.521	**<.001*** **
Text condition × Text type	24	5719	3.479	**<.001*** **
Text condition × Subject group	12	3278	5.262	**<.001*** **
Text type × Subject group	12	3278	0.892	0.555
Text condition × Text type × Subject group	24	5719	0.897	0.607

A significant two-way 'Text condition × Text type' interaction ($F(24, 5719) = 3.479$, $p < .001$) was witnessed. It proved that for Chinese learners as a whole, capital letters in text increase their cognitive load, complicate their cognitive processing, and lower their reading efficiency. Yet, we cannot say English major students exhibit a marked difference on cognitive load, cognitive processing and reading efficiency because with no significant 'Text type × Subject group' interaction was observed.

Bonferroni adjusted post-hoc tests are then performed on the two interactions for further comparisons. The results show: (1) participants generally perform word and phrase reading to a similar degree across the all-initial-capital and normal types. However, word and phrase reading show significant differences on the all-capital type, as participants generate more and longer fixations, more progressive and regressive saccades and longer reading time. This indicates that compared with the other two types of words and phrases, the all-capital ones pose a challenge to Chinese learners by increasing cognitive load, lowering reading efficiency and complicating cognitive processing. (2) Things became complicated on sentence condition as shown in Figure 1. The all-initial-capital sentences showed a marked different from normal type sentences. Students, when reading all-initial-capital sentences, generates more fixation ($p < 0.01$), longer fixation duration ($p < 0.01$), more progressive ($p < 0.01$) and regressive saccades ($p < 0.01$) and longer reading time ($p < 0.01$). Between all-initial-capital type and all-initial type, marked difference was found on fixation duration ($p < 0.001$), but not on fixation counts; and another marked different was found on mean saccade amplitude ($p < 0.01$), but not on progressive and regressive saccades. Between all-initial type and normal text type, marked differences were observed across all the six measures. Combining result in (1), it indicates that, on sentence condition, with an increased number of capital letters, Chinese learners experienced heavier cognitive load and lower reading efficiency. Cognitive features of all-initial-capital text reading were thus similar to those of all-capital text reading.

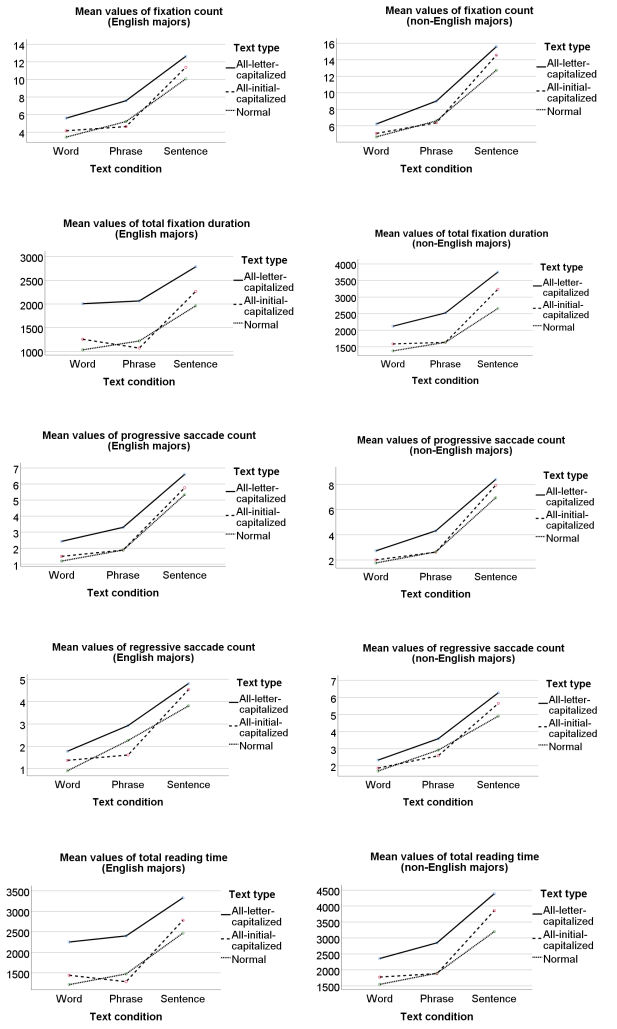

Figure 1. Six measures' mean values of English majors and non-English majors

There is another significant two-way interaction in 'Text condition × Subject group' ($F(12, 3278) = 5.262$, $p < .001$). Bonferroni adjusted post-hoc tests showed that, as in TABLE III., significant differences were observed in terms of all the six measures across three conditions. In comparison with English majors, non-English majors generate more and longer fixations, more progressive and regressive saccades, shorter saccades and more reading time. This can prove that when reading the same type text, the cognitive load and processing difficulty of English majors were significantly lower than those of non-English majors; while the reading efficiency of English majors were significantly higher than that of non-English majors. It is in line with our expectation, that English majors possess higher language proficiency. However, since no

significant two-way 'Text type × Subject group' interaction is found, capitalization was believed to pose a similar degree of challenge to both English and non-English majors. This challenge was great enough to counterbalance the advantages of English majors on 'Text condition', so no significant three-way 'Text condition × Text type × Subject group' interaction is found.

TABLE III. BONFERRONI ADJUSTED POST-HOC TEST BETWEEN TEXT CONDITION (WORD, PHRASE AND SENTENCE READING) ACROSS SUBJECT GROUPS (ENGLISH AND NON-ENGLISH MAJORS). ITEMS IN BOLD INDICATE SIGNIFICANT FINDINGS.

Measure	Text condition	*Mean difference (English vs. non-English)*	*Std. error*	*p*
FC	word	-0.936	0.252	**<.001*****
	phrase	-1.526	0.307	**<.001*****
	sentence	-2.938	0.353	**<.001*****
TFD (ms)	word	-262.003	74.949	**<.001*****
	phrase	-478.219	91.200	**<.001*****
	sentence	-880.291	105.102	**<.001*****
PSC	word	-0.468	0.138	**<.01****
	phrase	-0.845	0.168	**<.001*****
	sentence	-1.868	0.194	**<.001*****
RSC	word	-0.613	0.119	**<.001*****
	phrase	-0.764	0.145	**<.001*****
	sentence	-1.225	0.167	**<.001*****
MSA	word	1.069	0.135	**<.001*****
	phrase	-259.117	85.415	**<.01****
	sentence	-490.829	103.934	**<.001*****
TT	word	-951.997	119.778	**<.001*****
	phrase	-0.936	0.252	**<.001*****
	sentence	-1.526	0.307	**<.001*****

IV. DISCUSSION

A. Influence of captial letters on reading of Chinese learners

Studies on capital letters in English-speaking countries centers around the all-capital type form, which is considered to retard the reading speed of natives. In our study, eye movement measures reflected in the reading process of all-capital texts and normal texts got similar conclusion that all-capital texts also posed challenge for Chinese learners. Influences of capital letters on English reading of Chinese learners include heavier cognitive load, more complicated cognitive processing and lower reading efficiency. Therefore, there is no positive transfer of Chinese learners' capability of character reading to English all-capital word reading. Similarity in forms won't reduce the difficulty of recognizing foreign words.

All-initial-capital text, which is also one type of capitalization, has seldom been studied. According to our results, on reading words and phrases, no marked difference has been observed between all-initial-capital text and normal text. Yet on sentence condition, all-initial-capital text reading differentiated itself from normal text reading by presenting heavier cognitive load and lower reading efficiency. In all-initial-capital materials, each word contains one capital letter, each phrase contains 2 to 3 capital letters, and each sentence contains 6 capital letters in average. It could be concluded that if one sentence has more than 6 capitals letters, then the load and complexity in its cognitive processing is very much similar toward those of all-capital letter sentence.

Among the six eye movement measures, FC, TFD, RSC, MSA and TT are used to identify skilled readers [21, 22, 18]. Upon reading same text types, English majors are proved to be more skilled readers who can retrieve and process information in a logic-thinking mode in a quicker way. Nevertheless, when capital letters appeared in the experimental materials, the advantages of English majors on language proficiency and thinking mode were counter-balanced and they presented similar cognitive features as non-English majors.

People tended to remember alternating shapes better than square shapes [8]. It may not suit for Chinese native students. Chinese scripts are pictographic, ideographic and pictophonetic [30]. One character is a combination of form, sound and meaning. Intuition plays a very important role in recognizing and understanding them. Nevertheless, English scripts do not form images but are prescribed abstract signs, so recognition and understanding of them depend largely on logical thinking [30]. The intuitive thinking mode Chinese learners develop when acquiring Chinese language is quite different from the logical thinking mode that is required in perceiving alphabetical languages. We think this can account for the difficulties that Chinese learners experience in English reading.

B. Influence of captical letters on word-superiority effect on Chinese learners

Carroll [31] distinguished three levels of written language processing, i.e., feature, letter and word. Featural and letter information influences higher levels of processing, but the perception of individual letters is facilitated by the presence of a word or a word like context, which is called the word-superiority effect.

All the words in our experimental materials were selected from CET-4 word banks and have a relatively high frequency rate. All participants have learned English for more than 10 years and could provide correct answers for all the comprehension questions in the experiment. That meant the words in our materials were familiar to them. Based on word-superiority effect, the word *thanks* should be perceive as a whole. If we change *thanks* into *Thanks* or *thenks*, it ought to be quickly recognized and won't hinder the comprehension. However, during the experiment, we noticed that 16 of participants were written something down on the desk by using their finger. They said in the follow-up interview that they were changing the capital letters into lower-case letters. Another 15 participants also said that they needed to

switch capital letters back to lower-case letters in their minds in order to fulfill the reading. That means, for Chinese natives, a change in case of the first letter of a word is very different from that of any in-bedded letter of this word. Even for frequently used words, capital letters should be switched back to lower-cased letters for fulfilling word recognition. This hints a word processing after letter processing for Chinese learners, which contradicts the word-superiority effect. The type form change of a word's first letter restrains the word-superiority effect and controls Chinese student's to follow a bottom-to-up order in perception. If they lack the practice of capital letter reading, especially initial-capital word reading, cognitive load and processing difficulty on letter level will increase and then pass on to sentence level. This can count for the marked difference between reading all-initial-capital sentence and normal sentence.

V. CONCLUSION

This study aims to explore the influence of the capital form on English reading of Chinese learners. We found that capital letters pose challenge on Chinese learners' reading performance by increasing cognitive load, complicate perceptual processing and lowering reading efficiency. Though the rectangular form of all-capital words look like Chinese characters, it won't reduce the level of difficulty in cognitive processing. So the decisive point for correct perception is the link between form and meaning. For initial-capital words, Chinese learners exhibit a letter-to-word processing order, which shows no sign of word-superiority effect. English majors, if they lack capital letter reading practice, they will face the same challenge as non-English majors do on reading capitals despite the fact that they have a relative higher language proficiency and stronger logical thinking ability. Further studies are needed to explore the influence of form change of initial letter on reading of Chinese learners. Also, we need experimental data to study the intuitive thought Chinese student develop in learning Chinese and the logical thought they develop in learning English.

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