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Impact of Misplaced Words in Reading Comprehension of Chinese Sentences: Evidences from Eye Movement and Electroencephalography

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Abstract: This pilot study aimed to investigate the impact of misplaced words in Chinese sentences by using eye-tracker and electroencephalography (EEG) technology. There were 5 participants. Four of which were graduate students and one was a college student. Their average age was 24.4 years old. The participants were asked to read text with and without misplaced words. After reading, they were asked to answer a question that determined whether they understood the content of the stimulus previously displayed. Eye movement data and attention levels were recorded using an eye tracker and an EEG device. The data were saved in the background system automatically and synchronously while the experiment was performed. The findings suggest that: 1.) The number of misplaced words do not affect the reading comprehension of participants. Instead, wrong answers resulted from the question that evaluated the reading comprehension on one stimulus that contained too many information 2.) In increasing the number of misplaced words in a stimulus, participants did not spend more time gazing at them in comparison to other stimuli that had lesser or no misplaced words 3.) When asked to read a stimulus as quickly as possible, the analysis showed that most of the participants did not gaze longer at the regions of the misplaced words. They spent less than 5% of the time gazing at these regions of interest 4.) EEG data analysis yielded mixed results since some participants that gazed at misplaced words had high attention levels and some did not show an increase in their attention levels.

Keywords: misplaced words in Chinese, eye-tracker, electroencephalography (EEG)

1. Introduction

Cambridge University Effect claims that people can read a word even when the interior letters are jumbled. It is saying that people do not look at all characters in reading a word. Hence, if the first and last letter are in the right place, people can still read it and comprehend its meaning. However, a formally published paper is not available to reference it to researchers of Cambridge University. Apparently, the earliest demonstration of this effect belongs to Rawlinson. His study showed that randomization of letters in a middle of a word have minimal effect on the skilled reader's ability to comprehend a printed text (Rawlinson, 1976). Interestingly, in recent years there has been a circulating concept on the internet which is almost the same with the Cambridge University Effect. It implies that misplaced words in a sentence do not affect the reader's understanding of the content. Nation mentions in his study that although having no knowledge on the meanings of individual words hinders understanding, humans are capable of deriving meanings from text even if some of the words makes no sense (Nation, 2009). This also occurs in Chinese text that is why authors have become interested in studying this phenomenon. In account of this, researchers that have been investigating this topic use the eye tracking technology to analyze reading behaviors. However, using both the eye-tracker and EEG have not been done yet. This lead the researchers of this study to investigate whether there are obvious differences in the eye movement and electroencephalography data in reading and comprehending sentences with misplaced words versus sentences without misplaced

words. We aimed to deduce the participants' reading behavior more objectively by using the mentioned technologies.

2. Literature Review

Researchers which aimed to find methods on studying thinking processes that are invisible to human observation used eye-tracking to determine factors such as gaze points and dwell times on the locations of interest on a stimulus. This is mainly because when people get or process information through vision, eyesight is often more directed and attracted to texts, pictures, and animation (Jaušovec, 2000). Because it presents these advantages, eye-tracking technology has been used to conduct various studies on visual and content design (Chwo, Ho, Liu, & Chiu Lin, 2013) and on cognitive psychology and reading strategies (Thang, Jaafar, Ho, Chen, & Soh, 2015). For this study, we used eye gaze data to analyze reading behavior on Chinese sentences with misplaced words in order to find out whether or not they have direct effects on reading comprehension of texts presented. Reading comprehension is a focal point on this research since it is vital in understanding meanings of text which is essential in learning (National Reading Panel, 2000). In line with this, a research work conducted by Qian et al about the effects of the transposed morpheme on reading Chinese sentences used an eye-tracker to gather and analyze participant's reading behavior. Result showed that there was a significant difference between reading sentences in transposed and not transposed sentences (Qian, Cui, & Yan, 2010). However, in another study, results showed that the order of the word, both in English or in Chinese, did not affect the reading comprehension of participants. The important factor that should be present among participants is that they have language skills that are the same with the native speakers of the language used in the content of stimuli used in experiments (Ye, 2014). Also another investigation on reading comprehension was conducted by using both eye-tracking and event-related potential (ERP) in conducting experiments. Recording of how participants read required the coordination of two complex systems namely the word recognition and Eye-Movement (EM) control (Kliegl, Dambacher, Dimigen, Jacobs, & Sommer, 2012). In another study done by Baretta et al, electroencephalography (EEG) was utilized to investigate reading comprehension. Results showed that the type of text and word have different influences on cognitive load (Baretta, Tomitch, Lim, & Waldie, 2012).

Review of experiments previously conducted on reading comprehension has lead the researchers of this study in choosing an experiment design that involved both eye-tracking and electroencephalography. This has given us the ability to get data and investigate details on the eye-behavior and emotional index of participants while reading.

3. Research Questions and Hypotheses

According to the literature reviews presented in the previous section, research questions and hypotheses are as follows,
Q1: Is there a difference in the reading comprehension when there are misplaced words in a stimulus?
Q2: Is there a difference in the reading speed when there are misplaced words in a stimulus?
Q3: Is there a difference in the variables of electroencephalography data when there are misplaced words in a stimulus?

Works of Qian and Ye stated that the order of the word either in English or in Chinese does not affect the participants' reading comprehension (Qian et al., 2010; Ye, 2014). They just need more time to figure out the meaning of the misplaced words. Basing from this, the hypotheses of this study are as follows,
H1: There is a difference in the reading comprehension when there are misplaced words in a stimulus versus a stimulus that does not have misplaced words.
H2: Participants reading a stimulus with the misplaced word need much more time to understand the information. Hence, the reading speed will be slower in comparison to a stimulus without any misplaced words.

H3: In reading a stimulus with the misplaced word, the participants need to be more concentrated in understanding a content. The participant emotional index of attention might be higher in comparison to reading a stimulus which do not have misplaced words present.

4. .Methodology

4.1 Participants

The participants were randomly selected from Department of Electrical Engineering, National Taiwan Normal University. They were all male students. Their average age was 24.4 years old.

4.2 Materials

Two groups of stimuli were used in conducting the experiment. One was for the short essays and the other was for the reading comprehension questions answerable by yes or no. There were eight stimuli for the short essays. To prevent influencing the experimental result with participants' background knowledge, each stimulus was written in Mandarin (Chinese) for easy understanding. All of them were extracted from the news which described a certain condition. For the reading comprehension questions, eight stimuli were also used. The reading comprehensive question was displayed after the participant read the stimulus with an essay. The question assessed the reading comprehension to determine whether or not the participant understood the short essay. Questions were designed to ask about the concept or implication of the previous content read instead of asking participants to remember a certain detail.

4.3 Design

A 2x2x2 quasi-experimental within-subject and between-subject design was used in this study. What we manipulated were the independent variables that included the existence of the misplaced words (Yes, No), the number of the misplaced words (1, 3) and the type of the misplaced words (noun or verb). All of the misplaced words have a high frequency of usage in Chinese. In addition, all of the stimuli were displayed randomly so that the display order did not influence any data analysis. Comparison of time spent in reading the stimulus, the number of correctly answered questions, and changes of attention level were taken into account in analyzing participant data.

4.4 Instruments

For the eye movement data:
EyeNTNU-120 eye tacker was used in this study. The sampling rate is 120Hz. The stimuli were displayed in an ASUS X53S laptop (CPU: Core i7-27600, Memory: 8GB, Size of the screen: 15.6 inches). The participants can gaze at the stimulus using both of their eyes, but the camera data recording of the eye movement was only directed to the right eye of the participants. The features of the EyeNTNU-120 are as follows:

1. Given that the distance between the screen and the participant is under 60 cm, the error rate is less than 0.3∘
2. A chin-rest is used in experiments to reduce the occurrence of invalid or inaccurate data.
3. It supports various analysis tool for data collected so that it returns report on Hot Zone, Scan Path, Total Contact Time (TCT), Number of Fixations (NOF), Duration of the First Fixation (DFF), and Latency of the First Fixation (LFF).

For the EEG data:
Neurosky MindWave Mobile was the apparatus used to gather EEG data from participants. Its sampling rate is 512Hz. A single channel of a none-invasive electrode was placed on the participant's left forehead. The apparatus records eight bands of brainwaves which are the delta(0.5-2.75Hz), theta(3.5-6.75Hz), low alpha(7.5-9.25Hz), high alpha(10-11.75Hz), low beta(13-16.75), high

beta(18-29.75), low gamma(31-39.75Hz) and mid gamma(41-49.75). The eye movement data and electroencephalography data were recorded automatically and synchronously.

4.5 Procedure

In order for the participants to be familiar with the software, the researcher gave them a short orientation and overview of the experiment. The participants were assisted in wearing the Neurosky MindWave Mobile and were asked to rest their chin on the chin rest while the EyeNTNU120 eye tracker camera was directed to their right eye. Participants have gone through a nine-point calibration process to ensure data accuracy. After the calibration, the experiment started by letting the participants view the randomly arranged stimuli. They were asked to read the content of a stimulus as quickly as possible. The next stimulus was then displayed which contained a reading comprehension question about what was previously read and it was answerable by Yes or No using designated keyboard buttons. The eye movement data, electroencephalography data and answers to the comprehensive questions were recorded by the system all throughout the experiment.

5. Results And Discussions

Discussions of results are arranged according to the order of the research questions presented earlier in this study. This will cover the analysis and interpretation of the eye movement data and of the electroencephalography data.

5.1 The relationship between the number of participants that had wrong answers in the reading comprehension questions and the number of misplaced words.

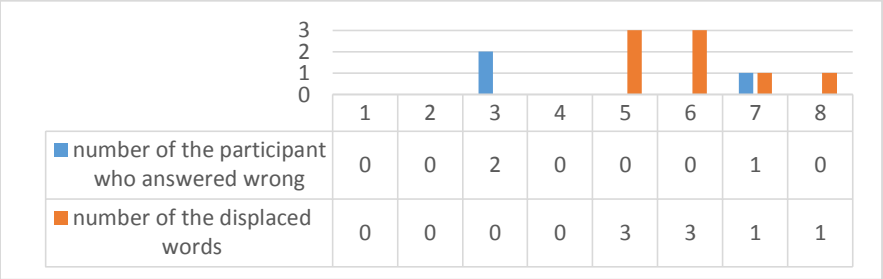


Figure 1. The relationship between the number of participants that had wrong answers and the number of misplaced words.

Fig. 1 shows that stimulus 3 had the highest number of participants who gave the wrong answer in the reading comprehension question. It is interesting to note that misplaced words were not present in stimulus 3. The researchers suspect that this is because of the too many information mentioned in the stimulus leading to the difficulty of participants in understanding the content correctly. While stimuli 5 and 6 had the highest number of misplaced words, which is three, all the participants answered the reading comprehension questions correctly. On the other hand, while stimuli 7 and 8 had only one misplaced word in their content, only one participant gave the wrong answer on the reading comprehension question for stimulus 7. The result suggests that the number of misplaced words does not directly affect the difficulty of participants in comprehending the content of the stimulus.

5.2 Reading Speed

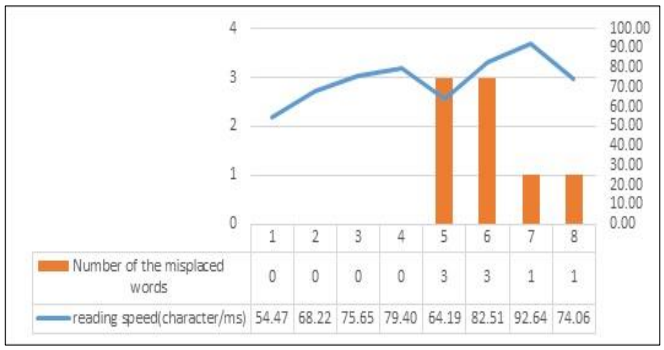


Figure 2. The analysis of the reading speed

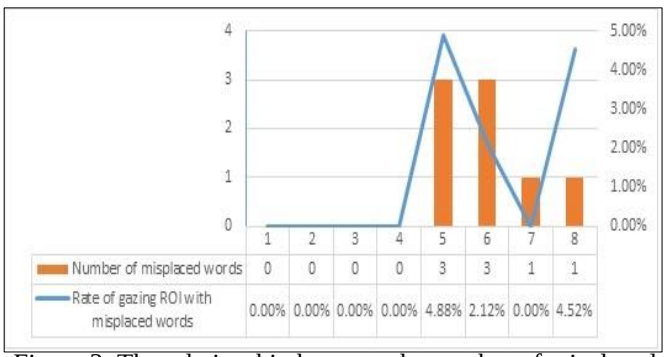


Figure 3. The relationship between the number of misplaced words and the average of gazing percentage on the ROIs which were the misplaced words.

Calculation on the reading speed of participants have been done based on the number of character parsed per second. Fig. 2 then shows the average character reading speed of participants on stimuli 5 and 6 were 64.19 and 82.51 characters per second. While the average character reading speed of participants on stimuli 7 and 8 were 92.64 and 74.06 characters per second. Hence, results suggest that increased number of misplaced words does not directly indicate an increased character reading time. In addition, Fig. 3 shows that average rate of gazing at the misplaced words was less than 5%. Therefore, average total contact time on the regions of interest was very small. As the participants were asked to read stimulus quickly, results suggest the majority of them did not necessarily notice the misplaced words.

5.3 The variation of the emotional index

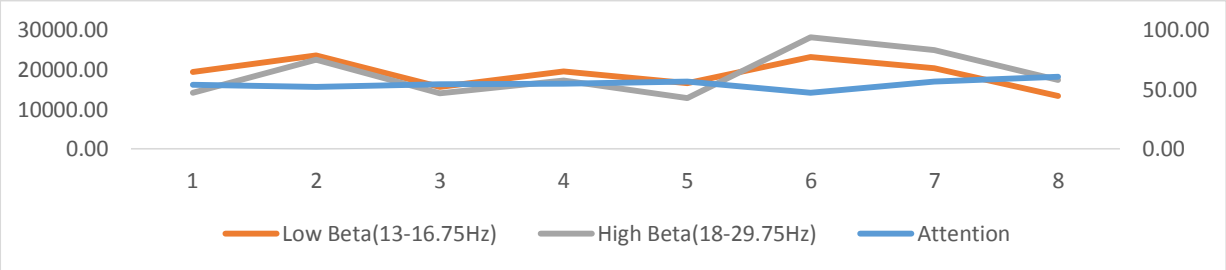


Figure 4. The variation of the Attention

Neurosky Mindwave Mobile records the changes of emotions the participants are experiencing during an experiment. Recordings include data on participant attention and meditation levels(Crowley, Sliney, Pitt, & Murphy, 2010). These factors have been included to be a third point of interest in our research question. Fig. 4 shows that the average attention level was generally the same whether there were misplaced words in the stimulus or not. To look at the results more closely, an analysis and comparison of the attention levels of each participant are presented in the following graphs.

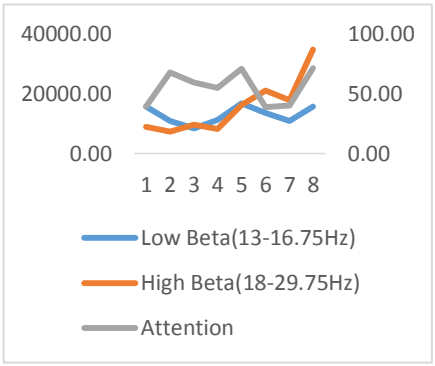


Figure5. Average change of the attention level of the participant No.1

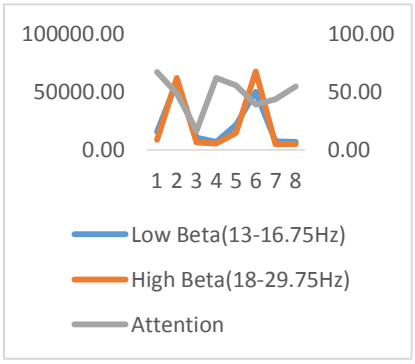


Figure 6. Average change of the attention level of the participant No.2

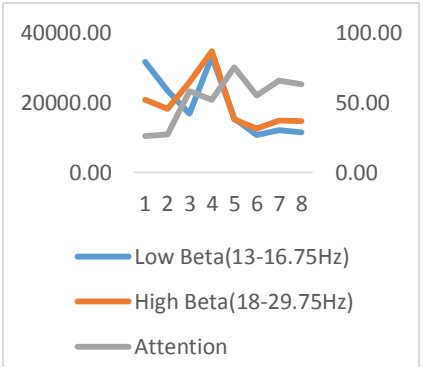
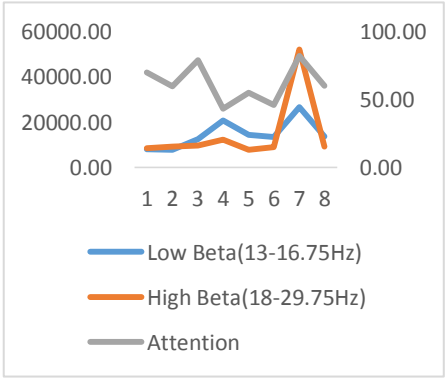


Figure 7. Average change of the attention level of the participant No.3



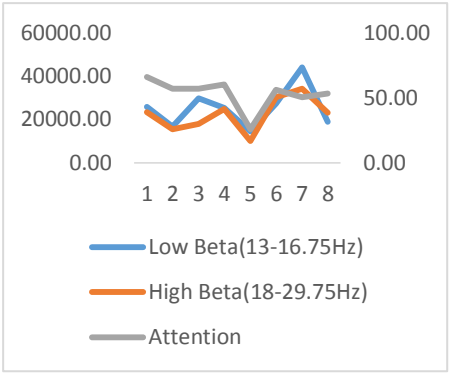


Figure 8. Average change of the attention level of the participant No.4

Figure 9. Average change of the attention level of the participant No.5

Although Fig. 5 to Fig. 9 show that to some participants that gazed at the stimuli with misplaced words have average attention levels found to be higher than on a stimulus with no misplaced words, one participant that also gazed at misplaced words showed no increase in attention levels (Fig. 7). EEG data analysis yielded mixed results since some participants gazed at misplaced words had high attention levels and some did not show an increase in their attention levels. As this is a pilot study, the sample size was limited. Therefore, findings may not generally apply to all population.

6. Conclusion and Future Work

Reading comprehension assessments result suggests that misplaced words in a stimulus do not necessarily contribute to difficulty in understanding the content. Analysis of data from this study is different from the findings of Qian that there is a significant difference in understanding transposed and not transposed sentences (Qian et al., 2010). We suspect that this can be attributed to the different backgrounds of participants and the materials used. This difference in results is another interesting point of study for a future research. Furthermore, as this is also a pilot study, the sample size might not be enough to find a difference in the analysis of electroencephalography data among students that noticed the misplace words and those who did not. The researchers plan to conduct a formal study with a bigger population to investigate further the findings of this pilot study.

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