# Learning with Multi-Representational Texts in a Second Language: An Eye-Tracking Investigation

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**Abstract:** Integrating verbal and pictorial information is fundamental in learning multi-representational materials and is reported to correlate with various positive outcomes of learning. To investigate how non-native English readers engage with multi-representational texts, the eye movements of 32 university students were examined while they read a multi-representational text in their second language (L2). The role of prior knowledge, L2 vocabulary knowledge and L2 reading comprehension ability was also investigated. No significant correlations emerged between eye-movement patterns and individual differences but there were significant correlations between eye-movement patterns and learning outcome. This study found partial support that greater integrations between text and pictures by non-native English readers was associated with a better learning outcome. Text-dominant processing and text-guided integrative processing appear to be equally important when reading multi-representational texts in the L2.

**Keywords:** Multi-representational learning, integrative processing, eye-movements, reading in a second language, learning from text

## Introduction

### The nature of reading multi-representational texts

Most studies that involve native readers learning with multi-representational texts suggest that their reading is text-dominant. Readers predominantly attend to text and sometimes neglect to devote sufficient amount of attention at inspecting corresponding pictures. Multimedia researchers argue that pictures should not be neglected as successful comprehension of multi-representational texts necessitates the readers to integrate information from both representations. Text-picture integration is fundamental as it allows readers to construct a coherent mental representation of the learning content (Mayer, 2005). Eye-movements indicative of the text-picture integration process are associated with various positive outcomes of learning. Readers who make more and longer attempts at integrating perform better in several learning tasks than those who make less and shorter attempts. This more strategic behavior is characterized by more frequent integrative transitions between text and picture, longer text re-reading time while re-inspecting picture and longer picture re-inspection time while re-reading text (Mason, Tornatora & Pluchino, 2013, 2015).

Despite the plethora of studies published, surprising little attention has been given to people reading multi-representational texts in their second language (L2). Studies comparing first language (L1) and L2 reading have found that reading in L1 and L2 differs. L2 reading patterns for instance are usually characterized by longer sentence reading times, more fixations and shorter saccades (Cop, Drieghe & Duyck, 2015). This present study therefore argues for the importance of studying the non-native readers since their experience with multi-representational texts may differ from their native-reader counterparts. Their difficulty in comprehending the verbal information may lead them to ignore the pictures as they focus on the reading in a less familiar language. Alternatively, it may guide them to use the pictures as a source, allowing them to gain a deeper understanding of the text.

We also examined individual differences that are commonly linked to the engagement with multi-representational texts: prior knowledge and reading comprehension ability. Empirical support regarding their role in facilitating learning of multi-representational texts suggests positive associations with learning outcomes (Mason, et al., 2015). Additionally, prior knowledge is shown to correlate positively with text-picture integration (Mason, et al., 2013). Reading comprehension on the other hand is argued to facilitate text as well as image comprehension (Scheiter, Schüler, Gerjets, Huk & Hesse, 2014). For people reading in their L2, vocabulary knowledge is known to play an important role (Droop & Verhoeven, 2003).

## The present study

To explore the non-native English readers' reading of a multi-representational text in English, their eye-movement behavior was examined. We specifically examined their text-picture integration since it is integral to comprehension and learning successfully from multi-representational texts. To this end, two research questions were addressed in this study:

1. Is the eye-movement pattern of non-native English readers reading an authentic multi-representational text in English related to their English vocabulary knowledge, English reading comprehension ability and their prior knowledge in the subject matter?
2. Is the eye-movement pattern of non-native English readers reading an authentic multi-representational text in English related to their learning of the multi-representational text?

## Method

### Participants

Fifty undergraduates and postgraduates who used English as their L2 were recruited. However, due to calibration problems and drifts in gaze data when reading a long authentic text for an average of 4.84 minutes, only the data of 32 participants could be analyzed. Participants had not studied science since the age of 17 to ensure the material they were reading was not already over-learnt, had normal or corrected-to-normal vision and were at most 'good' users of English. Their English proficiency was determined by their performance in an English proficiency test such as IELTS or TOEFL. In addition, the reading direction of their L1 matched that of English, i.e. left-to-right, and top-to-bottom, as this may influence how readers look at text and pictures.

### Reading material

The reading material was a single two-page spread from a science textbook for Year Seven (Levesley, Johnson & Gray, 2008) that discusses the properties of solids, liquids and gases. It was chosen after piloting as it includes a number of representation types which serves different functions and whose integration was expected to be important for learning. The material consists of chunks of text and several types of graphic representations (photograph, diagrams). For eye movement analyses, the material was divided into 28 areas of interest (AOIs). Each is classified as either a text or a picture AOI. There are 21 text AOIs made up of paragraphs, headings and questions. Each graphic representation is an AOI in itself, accounting for 7 picture AOIs.

### Measures

#### Vocabulary knowledge in English

The English vocabulary task used was the Lexical Test for Advanced Learners of English (LexTALE) which assesses English vocabulary knowledge. The test involves an un-speeded visual lexical decision task in which each participant was presented with 60 letter strings and they had to decide whether or not each letter string was an existing English word.

#### Reading comprehension ability in English

Participants' reading comprehension ability was assessed with the Gray Silent Reading Tests (GSRT).

#### Prior knowledge of the topic

The participants' pre-existing knowledge regarding the properties of solids, liquids and gases was assessed with 10 multiple-choice items. Each has four options with one correct answer. All items were adapted from a list of assessment items available on the American Association for the Advancement of Science Project 2061 Science Assessment website, under the topic Atoms, Molecules and States of Matter.

#### Learning outcomes

The post-test was a paper-and-pencil task assessing the participants' recall and comprehension of the reading material. It comprised eight open-ended questions reproduced from the question section of the reading material. The last question however was slightly different from the original. In addition to describing "the movements of the particles in solids, liquids and gases" in just words, the participants were also asked to describe them through drawing(s). This additional element assessed the participants' recall and comprehension of the pictorial information, in particular. Answers to all eight questions were scored according to their correctness and completeness to provide a maximum post-test score of 30 (of which 16 points were from the final question which included drawing). The answers were independently scored by two raters.

## Eye movement measures

Because the way in which the non-native English readers integrate verbal and pictorial information in the text is essential for this study, we collected several measures that are normally used to measure this process. The measures were based on the gaze shifts between text and picture AOIs. Integrative transition is a frequency measure indicating the number of attempts at integrating verbal and pictorial information (Mason, et al., 2015). Two temporal measures were also calculated to identify the total time spent on integrative processing during the re-processing of the material. Look-from text to picture fixation time refers to the total time spent re-inspecting a picture AOI while re-reading a text AOI, whereas look-from picture to text fixation time refers to the total time spent re-reading a text AOI while re-inspecting a picture AOI. These second-pass reading measures were examined because it is assumed to reflect a more intentional and purposeful processing of the material (Mason, et al., 2015). Additionally, the total times spent making text-to-text and picture-to-picture integrations during second-pass reading were also calculated. Look-from text to text fixation time refers to the total time spent on a text AOI while re-reading another text AOI, whereas look-from picture to picture fixation time refers to the total time spent on a picture AOI while re-inspecting another picture AOI.

## Apparatus

Eye movements were collected using the Tobii Pro TX300 eye-tracker (Tobii Technology, Stockholm, Sweden) with a 300 Hz sampling rate. The stimulus was presented on a 23-inch TFT monitor with a 1920 x 1080 pixel-resolution. Data were recorded with Tobii-Studio software. The eye-tracker allows the participants freedom of head movement at 37 x 17 cm or 15 x 7".

## Procedure

All participants were tested individually. The study comprised three stages; pre-experimental, experimental and post-experimental. All were carried out in a single session. The pre-experimental stage involved the administration of GSRT and the prior knowledge test. In the experimental stage, the participants sat in front of a monitor with the built-in eye-tracking system and were asked to read the stimulus silently and carefully as they would have to answer questions afterwards. The participants read at their own pace. Before the experiment commenced, the system was calibrated on a nine-point grid. All participants finished reading the stimulus under 10 minutes. The post-experimental stage entailed the administration of the post-test, LexTALE and a background questionnaire. The participants completed all three stages under 1 hour and 45 minutes.

# Results and discussion

The descriptive values are displayed in Table 1.

Table 1: Means and standard deviations for readers' individual difference measures

| | M | SD |
|---|---|---|
| English vocabulary knowledge (min. = 0, max. = 100) | 73.36 | 15.18 |
| English reading comprehension ability (min. = 0, max. = 65) | 50.25 | 5.15 |
| Prior knowledge (min. = 0, max. = 10) | 7.47 | 2.23 |
| Learning outcome (min. = 0, max. = 30) | 17.95 | 3.5 |

## Eye-movement behavior and individual differences

One of the aims of the study was to examine whether non-native English readers' eye-movement patterns are related to their individual characteristics such as prior knowledge or reading comprehension. A correlation analysis however did not find significant associations between any of the individual differences and any measure of eye-movements (see Table 2).

Table 2: Correlations between eye movement and individual difference measures

| | English vocabulary knowledge | English reading comprehension ability | Prior knowledge |
|---|---|---|---|
| Integrative transition | .219 | .188 | .250 |
| Look-from text to picture fixation time | -.021 | -.025 | .245 |
| Look-from picture to text fixation time | -.129 | .194 | .224 |
| Look-from text to text fixation time | .108 | .022 | .126 |

| | | | |
|---|---|---|---|
| Look-from picture to picture fixation time | .071 | .189 | -.044 |

*All *p*s are above .05

This is rather surprising especially with regard to prior knowledge which has been argued to facilitate text-picture integration (Mason, et al., 2015; Scheiter, et al. 2014). The non-native readers' English reading comprehension ability and English vocabulary knowledge as well as what they have already known about the subject matter therefore cannot explain how they read and processed the multi-representational material.

### Eye-movement behavior and learning

To investigate whether the non-native English readers' eye-movement behavior is associated with their learning of the material, correlations were calculated between the eye movement measures and learning outcome. Learning outcome ($M$ = 17.95, $SD$ = 3.5) correlated positively with integrative transitions ($r$ = .411, $p$ = .020), look-from text to picture fixation time ($r$ = .426, $p$ = .015) and look-from text to text time ($r$ = .388, $p$ = .028). However, it did not correlate with two other measures; look-from picture to text fixation time ($r$ = .266, $p$ = .142) and look-from picture to picture fixation time ($r$ = .137, $p$ = .456). Thus, it seems that those who performed better in the post-test were readers who integrated verbal information for a longer time during the re-processing of the material. They also integrated verbal and pictorial information to a greater extent during the learning episode. However, this was only partially supported because look-from picture to text fixation time did not correlate with learning outcome. This suggests that similar to L1 readers, the L2 readers also have text-dominant processing and text-guided integrative processing (indicated by look-from text to text fixation time and look-from text to picture fixation time) and so were just as important for learning from the multi-representational material.

## Conclusion

This study aimed at extending current research on multi-representational learning by exploring readers' engagement with a multi-representational text in their L2. We examined their eye-movement behavior when reading and processing the text and found that the individual differences examined could not explain this behavior. We were also particularly interested in how these readers integrated the text and pictures and found support for the importance of integrating both representations to learn successfully from multi-representational texts. It appears that text-dominant processing and text-guided integrative processing are equally important. Because the participants were reading in their L2, they needed more time to process the text. Hence, they benefited more from authentic multi-representational textbooks by not only integrating verbal and pictorial information to a greater extent but also by using text to guide this process. Thus, it seems that successful L2 readers are as equally dependent as L1 readers on text-guided interpretation and integration of pictures. How different these processes are in L1 and L2 reading and how it could contribute to learning from multi-representational texts may be of interest for future research, as the number of people studying in their L2 continues to grow.

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