



## Processing Academic Science Reading Texts through Context Effects: Evidence from Eye Movements

Soh Or-Kan

School of Language Studies & Linguistics, Universiti Kebangsaan Malaysia, MALAYSIA

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### ABSTRACT

This study aimed at examining context effects of processing science terminology in Chinese during the reading process. The science texts were first chosen, and then they were replaced by science terminology with familiar words; other common words remained in both texts. The results implied that readers spent longer rereading durations and total fixation durations for the same common words in science texts than for corresponding texts. Readers performed shorter gaze durations for replaced words than the science terminology. However, the first fixation durations for the two-word types did not show significant differences from each other. Besides, readers sought for more contextual information to aid their comprehension. The adult readers seemed to successfully process the meanings of each Chinese characters but they failed to access the meanings of science terminology at the initial processing stage. With the assistance of contextual information, the adult readers were able to comprehend the unfamiliar words. Instruction for teaching science in school was suggested to improve the learning processes.

**Keywords:** classroom instruction, academic science reading texts context effects, eye movements, science terminology, context effects

### INTRODUCTION

Adult readers commonly learn new words using contextual information to infer the meanings of certain vocabulary (Carlisle, Fleming, & Gudbrandsen, 2000; Jian, Chen & Ko, 2013; Landauer & Dumais, 1997, Nagy, Anderson, & Herman, 1987; Soh, 2016). Stanovich's (1980) interactive-compensatory model has been used to explain context effects. Readers are not conformed to the conventional reading process such as the bottom-up or the top-down model. Contextual effect is defined as the interaction between readers as well as the passage (Nagy et al., 1987). Also, the passage gives clues for readers to decipher and infer its contextual meanings (Soh, 2016). Therefore, readers can process the contextual information not in sequential stages even though it is based on its features, orthographic knowledge, semantics, syntax and vocabulary. Most empirical studies employed interactive-compensatory model to examine context effects and their measures between readers' reaction times and their

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**Correspondence:** Soh Or-Kan, *School of Language Studies & Linguistics, Universiti Kebangsaan Malaysia, Malaysia.*

✉ [roy57803@gmail.com](mailto:roy57803@gmail.com)

### **State of the literature**

- Previous studies used different contextual information such as relevant, irrelevant and neutral for the target words in naming tasks. Readers from both adults and children used context effects to comprehend the texts.
- This study adopted Chaffin et al.'s (2001) model to examine how readers used contextual information to process different target words.
- Science texts were used as the reading materials and these reading texts had given the opportunities to the readers to decide which section of the text was used to seek for necessary contextual information to comprehend the science terminology and replaced words in both types of texts.

### **Contribution of this paper to the literature**

- This study showed a contradicted verdict compared to the past studies: Participants with least background knowledge tried to set up contextual information to help them to infer the unfamiliar science terminology during the late integrations of academic reading stage.
- Surprising, the participants' first fixation and gaze durations were longer in science texts than corresponding texts. This was the evident indicators for participants aware of using contextual information to interpret the difficult science terminology during the initial and late processing.
- The semantic and syntactic processing of sentences and texts appeared to be similar regardless of the orthographic and logographic processing.

recognition of word. The results implied that adult readers consistently spent more processing time for contextual information that facilitated semantic prediction (e.g. Carlisle et al., 2000; Kim & Goetz, 1994; Nagy et al., 1987; Schwantes, 1982; Stanovich, 1980, 1984; Stanovich, West & Feeman, 1981; West, Stanovich, Feeman & Cunningham, 1983).

The past empirical research also associated the relationships between contextual information and decoding skills with the interactive-compensatory model (Kim & Goetz, 1994; Schwantes, 1982; Stanovich, 1980, 1984; Stanovich et al., 1981; West et al., 1983). Readers with low reading ability tended to perform poor decoding ability and they relied mostly on contextual information. Readers with high reading ability, on the other hand, tended to perform good decoding ability as they are able to process the reading texts effectively. Younger readers exhibited bigger context effects than older reader as the vocabulary storage for the latter was limited (Kim & Goetz, 1994; Perfetti, Goldman, & Hogaboam, 1979; Stanovich et al., 1981). Young readers also displayed genuine interest in learning science texts based on the contexts (Baram-Tsabari, Sethi, Bry & Yarden, 2010).

Even though considerable research studies were carried out to examine context effect, majority of these studies focused on the relationships between the context effect and the word recognition. Most research was carried out to examine the process of context effects in learning new words through reading academic texts (Brusnighan & Folk, 2012). In this study, the research focused on how readers process or learn new academic words using contextual information.

## LITERATURE REVIEW

**Eyetracking Research in Context Effects**

Eyetracking has been used to examine the process of reading for more than 20 years. Rayner agreed that during a complex information processing task such as reading, eye movements and attention are linked (Rayner, 1998). Lai, Tsai, Yang, Hsu, Liu, Lee, Lee et al. (2013) also reviewed eye-tracking studies related to learning and pointed out several research trends of increasing interest. These include re-examining existing learning theories and investigating effects of instructional design and students' information processing strategies on learning. In science and mathematics domains, several studies have used eye-movement data to understand the interactions between cognitive processes and learning outcomes (Canham & Hegarty, 2010; Jarodzka, Scheiter, Gerjets & van Gog, 2010; She & Chen, 2009; Tsai, Hou, Lai, Liu & Yang, 2012).

Recently, eyetracking has been employed to investigate the how context effects assist the readers to process the familiar and unfamiliar words (e.g. Brusnighan & Folk, 2012; Chaffin, Morris & Seely, 2001). Chaffin et al. (2001) conducted a study using eyetracking to investigate how undergraduates constructed the contextual meanings using novel, high- and low-frequency of words in one sentence. These undergraduates spent longer reading time on the low-frequency words and this phenomenon suggested that they inferred new words based on the contextual information. The researchers further implied that these undergraduate spent more reading durations on informative contexts. It indicated that the readers had the ability to differentiate informative and uninformative contexts which helped them to comprehend the meanings of the target words.

However, Brusnighan and Folk (2012) designed different contextual information by adding in morphemes into the reading materials. Each sentence frame consisted of 2 sentences where common English compound words that showed either semantic transparency or opacity in the informative and neutral contexts was presented: (a) The function of Sentence A was to show differences of meanings of the target words; and (b) The function of Sentence B was to show the synonym of the target words. After that, the eye movements of the readers for the target words were analyzed. Readers as usual used up more reading duration in the informative contexts where the target words acted as a facilitator to assist readers to comprehend the texts. The outcomes implied that the readers were affected by the semantic transparency in an informative context and this processing time for familiar compound words facilitated word recognition. The results indicated that the reading durations were not affected by the synonymous anaphors presented in Sentence B, under either the informative or the neutral contexts. This implied that they had deduced the meanings of the target words when processing Sentence A prior to putting in additional cognitive resources to further deduce the meaning of the target words in Sentence B.

The aforementioned findings confirmed that the context effect was strongly associated with the process of the word recognition. All these previous studies were done on the English word recognition. It is still unclear that these studies could be generalized to a different Chinese writing system.

### **Characteristics of Chinese Writing Systems**

Hoosain (1992) claimed that the alphabet English words and the logographic Chinese words were different in terms of their space utilization, written units and structures. Most Chinese characters carry their own morphemes and form their independent meanings. Chinese words are be combined with more than one morphemes to form compound words (Packard, 2000; Ramsey, 1987) and adult readers are normally able to infer the meanings of the word easily.

In academic reading such as science texts, many of the words carry domain specific meanings and they are composed of one to many characters without boundaries between them. Thus, the process of comprehending Chinese texts is complex because it involves segmenting words which delineate sentences. If the readers are not familiar with the Chinese text, they encounter difficulty to segment the words in the beginning. Shen and her researchers (2012) have clearly stated that the Chinese character must be first segmented before the reader is able to identify the lexical constructions. Unlike alphabetic reading, the information is provided in the texts because spaces in the texts show the location of readers' eye movements as word recognition proceeds (Rayner, 1998; Rayner & Pollatsek, 1981).

In order to resolve the problems on Chinese characters which provide no word spacing information for vocabulary identification, the readers are required to have basic proficiency of Chinese reading background knowledge such as the ways to complete the segmentation of words before the words are being processed and the ability to locate Chinese words. This theory was supported by past studies that adult readers had the preference to view the Chinese characters through locations even though they are not able to familiarise with the Chinese academic terminology (e.g. Chen & Ko, 2011; Jian & Ko, 2012; Li, Rayner, & Cave, 2009; Yan, Kliegl, Richer, Nuthmann & Shu, 2010).

Based on the observation in Jian and Ko's (2012) research, readers spent longer processing and rereading durations for common words stringed with academic science terminology in science texts. In theory, readers have to reread the reading texts because they encounter difficulties when reading the texts (Inhoff & Wu, 2005; Rayner, 1998; Rayner & Juhasz, 2004). This peculiar situation occurred because the readers might be too focused to look for contextual information to understand the unfamiliar physics words and this had resulted they spent longer time rereading these common words.

## **Eyetracking Research in Reading Science Texts**

The use of the eye tracking method to explore learners' cognitive processes in the domain of science education is a new research approach. There have been some studies dealing with science problem-solving and learning with multimedia presentation (e.g. Hegarty & Just, 1993; Yang, Chang, Chien, Chien & Tseng, 2013). Hyona and colleagues (2002, 2003 & 2006) had systematically documented the significance and usefulness of eye fixation patterns to understand the complexity of science texts. In one of their studies, they examined the reading strategies used by adult readers when reading a multiple-topic science text. They significantly found out that fast linear readers did not make return fixations on the previous texts but slow linear readers made many re-inspections before moving on as well as many forward fixations. Nonselective readers made many look-backs to previous sentences. They also concluded that there were three types of readers who read science texts: (a) fast linear readers; (b) slow linear readers and (c) topic structure processors. Correlations between eye-movement measures and verbal reports indicated the participants' awareness of reading speed, as well as a fair awareness of their look-back and rereading behaviour.

Tai, Loehr and Brigham (2006) also carried a study on utilizing the eye-tracking technique to explore what students with different subject backgrounds (chemistry, biology and physics) looked at while solving the standardized science examination problems. They found out that the expert spent fewer eye fixations and saccades to process information in specific zones than the novices (e.g. problem statement zone, graph or image zone, multiple choices zone, abrupt, rapid eye-gaze movement between different positions).

In one of the previous studies (Mason, Pluchino, Tornatora, & Ariasi, 2013), eleventh graders' visual behavior during reading was monitored in three reading conditions: text only, text with a concrete illustration, and text with an abstract illustration in a pretest, immediate, and delayed posttest design. Eye-fixation data revealed that the abstract illustration promoted more efficient processing of the text. Analyses of the gaze shifts between the two types of external representation indicated that the readers of the text with the abstract illustration made a greater effort to integrate verbal and pictorial information.

Recently, pilot studies have attempted to use eye-tracking technology to explore students' computer game in science learning experience (Alkan & Cagiltay, 2007), examine the multimedia effects on science learning (She & Chen, 2009), re-examine multimedia learning theories or enhance multimedia learning (van Gog & Scheiter, 2010) and discuss its unique contributions in the study of multimedia science learning (Hyona, 2010; Mayer, 2010).

From the aforementioned studies, the research on the context effect associated with the process of word recognition is little known. Hence, this present study aimed at investigating how the context effect influences students' reading processes in different kinds of scientific texts.

## RESEARCH METHODOLOGY

### **The study**

Previous studies used different contextual information such as relevant, irrelevant and neutral for the target words in naming tasks (e.g. Kim & Goetz, 1994; Schwantes, 1982; Stanovich et al., 1981; West et al., 1983). This study adopted Chaffin et al.'s (2001) model to examine how readers used contextual information to process different target words. In this study, science texts were used as the reading materials and these reading texts had given the opportunities to the readers to decide which section of the text was used to seek for necessary contextual information to comprehend the science terminology and replaced words available in the science and corresponding texts. The previous studies showed that readers from both adults and children used context effects to comprehend the texts during their reading (Perfetti et al., 1979; Stanovich, & West, 1981). In this study, undergraduates were expected to show greater context effect with unfamiliar words (science terminology) than with familiar words (replaced words). They were also expected to learn new words based on the contextual information.

### **Participants**

Eighty native Chinese speakers from a Malaysian public university voluntarily took part in this eyetracking experiment. They had either normal or corrected-to-normal vision. They had more than twenty years of speaking mandarin. They were from the Faculty of Business Management. All of them reported that they had no habit of reading science materials. Therefore, they had no background knowledge of sciences. The age range of participants was from 21 to 23 years old. Female participants comprised 60.7% and male participants were 39.3%. Before the experiment, the participants were requested to sit for a Reading Comprehension Screening Test (Ko & Chan, 2006). The objective of the test was to evaluate the students' proficiency levels for English Language. It yielded a Cronbach's internal reliability coefficient of .90. Students who passed this test exhibited a basic English reading ability.

### **Designs of Reading Materials**

Six texts were originally taken and shortened to meet the requirements of text readability. The National Geographic magazines (English and Chinese versions) were chosen as the main sources of the identical texts. These magazines were chosen because students needed no prior knowledge to understand the texts. The texts were also updated and novel. Each text comprised the same context and ranged from 400-450 characters in length. The science terminology and the replaced words were deemed as the target words in the texts. Replaced words were used in the correspondence texts and they had familiar words closed with the contexts of science texts. The theme chosen for the corresponding texts consisted of global warming, pollution and information technology.

The designs of both science and corresponding texts contained 50 instances of academic science terminology and 50 instances of replaced words. In addition, these six science texts and six corresponding texts were labelled A1-A5 and B1-B5 respectively. Both kinds of texts had the same length of 400 common words and they were arranged in a randomised order. Therefore, each participant read three (3) different types of texts - science texts and corresponding texts. A science professor was invited to identify the academic science terminology within these texts. This professor is also an expert in Chinese language. After that, the translations were sent to a Chinese expert for verifications.

Chinese Latent Semantic analysis (Chen, Wang & Ko, 2009) was employed to evaluate the readability of both types of texts. It was an objective method to analyse and confirm the readability of different genres (Jian, Chen & Ko, 2013). In this study, the suitability of vocabulary used and coherence of sentence structures were the two criteria applied to all texts. The result ( $p > .11$ ) exhibited no significant difference. We could conclude that the environmental texts and correspondence texts had the readability value.

### **Research Procedures**

Tobii X120 non-intrusive eyetracker with 120 Hz sample rate was employed in this study because it allowed participants for slight head movements, minimize participants' tiredness of eyes and detect participants' eye movements from a word to a word or a word to a character. Lai and Chen's (2012) eyetracking research set-up was in position to collect data. The display screen of a computer was placed 65cms at distance from the participants. This seating position resulted in a visual stimulus over 24 x 18 degree of visual angle. The reading texts were shown on a 19" LED monitor. The entire text was visible on the screen and the participants did not have to scroll the page. The English texts were designed using Times New Roman, 20 points font. However, the size of the Chinese words on screen was 23 x 23 pixels.

Before the actual experiment, all the participants attended a briefing session. First, all the participants went through 2 trial experiments. The participants were able to familiarize with the eyetracking research procedures. The trials were similar to the real experiment. After that, the participant was called individually into the experiment room and underwent a standard 9-point calibration process. The participant could pace their reading time. Yes-no comprehension questions were designed to ensure their attention to the texts. Once the science materials were compiled, the researcher discussed them with several science experts for the design of the comprehension questions and they were also invited to review them. Taking into account these expert opinions, the comprehension questions were revised and compiled into formal experimental materials. Participants took about 20 to 30 minutes to complete the experiment. An example of the yes-no comprehension question in [Figure 1](#).

In even the bleakest climate change scenarios for the end of this century but a new study published Monday snuffs out such hope, projecting temperatures that rise lockstep with carbon emissions until the last drops of oil and lumps of coal are used up. Global temperatures will increase on average by 8 degrees Celsius (14.4 degrees F) over preindustrial levels by 2300 if all of Earth's fossil fuel resources are burned, adding five trillion metric tons of carbon to the atmosphere, according to the research by Canadian scientists published in *Nature Climate Change*. In the Arctic, average temperatures would rise by 17 degrees C (30.6 degrees F). If these temperatures do become reality, greenhouse gases would transform Earth into a place where food is scarce, parts of the world are uninhabitable for humans, and many species of animals and plants are wiped out, experts say. It also would heat the world to a level approaching that of the early Eocene period, 52 million to 56 million years ago, when palm trees grew as far north as Alaska and crocodiles swam in the Arctic. Mammals survived Eocene temperatures; this is when early primates appeared. Polar melt would commit the Earth to sea-level rise that would mean upheaval for coastal populations, which make up more than 40 percent of humanity. Not only could tropical rain forest systems collapse, but drought in southern Europe and the United States would be completely catastrophic for agriculture. Wealthy nations might maintain food supply, but not places like southern Africa. A lot of people would have to leave, or a lot of people would die.

**The climate change will lead to the short of food and the extinction of animals.**

Yes

No

**Figure 1.** Yes-no Comprehension Question from Science Text

## RESULTS

The study employed a two-way mixed research: 2 (science vs corresponding texts) x 2 (science terminology vs replaced words). ANOVA was applied to the eye-movement variables. The results were computed by two analyses: (1) Global and (2) Local. Global analyses were used to indicate the association between overall reading difficulty levels and the texts (Li, Liu & Rayner, 2011; Shen et al., 2012). In this study, science texts and corresponding texts were used to examine the eye-movement indices such as the (1) total reading time spent on a reading text; (2) average saccade length between two successive fixations when reading texts; (3) average number of regressive saccades of the total regressive saccades for a text and; (3) average fixation duration of all the fixation counts for a text were reported in **Table 1**.

Local analyses, on the other hand, were conducted to measure the initial and late processing durations for science terminology and replaced words. Local analyses were used to reflect the process of examining how participants read a specified target word. In addition,

**Table 1.** Global Eye Movement Analyses for Participants' Reading on Science and Corresponding Texts

Eye-movement Variables	Science Texts M (SD)	Corresponding Texts M (SD)
Average Total Reading Time (s)	78.20 (30.08)	49.89 (29.07)
Average Saccade Length (ms)	4.66 (0.90)	4.97 (1.05)
Average Number of Regressive Saccades (ms)	89.17 (37.87)	57.76 (25.70)
Average Fixation Duration (ms)	227.80 (20.09)	230.50 (19.80)

**Table 2.** Comparisons of Participants' Eye Movements while Reading Science Terminology and Replaced Words

Eye-Movement Variables (ms)	Science Terminology M (SD)	Replaced Words M (SD)
First Fixation Durations	244.78 (35.47)	242.67 (35.01)
Gaze Durations	304.78 (67.05)	298.78 (56.89)
Rereading Time	625.45 (284.76)	344.78 (254.15)
Total Fixation Durations	978.65 (313.24)	617.68 (235.56)

**Table 3.** Comparisons of Participants' Eye Movements while Reading the Common Words in Science and Corresponding Texts

Eye-Movement Variables (ms)	Science Terminology M (SD)	Replaced Words M (SD)
First Fixation Durations	225.78 (22.66)	217.89 (23.56)
Gaze Durations	249.80 (36.78)	237.67 (32.55)
Rereading Time	280.67 (118.34)	187.23 (85.47)
Total Fixation Durations	534.62 (133.24)	432.22 (125.21)

temporal perspective was employed to differentiate the reading process from initial to late stages (Chaffin et al., 2001; Jian & Ko, 2012, Shen et al., 2012; William & Morris, 2004). In local analyses, the eye movement indices were inclusive of the (1) first fixation duration was the duration participants first fixate the word (Rayner, 1998); (2) gaze duration was the duration used to decode the word meanings (Brusnighan & Folk, 2012; Jian & Ko, 2012); (3) rereading duration was the duration used on all fixations; and (4) total fixation time was the duration used to process a word. **Table 2** and **Table 3** showed the results of local analyses.

### Global Analyses

A t-test was conducted to analyze the eye-movement indices and determine if participants ( $t_1$ ) and items ( $t_2$ ) for all the indices exhibited significant differences. **Table 1** showed the participants' reading behaviours for science and corresponding texts from the global perspectives. Apparently, the result showed longer average total reading durations for the science texts than for the corresponding texts:  $t_1$  (80) = 11.41,  $p < .001$ , Cohen's  $d = 1.33$ ;  $t_2$  (20) = 5.40,  $p = .002$ , Cohen's  $d = 3.44$ . Average saccade length was shorter for science texts compared with the corresponding texts:  $t_1$  (80) = -5.13,  $p < .001$ , Cohen's  $d = -0.35$ ;  $t_2$  (20) = -3.29,  $p = .57$ , Cohen's  $d = -2.30$ . Average number of regressive saccades showed greater

significance for science texts than for the corresponding texts:  $t_1(80) = 8.56$ ,  $p < .001$ , Cohen's  $d = 0.99$ ;  $t_2(20) = 6.90$ ,  $p = .005$ , Cohen's  $d = 1.10$ . Finally, average fixation duration was longer for science texts than for corresponding texts:  $t_1(80) = 9.25$ ,  $p < .001$ , Cohen's  $d = 0.39$ ;  $t_2(20) = 2.50$ ,  $p = .008$ , Cohen's  $d = 2.01$ .

These results obviously showed that the science texts were more difficult for participants. They spent about 30 seconds in total reading time on science texts compared to corresponding texts where the participants spent only 29.07. These longer and shorter reading times for both texts signified two circumstances. First, the participants spent more time to process the science terminology. Second, the participant also spent quite some time on the common words. Undeniably, participants tended to incline to common words when they further processed the texts. To examine the relevancy of this speculation, local measurements were carried out to compare academic science terminology verses the replaced words and the common words for both types of texts.

### Local Analyses

In local analyses, the variables such as science terminology, the replaced words and the common words for both types of texts in the initial and late processing times were further assessed. The measures used in the initial process contained first fixation durations and gaze durations. The late processing time comprised reading time, and total fixation time. The eye movement variables showed the reanalysis of the target words. It was because of the insufficient integration of relevant information and the short of comprehension ability to the target words.

#### *Initial Processing Durations*

**Table 2** indicated the participants' first fixation durations showed no significant differences between the science terminology and the replaced words,  $ps > .04$  but the gaze durations were longer for the science terminology than for the replaced words:  $t_1(80) = 3.43$ ,  $p < .001$ , Cohen's  $d = 0.64$ ;  $t_2(20) = 1.56$ ,  $p = .014$ , Cohen's  $d = 0.59$ .

#### *Late Processing Durations*

**Table 2** reflected that participants had longer rereading time for the science terminology than for the replaced words:  $t_1(80) = 6.69$ ,  $p < .001$ , Cohen's  $d = 2.19$ ;  $t_2(20) = 3.40$ ,  $p < .001$ , Cohen's  $d = 0.97$ . They had also exhibited longer total fixation durations:  $t_1(80) = 7.10$ ,  $p < .001$ , Cohen's  $d = 2.16$ ;  $t_2(20) = 3.30$ ,  $p < .001$ , Cohen's  $d = 0.93$ .

An additional analysis based on Academia Sinica Taiwan (1997) was conducted to verify (1) first fixation durations or gaze durations and (2) frequency of characters for the two-word types (science terminology versus replaced words) and they were considered an analysis unit. They showed no significant differences ( $ps > .05$ ) as the adult readers were able to decode the individual characters that had unfamiliar science terminology. Besides, the frequency of characters did not differ significantly ( $ps > .05$ ) because of the participants' capability of

**Table 4.** Percentage for Fixations

Locations	Science Texts M (SD)	Corresponding Texts M (SD)
<b>Initial Processing Stage</b>		
Current Sentences	78 (19)	2 (3)
Preceding Sentences	6 (5)	7 (6)
Following Sentences	16 (14)	14 (9)
Other Sentences	6 (6)	9 (9)
<b>Late Processing Stage</b>		
Current Sentences	75 (13)	72 (11)
Preceding Sentences	6 (3)	5 (7)
Following Sentences	17 (9)	15 (10)
Other Sentences	11 (7)	6 (4)

identifying individual characters within familiar characters in the replaced words and unfamiliar science terminology.

### Comparison of Participants' Eye Movements for Common Words While Reading Science and Corresponding Texts

#### *Initial Processing Duration*

**Table 3** exhibited longer first fixation durations for the common words in science texts than for the corresponding texts:  $t_1(80) = 3.71, p < .001, \text{Cohen's } d = 0.34$ ;  $t_2(20) = 5.26, p < .001, \text{Cohen's } d = 0.26$ . Participants had longer gaze durations:  $t_1(80) = 5.25, p < .001, \text{Cohen's } d = 0.36$ ;  $t_2(20) = 6.78, p < .001, \text{Cohen's } d = 0.33$ . However, the values between .24 to .26 suggested that the effect sizes were very small.

#### *Late Processing Durations*

**Table 3** showed longer rereading time for the common words in science texts than for the corresponding texts:  $t_1(80) = 8.25, p < .001, \text{Cohen's } d = 1.17$ ;  $t_2(20) = 9.37, p < .001, \text{Cohen's } d = 0.66$ . They had longer total fixation durations:  $t_1(80) = 8.25, p < .001, \text{Cohen's } d = 1.05$ ;  $t_2(20) = 9.02, p < .001, \text{Cohen's } d = 0.62$ .

### Fixation Duration for Contextual Information

**Table 4** the process of participants sought for context effects during reading the texts especially when they encountered science terminology, the percentage of the initial first and second science terminology fixations was calculated. In order to set the baseline comparison, 6 sentence locations with target words (science or replaced words) such as (1) the current sentences, (2) the preceding sentences (3) the following sentences, (4) other sentences were identified to analyze the fixation durations across the locations of the corresponding texts.

In the initial processing stage, the results showed a main contextualized effect of sentence locations:  $F(5, 180) = 701.13$ ,  $p < .001$ ,  $\eta^2 = .93$ . The results indicated that the participants located the fixations on the current sentences which contained the target words rather than the other sentences. The main effects of word types as well as the interaction of effect of sentence locations and word types showed no significant differences:  $ps > .10$ .

In the late processing stage (see [Table 4](#)), the percentage of second fixations on the re-encountered science terminology or replaced words was calculated to examine how the contextual information was used to comprehend the target words better when reading the texts. The results also indicated a main contextualized effect of sentence locations:  $F(5, 180) = 910.89$ ,  $p < .001$ ,  $\eta^2 = 0.91$ . The outcomes implied that the participants preferred to locate their fixations on the current sentences which contained the target words rather than the other sentences. The main effects of word types as well as the interaction of effect of sentence locations and word types showed no significant differences:  $ps > .10$ .

From the initial and late processing results, we were able to obviously conclude that the processing for science terminology and replaced words were not equal. As mentioned previously, participants used additional rereading durations on science terminology than on replaced words. An additional calculation on the rereading times for science terminology or replaced words needed in the process of comprehending the texts was implemented. The results clearly showed that 80% of the science terminology had to be read repeatedly and it outnumbered the replaced words, of which approximately 71%:  $\chi^2(1, N=80) = 52.45$ ,  $p < .001$ . In addition, each science terminology was reread on an average of 2.45 times but the replaced words were reread on an average of 1.37 times:  $t(8) = 7.13$ ,  $p < .001$ , Cohen's  $d = 1.34$ .

## DISCUSSIONS

The present study aimed at employing the eye-tracking technology to investigate the context effect for students from a private university when processing academic words which comprised the science terminology and replaced words. Past studies (e.g. Carlisle et al., 2000; Nagy et al., 1987; Perfetti & Lesgold, 1977; Rahman & Bisanz, 1986; Stanovich, 1980, 1984; Stanovich et al., 1981) on context effect mainly focused on two areas: (1) re-action durations to reflect the context effects and (2) results of the context effect. This study focused on the process of context effect when reading academic texts. The discussions were based on reading theory and empirical research in the literature.

From the data, the rereading time was longer and the average mean of saccade length was shorter indicated that the participants spent more time on unfamiliar science terminology and also the common words in science texts. Besides, the gaze durations were longer for science terminology than for replaced words. From the temporal perspective, participations indicated that they needed more time to decode the whole science terminology during their initial reading stage. Surprisingly, the participants' first fixation and gaze durations were longer in science texts than corresponding texts. This was the evident indicator for participants

who were aware of using contextual information to interpret the difficult science terminology during the two stages (initial and late processing).

Past studies (Chaffin et al., 2001; Garrod, O'Brien, Morris & Rayner, 1990) had clearly explained that adult readers tended to generate elaborative inference from known words to assist them to understand the science terminology. This study showed a contradicted verdict compared to the past studies but it was quite similar with the results shown in Jian and Ko's (2012) study. The same familiar words were reread by participants. Thus, they spent more rereading durations on the science texts than on the corresponding texts. Participants with least background knowledge tried to set up contextual information to help them to infer the unfamiliar science terminology during the late integrations of academic reading stage.

The participants showed 220-250 ms in their first fixation durations regardless of the science terminology or common words in the science texts and this result showed no significant results for the first fixation durations between the science and replaced words in this study. This finding was consistent with the results in the past studies on Chinese reading (Chen & Ko, 2011; Jian & Ko, 2012; Li et al., 2011; Yan et al., 2010) because (a) the participants might not face difficulty to recognize each component character of either the science or replaced words:  $p > .10$  and (b) the participants with high and low science knowledge indicated no differences when reading unfamiliar science terminology: 220-250ms.

Besides, participants used contextual information to process the science terminology by repeating the reading process for both science and common words. Participants would first fixate the science terminology within the current sentences and then the next sentences for more contextual information. Their eye movements from the current sentences to the previous sentences were relatively lesser for both types of academic reading texts. However, their processing durations for the present sentences were different because they had to read the science terminology repeatedly and the percentage of reading for each science words was higher than the replaced words. This data conformed to Chaffin et al. (2001)'s study. In their research, the participants spent longer time for informative contexts and lesser time for uninformative contexts. In order to process the words which had the direct connection to the contextual information, the participants had spent more time on the current sentences. After that, the participants turned to the subsequent sentences, previous sentences or other locations for more information. In this study, the reason for the participants not to return to the previous sentences after reading the first sentence was because they might have learnt the contents from the previous sentences and discovered that they could understand the texts. Hence, the results in [Table 4](#) implied that their eyes moved to the subsequent sentences and it was supported by the percentage increased for fixations on other sentences than the previous sentences.

This study responded to the reading theory of the interactive compensatory model (Stanovich, 1980). In this model, participants used the top-down information to compensate for the process of unfamiliar words. Therefore, participants had to depend on contextual

information to compensate for the least of background knowledge required to process the unfamiliar academic terminology.

In conclusion, this study explained the processes of reading academic terminology among adult readers. Participants seemed to be successfully decode the character's meanings from the science texts but they failed to understand the meanings of the science terminology. As the participants continued with their readings, they sought assistance from the familiar words surrounding the science terminology to comprehend the unfamiliar words. It was because the semantic and syntactic processing of sentences and texts appeared to be similar regardless of the orthographic and logographic processing.

### **Implications for Science Teaching**

In teaching science texts, teachers have to be aware of students' needs – to understand the science terminology. Thus, teachers are encouraged to teach the science terminology and the texts in isolation. When students familiarize with the terminology, they have the interest in learning science (Baram-Tsabari et al., 2010). In addition, teachers have to implement repeated reading protocols as one of the classroom interventions. Students have to practise rereading the same science texts aloud after school hours. This practice aims at establishing the students' background knowledge for difficult texts later. After they have mastered the rereading skills, they are able to comprehend higher-level of reading texts. This implication is in line with the research done by Foster, Ardoin, Binder (2013). The researchers examined the contextual information and science texts, aligning the protocol with typical classroom implementation of this protocol, by having learners reread the same passage multiple times in the same session. They inferred information during their re-reading durations. They showed improved fluency on the second and third rereading reflecting reduced word processing demands and by reducing their need to reconsider previously reading content, thereby potentially impacting higher-level comprehension processes. In addition, many studies have suggested that scientists use different representations not only to promote student understanding of scientific phenomena but also to share and teach science knowledge in classrooms (Kozma 2003; Schnotz & Kulhavy 1994; van Sommeren et al. 1998). Employing different representations of the same concept can enhance students' thinking processes in their acquisition of science knowledge. Representations help students consolidate abstract concepts: representations can display multiple relationships and processes that are difficult to describe with text alone (Patrick et al. 2005). Science teachers are able to use different text representations when teaching texts because different text representations enable students to learn science interestingly.

### **Limitations & Future Studies**

The positions of target words in science were not controlled consistently within a single sentence. Some of them were dispersed across several sentences. Rayner and Duffy (1986) had explained that this situation could lead to a spillover effect as the low-frequency science

terminologies were closely located in one sentence and they prolonged their gaze durations on the present word and the word that follows.

The target words in science were not consistently controlled because (a) academic texts was standard, the change of word positions might distort the structure, syntactic and reduce the readability and fluency of the texts and (b) both of the text structures were the same and if the position effect happened, it would affect the science terminology and the replaced words. Hence, this study showed no systematic bias in analyzing the eye movement data.

Researchers might apply eye-tracking techniques to explore the relationships between contextual effect and its instruction in science classes in the future. In addition, they might explore the cognitive process of online learning and the effect of contextual effect. They could apply the research to other languages to show the cognitive differences when they process contextual effect.

## REFERENCES

- Alkan, S., & Cagiltay, K. (2007). Studying computer game learning experience through eye tracking. *British Journal of Educational Technology*, 38(3), 538-542.
- Baram-Tsabari, A., Sethi, R. J., Bry, L., & Yarden, A. (2010). Identifying Students' Interests in Biology Using a Decade of Self-Generated Questions. *Eurasia Journal of Mathematics, Science and Technology Education*, 6(1), 63-75.
- Bruningham, S. M., & Folk, J. R. (2012). Combining contextual and morphemic cue is beneficial during incidental vocabulary acquisition: Semantic transparency in novel compound word processing. *Reading Research Quarterly*, doi:10.1002/RRQ.015
- Canham, M., & Hegarty, M. (2010). Effects of knowledge and display design on comprehension of complex graphics. *Learning and Instruction*, 20, 155-166.
- Carlisle, J. F., Fleming, J. E., & Gudbrandsen, B. (2000). Incidental word learning in science classes. *Contemporary Educational Psychology*, 25(2), 184-211.
- Chaffin, R., Morris, R. K., & Seely, R. E. (2001). Learning new word meanings from context: a study of eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 27(1), 225.
- Chen, M., & Ko, H. (2011). Exploring the eye-movement patterns as Chinese children read texts: a developmental perspective. *Journal of Research in Reading*, 34(2), 232-246.
- Chen, M. L., Wang, H. C., & Ko, H. W. (2009). The construction and validation of Chinese 28 Semantic Space by using Latent Semantic Analysis. *Journal of Chinese Psychology*, 51(4), 415-435.
- Foster, T. E., Ardoin, S. P., & Binder, K. S. (2013). Underlying changes in repeated reading: An eye movement study. *School Psychology Review*, 42(2), 140.
- Garrod, S., O'Brien, E. J., Morris, R. K., & Rayner, K. (1990). Elaborative inferencing as an active or passive process. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16(2), 250.
- Hegarty, M. & Just, M. A. (1993). Constructing mental models of machines from text and diagrams. *Journal of memory and language*, 32(6), 717-742.
- Hoosain, R. (1992). Psychological reality of the word in Chinese. *Advances in psychology*, 90, 111-130.
- Hyönä, J. (2010). The use of eye movements in the study of multimedia learning. *Learning and Instruction*, 20(2), 172-176.

- Hyönä, J., Lorch Jr, R. F., & Kaakinen, J. K. (2002). Individual differences in reading to summarize expository text: Evidence from eye fixation patterns. *Journal of Educational Psychology, 94*(1), 44.
- Hyönä, J., Lorch, R. F., & Rinck, M. (2003). Eye movement measures to study global text processing. In J. Hyönä, R. Radach, & H. Deubel (Eds.), *The mind's eye: Cognitive and applied aspects of eye movement research* (pp. 313–334). Amsterdam: Elsevier.
- Hyönä, J., & Nurminen, A.-M. (2006). Do adult readers know how they read? Evidence from eye movement patterns and verbal reports. *British Journal of Educational Psychology, 97*, 31–50. doi:10.1348/000712605x53678
- Inhoff, A. W., & Wu, C. (2005). Eye movements and the identification of spatially ambiguous words during Chinese sentence reading. *Memory & cognition, 33*(8), 1345-1356.
- Jarodzka, H., Scheiter, K., Gerjets, P., & van Gog, T. (2010). In the eyes of the beholder: How experts and novices interpret dynamic stimuli. *Learning and Instruction, 20*, 146–154.
- Jian, Y. C., Chen, M. L., & Ko, H. W. (2013). Context Effects in Processing of Chinese Academic Words: An Eye-Tracking Investigation. *Reading Research Quarterly, 48*(4), 403-413.
- Jian, Y. -C., & Ko, H. -W. (2012). Investigating the effects of background knowledge on Chinese word processing during text reading: evidence from eye movements. *Journal of Research in Reading, 37*(S1), S71-S86.
- Kim, Y. H., & Goetz, E. T. (1994). Context effects on word recognition and reading comprehension of poor and good readers: A test of the interactive-compensatory hypothesis. *Reading Research Quarterly, 179*-188.
- Ko, H. W., & Chan, E. L. (2006). *Elementary School Reading Comprehension Screening Test (Grade 2 to 6)*. Taipei: Special Education Unit, Ministry of Education.
- Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learn Instr, 13*(2), 205–226.
- Lai, M. L., & Chen, Y. H. (2012). Examining preschoolers' attention during storybook reading: evidence from eye movements. *Journal of Early Children & Care, 8*, 81-96.
- Lai, M. L., Tsai, M.-J., Yang, F.-Y., Hsu, C.-Y., Liu, T. C., Lee, S. W. Y., et al. (2013). A review of using eye-tracking technology in exploring learning from 2000 to 2012. *Educational Research Review, 10*, 90–115.
- Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological review, 104*(2), 211.
- Li, X., Liu, P., & Rayner, K. (2011). Eye movement guidance in Chinese reading: Is there a preferred viewing location? *Vision Research, 51*(10), 1146-1156.
- Li, X., Rayner, K., & Cave, K. R. (2009). On the segmentation of Chinese words during reading. *Cognitive Psychology, 58*(4), 525-552.
- Mason, L., Pluchino, P., Tornatora, M. C., & Ariasi, N. (2013). An eye-tracking study of learning from science text with concrete and abstract illustrations. *The Journal of Experimental Education, 81*(3), 356-384.
- Mayer, R. E. (2010). Unique contributions of eye-tracking research to the study of learning with graphics. *Learning and instruction, 20*(2), 167-171.
- Nagy, W. E., Anderson, R. C., & Herman, P. A. (1987). Learning word meanings from context during normal reading. *American educational research journal, 24*(2), 237-270.
- Packard, J. L. (2000). *The morphology of Chinese: A linguistic and cognitive approach*. Cambridge University Press.

- Patrick MD, Carter G, Wiebe EN (2005) Visual representations of DNA replication: middle grades students' perceptions and interpretations. *Journal of Science Educational Technology*, 14(3), 353-365.
- Perfetti, C. A., Goldman, S. R., & Hogaboam, T. W. (1979). Reading skill and the identification of words in discourse context. *Memory & Cognition*, 7(4), 273-282.
- Perfetti, C. A., & Lesgold, A. M. (1977). Discourse comprehension and sources of individual differences. In M. A. Just & P. A. Carpenter (Eds.). *Cognitive processes in comprehension* (pp. 141-183). Hillsdale, NJ: Erlbaum.
- Rahman, T., & Bisanz, G. L. (1986). Reading ability and use of a story schema in recalling and reconstructing information. *Journal of Educational Psychology*, 78(5), 323.
- Ramsey, S. R. (1987). *The languages of China*. Princeton University Press.
- Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, 124(3), 372.
- Rayner, K., & Juhasz, B. (2004). Eye movements in reading: Old questions and new directions. *European Journal of Cognitive Psychology*, 16(1-2), 340-352.
- Rayner, K., & Duffy, S. A. (1986). Lexical complexity and fixation times in reading: Effects of word frequency, verb complexity, and lexical ambiguity. *Memory & Cognition*, 14(3), 191-201.
- Rayner, K., & Pollatsek, A. (1981). Eye movement control during reading: Evidence for direct control. *The Quarterly journal of experimental psychology*, 33(4), 351-373.
- Schwantes, F. (1982). Text readability level and development differences in context effects. *Journal of Literacy Research*, 14(1), 5-12.
- She, H. C., & Chen, Y. Z. (2009). The impact of multimedia effect on science learning: Evidence from eye movements. *Computers & Education*, 53(4), 1297-1307.
- Shen, D., Liversedge, S. P., Tian, J., Zang, C., Cui, L., Bai, X., et al. (2012). Eye movements of second language learners when reading spaced and unspaced Chinese text. *Journal of Experimental Psychology: Applied*, doi:10.1037a0027485
- Soh, O. K. (2016). Examining the reading behaviours and performances of sixth-graders for reading instruction: evidence from eye movements. *Journal of e-Learning and Knowledge Society*, 12(4).
- Stanovich, K. E. (1980). Towards an interactive compensatory model of individual differences in the development of reading fluency. *Research Quarterly*, 16(1), 32-71. doi:10.2307/747348
- Stanovich, K. E. (1984). The Interactive-Compensatory Model of Reading A Confluence of Developmental, Experimental, and Educational Psychology. *Remedial and special education*, 5(3), 11-19.
- Stanovich, K. E., & West, R. F. (1981). The effect of sentence context on ongoing word recognition. Tests of a two-process theory. *Journal of Experimental Psychology: Human Perception and Performance*, 7(3), 658-672. doi:10.1037/0096-1523.7.3.658
- Stanovich, K. E., West, R. F., & Feeman, D. J. (1981). A longitudinal study of sentence context effects in second-grade children: Tests of an interactive-compensatory model. *Journal of Experimental Child Psychology*, 32(2), 185-199.
- Schnitz W, Kulhavy RW (eds) (1994) *Comprehension of graphics*. Amsterdam: Elsevier.
- Tai, R. H., Loehr, J. F., & Brigham, F. J. (2006). An exploration of the use of eye-gaze tracking to study problem-solving on standardized science assessments. *International journal of research & method in education*, 29(2), 185-208.

- Tsai, M.-J., Hou, H. T., Lai, M. L., Liu, W.-Y., & Yang, F. Y. (2012). Visual attention for solving multiple-choice science problem: An eye-tracking analysis. *Computers & Education*, 58(1), 375-385.
- Van Gog, T., & Scheiter, K. (2010). Eye tracking as a tool to study and enhance multimedia learning. *Learning and Instruction*, 20(2), 95-99.
- van Sommeren M, Reimann P, Boshuizen H, de Jong TD (eds) (1998) Learning with multiple representations. Permagon, Amsterdam.
- West, R. F., Stanovich, K. E., Feeman, D. J., & Cunningham, A. E. (1983). The effect of sentence context on word recognition in second-and sixth-grade children. *Reading Research Quarterly*, 6-15.
- Williams, R., & Morris, R. (2004). Eye movements, word familiarity, and vocabulary acquisition. *European Journal of Cognitive Psychology*, 16(1-2), 312-339.
- Yan, M., Kliegl, R., Richter, E. M., Nuthmann, A., & Shu, H. (2010). Flexible saccade-target selection in Chinese reading. *The Quarterly Journal of Experimental Psychology*, 63(4), 705-725.
- Yang, F. Y., Chang, C. Y., Chien, W. R., Chien, Y. T., & Tseng, Y. H. (2013). Tracking learners' visual attention during a multimedia presentation in a real classroom. *Computers & Education*, 62, 208-2201.

## APPENDICES

### Appendix 1

#### Sample of Science Text

本世纪末，哪怕是在最糟糕的气候变化预想中，但本周一发表的一项新研究扼杀了这个希望，预测温度将与碳排放量同步上升，直到我们用光最后的煤和石油。据加拿大科学家发表在《自然气候变化》期刊上的研究，如果地球上的所有化石燃料资源都被燃烧殆尽的话，那么全球气温到2300年时将会比工业化之前的水平升高8摄氏度，并将5万亿吨的碳排放到大气中。北极地区的平均温度将升高17摄氏度。专家表示，倘若预测成真的话，温室气体会将地球变成一个食物稀缺、部分地区不适宜人类居住、许多动植物灭绝的星球。这会将世界加热到接近始新世早期（5600万年前）的状态，当时棕榈树能够生长到北至阿拉斯加的地方，鳄鱼则畅游在北极地区。哺乳动物从始新世的

高温中幸存了下来；早期灵长类动物也正是出现在那个时期。极冰融化会导致地球海平面上升，那意味着占人类总数40%以上的沿海居民生活变得动荡。不止是热带雨林系统会崩溃，对于农业而言堪称是彻头彻尾的灾难。富裕国家或许还能维持食物供给，但像非洲南部这样的地方则绝无可能。许多人将不得不背井离乡，甚至死于饥馑。

In even the bleakest climate change scenarios for the end of this century but a new study published Monday snuffs out such hope, projecting temperatures that rise lockstep with carbon emissions until the last drops of oil and lumps of coal are used up. Global temperatures will increase on average by 8 degrees Celsius (14.4 degrees F) over preindustrial levels by 2300 if all of Earth's fossil fuel resources are burned, adding five trillion metric tons of carbon to the atmosphere, according to the research by Canadian scientists published in *Nature Climate Change*. In the Arctic, average temperatures would rise by 17 degrees C (30.6 degrees F). If these temperatures do become reality, greenhouse gases would transform Earth into a place where food is scarce, parts of the world are uninhabitable for humans, and many species of animals and plants are wiped out, experts say. It also would heat the world to a level approaching that of the early Eocene period, 52 million to 56 million years ago, when palm trees grew as far north as Alaska and crocodiles swam in the Arctic. Mammals survived Eocene temperatures; this is when early primates appeared. Polar melt would commit the Earth to sea-level rise that would mean upheaval for coastal populations, which make up more than 40 percent of humanity. Not only could tropical rain forest systems collapse, but drought in southern Europe and the United States would be completely catastrophic for agriculture. Wealthy nations might maintain food supply, but not places like southern Africa. A lot of people would have to leave, or a lot of people would die.

Sample of Corresponding Text

本世纪末，哪怕是在最糟糕的气候变化预想中，但本周一发表的一项新研究扼杀了这个希望，预测温度将与碳排放量同步上升，直到我们用光最后的煤和石油。据加拿大科学家发表在《自然气候变化》期刊上的研究，如果轨道上的所有化石燃料资源

都被燃烧殆尽的话，那么全球气温到2300年时将会比农业化之前的水平升高8摄氏度，并将5万亿吨的碳排放到气温中。北极地区的平均温度将升高17摄氏度。专家表示，倘若说话成真的话，温室气体会将轨道变成一个食物稀缺、部分地区不适宜大猩猩居住、许多动植物灭绝的星球。这会将世界加热到接近始新世早期（5600万年前）的状态，当时榴莲树能够生长到北至阿拉斯加的地方，乌龟则畅游在北极地区。哺乳植物从始新世的高温中幸存了下来；早期灵长类专家也正是出现在那个时期。极冰融化会导致轨道海平面上升，那意味着占大猩猩总数40%以上的沿海居动物活变得动荡。不止是热带雨林系统会崩溃，对于农业而言堪称是彻头彻尾的灾难。富裕国家或许还能维持碳排供给，但像非洲大象这样的地方则绝无可能。许多人将不得不背井开荒，甚至死于饥馑。

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