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The effects of digital scaffolding on adolescent English reading in Japan: An experimental study on visual-syntactic text formatting

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This experimental study examined how VSTF (Visual-Syntactic Text Formatting)-based text benefits reading speed, reading comprehension, reading efficiency and retention for middle and high school students. Prospective within-subjects tests were conducted in Japan on a total of 132 students: 76 high school students from 12th grade and 56 middle school students from eighth grade. Students read both block-formatted text and VSTF-based text and answered quizzes and subjective questionnaires related to what they read. Objectively, although middle school students did not show a significant difference between using block-formatted text and VSTF-based text, low proficiency students in high school showed a significant increase in reading speed, reading comprehension, reading efficiency and retention, while high proficiency students in high school showed a significant increase in reading speed and retention. Regarding subjective questionnaires, most students among all of the grades felt reading VSTF-based text was more effective than

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reading block-formatted text. Based on these results, future long-term studies with multiple texts should be considered.

Keywords: computer-assisted language learning, language acquisition, English reading, syntactic awareness, visual-syntactic text formatting

Introduction

Regarding the shift towards modern education, new technology and methods that scaffold English reading have been invented. Some of the examples of those are audio-visual support (Chun & Plass, 2000), highlighting of words (Hzang & Liou, 2007) and advance organizers (Len & Chun, 2007). Although studies show that these technological implementations help learners, traditional block formatting is still retained. Warschauer, Park and Walker (2011) said that traditional block formatting is arbitrary, and texts do not always have to be presented in such a way.

Visual-Syntactic Text Formatting (VSTF) is a new way to read texts, which radically restructures sentences and allows readers to process complex English structures. This applies natural language processing techniques to automatically parse text to emphasize sentence and phrase structures. Specifically, VSTF breaks sentences up at salient clause and chunk boundaries, fits each row of text into one or two fixation eye spans, uses clear indents to denote syntactic hierarchies, renders active verbs in colored font and creates visual clusters across multiple rows that help readers retain and integrate multi-phrase images in their mind (Tate *et al.,* 2019). The software company, LiveInk® developed VSTF two decades ago and is currently partnering with a few publishers to promote VSTF (Warschauer, Park & Walker, 2011). The current LiveInk® software parsing engine performs over two million calculations to transform a 30-word, ninth grade level sentence (Walker, Vogel & Fletcher, 2004). Figure 1 depicts VSTF and traditional block formatting side-by-side. This text was borrowed from Provision by Kirihara-Shoten.

Visual-syntactic formatted text

Yogurt
has been eaten for centuries
in the Balkan Peninsula,
which
includes Bulgaria.

Daily consumption
of yogurt
is one
of the reasons
so many people
in that region
live past one hundred.

Traditional block-formatted text

Yogurt has been eaten for centuries in the Balkan Peninsula, which includes Bulgaria. Daily consumption of yogurt is one of the reasons so many people in that region live past one hundred. Yogurt is rich in high-quality protein and calcium, and research has found it to be beneficial in controlling blood pressure and preventing cancer. The fermentation process makes yogurt easier to digest than milk. Milk gives some people diarrhea, but even they have no problem eating yogurt.

Figure 1. VSTF and traditional block formatting

There are multiple publications conducted in the US demonstrating the beneficial effects

of VSTF on students' English reading skills, but there is little research on VSTF conducted in non-native English-speaking countries as of now. Therefore, this paper will examine the effects of VSTF on students' English reading skills at a middle school and a high school in Japan, after exploring the theoretical and experimental background behind VSTF.

Previous studies

In order to clarify the significance of VSTF as it pertains this study, some previous studies will be examined from two perspectives: theoretically and experimentally.

Theoretical background

Syntactic awareness. A number of theorists have placed word knowledge at the center of their reading model, such as Reading Systems Framework, but some other theorists such as Grabe (2009) says that syntactic information in words or word groups is essential for understanding the meaning within texts. Gernsbacher (1997) proposed the Structure Building Model to explain the cognitive process behind reading. The three primary processes of the Structure Building Model are laying a foundation, mapping information onto the foundation, and shifting to build new substructures. Readers first engage in laying a foundation, which usually happens at the beginning of stories and sections. Readers then either map incoming new information onto the existing foundation or shift to create new substructures depending on whether the information is coherent or not. However, Gernsbacher (1997) argued that language learners – especially poor readers – tend to shift and create too many substructures, which makes it difficult for them to assemble information into a whole structure. This means that these individuals focus their attention on local levels and construct a linear structure instead of hierarchical structure (Park, 2017). Further, Bernhardt (2000) suggested that developing syntactic awareness is more difficult than developing other linguistic skills for learners. L2 students initially produce high syntactic error rates until they become proficient. It seems reasonable to utilize a system to draw more attention on syntax when reading. In order to resolve this challenge, Gascoigne (2006) proposed that one of the ways to make readers put their attention on structures is the use of technology.

Eye span and eye regressions. There are two noticeable eye features related to reading: eye spans and eye regressions. When one reads something, they can only see a limited amount of space. Because of the limitation of human eye spans, only nine to fifteen characters on average can be seen at a time (Demb, Boynton, & Heeger, 1997). The center of where we see is often the most important, however the periphery is important as well when they read (Kadota & Noro, 2001). In a research study on the eye span, Ikeda and Saida (1978) made the readers' eye span smaller like windows, which ended up decreasing their reading speed, relative to control groups. This research suggests that how readers catch the information more effectively within their eye span is important for effective reading.

The second noticeable eye feature is eye fixations and regressions. Humans cannot read well while their eyes are moving, so they fix their eyes at a point and shift from one fixation to the next fixation. This movement is called a saccade (Garrod, 1992; Sell& Ando, 1986). However, research has found that it sometimes requires regressions which means they re-fix their eyes towards where they previously read. This phenomenon occurs whenever readers need to re-examine previous viewed words and to re-interpret phrase and clause

relations between words due to either interference with working memory or because of skipped words at the edge (Garrod, 1992; Walker, Vogel & Fletcher, 2004; Walker, Schloss, Fletcher, Vogel & Walker, 2005). Walker says that 20 percent or more of eye movements are regressions and this process is like a "garden path" (Walker, Vogel & Fletcher, 2004; Walker, Schloss, Fletcher, Vogel & Walker, 2005; Walker *et al.,* 2007). This feature suggests that how readers try to decrease the regressions and how the text is formatted to reduce eye regression is related to reading effectiveness.

Working memory and the brain. When people remember something that they read, they go through three steps; sensory register, working memory and long-term memory (Ormrod, Anderman & Anderman, 2017; Kadota & Noro, 2001). Among those, working memory, where people retain information for a short term and process it for language understanding, learning and implication plays the most important role (Funabashi, 1997). The information that reaches the sensory register through the sensory organ is sent to the working memory. However, all of this information cannot be stored since the capacity for working memory is limited. It can save 7 +/–2 chunks at a time for about 10 to 20 seconds, unless people consciously do something with it (Kadota & Noro, 2001). Another feature of working memory is that the relationship between processing and retaining is a "trade-off" within our brain's capacity (Carpenter & Just, 1989). It means that if one needs to process a lot in their head, they cannot use the working memory for retention. Only the information that went through working memory and processed well has a chance to reach long-term memory, which has less limited capacity (Ormrod, Anderman & Anderman, 2017).

In regard to working memory, researchers have proposed some reading strategies. One of the reading strategies is chunking (Cowan, 2012). If one put all the information that they read in their working memory, their working memory will be overloaded. Dividing information into chunks and imagining the situations as chunks makes readers use their working memory effectively (Yubune, 2010). Chunking is also effective for readers to read texts without translation. Translation requires more processing than reading, which decreases the capacity for retention (Kadota & Noro, 2001; Loewen, 2005). Thus, chunking makes readers use their working memory effectively.

Another strategy using working memory is making a hierarchy of the information/chunks. As mentioned before, the capacity of working memory is limited, therefore suppressing irrelevant information can facilitate readers in making the most of their working memory (Park, 2017). Understanding the hierarchy among chunks and getting rid of less important information only makes readers remember better (Park, 2017; Walker *et al.,* 2007).

Experimental background

Using the principles in theoretical background mentioned above, many research studies have been conducted implementing technology for improving English reading. Before VSTF became known, studies were carried out using methods such as phrase condition (Cromer, 1970) and phrase spacing (Jandreau & Bever, 1992). As an improvement upon those, VSTF was also researched in elementary schools through colleges for the last two decades. Initial studies by VSTF developers reported gains in reading speed, reading comprehension and retention, and less eye stress especially for English native speakers, in the US schools. Specifically, VSTF is an effective tool for university students (Walker, Vogel & Fletcher, 2004; Walker, Schloss, Fletcher, Vogel & Walker, 2005), high school students (Fletcher, Vogel &

Walker, 2005; Walker *et al.,* 2007; Warschauer, Park & Walker, 2011), and middle school students (Tate *et al.,* 2019; Walker, Schloss, Fletcher, Vogel & Walker, 2005; Warschauer, Park & Walker, 2011). The effect on primary school students is variable depending on their grade levels. One of the most recent research studies performed by Park, Xu, Collins, Farkas, and Warschauer (2018) demonstrate that VSTF has a positive effect on sixth grade students, but not on fourth grade students. In addition to the effects of grade level, previous studies also found that the relative improvements that users get is vary depending on their English proficiency; VSTF is highly sufficient for mid-level students and relatively less sufficient for top and bottom level students of performance (Tate *et al.,* 2019). Further, students who kept using VSTF and improved their English ability showed improvement on the block formatted text as well (Walker, Schloss, Fletcher, Vogel & Walker, 2005; Warschauer, Park & Walker, 2011). It suggests that there are no concerns that reading VSTF-based text for English will hinder reading block-formatted text.

Some research studies were done later to see whether VSTF is effective to ESL learners who study English as a second language. It was found that VSTF is more useful to ESL learners than non-ESL learners. This is because structure understanding is more challenging to them than word meanings, and VSTF facilitates readers in understanding structures (Tate *et al.,* 2019; Warschauer, Park & Walker, 2011). Nonetheless, there are few studies done in non-English speaking countries. A study conducted by Kanda (2012) in a Japanese university was a pilot test and total subjects numbered only 17 students. They saw improvement in reading comprehension, but not in reading speed. And it seems that the study has potential for improvement, especially regarding getting appropriate subjects and using computers smoothly.

Research questions

This current study was conducted to further examine VSTF's effectiveness in improving English reading ability of Japanese middle and high school students. Previous studies were mainly conducted for learners whose first language is English and learners who study English as a second language in the United States. However, this has not been comprehensively studied in Japanese schools. Studying the Japanese middle and high school students' population will enable researchers to approach this field from different perspectives mainly because students do not typically use and see English outside of class. Based on previous studies and the participants' English levels of this study, three research questions are considered.

1. Does VSTF have a beneficial effect in Japanese high schools and middle schools, in terms of reading speeds, reading comprehension, reading efficiency and retention?
2. Do the effects on outcomes change depending on students' English levels?
3. Do students feel that they are reading more effectively with VSTF-based text than traditional block-formatted text?

The specific hypotheses are as follows. First, VSTF would have a positive impact on students' reading speeds, reading comprehension, reading efficiency and retention. Secondly, low-proficiency/grade students would get more benefits from VSTF than high-proficiency/grade students. Thirdly, students would feel positive effects from VSTF.

Method

School district

The study took place in a high school and a middle school in Japan. The high school is one of the top public high schools in the prefecture and most of the students attend universities after their graduation. The middle school is a normal public school which is located in the same prefecture as the high school and enrolls local students. However, both of the schools are located in the countryside, and few foreign people who speak non-Japanese languages live in that area. Thus, it is not easy for students to be internally motivated to study English.

Subjects

The final sample of the study included 132 students who agreed to participate in this experiment: 76 high school students from 12th grade and 56 middle school students from 8th grade. In the high school English classes, students were divided into several classes depending on their English levels. The study was conducted in the highest level and the lowest level of English classes within the 12th grade, with 38 students per class. In the middle school English classes, there are no academic-level differences among classes within a grade. In all, 56 middle school students participated from two classes. In sum, there are three groups: high proficiency students in high school (n=38), low proficiency students in high school (n=38) and middle school students (n=56).

Study design

In multiple studies conducted within the past two decades, there were two types of parameters looked in VSTF: performance, which measures short-term outcomes, and transference, which measures long-term outcomes for students. This study focused on performance rather than transference.

To see the effectiveness of VSTF on high school students' reading time, reading comprehension, reading efficiency and retention, a 40-minute within-subjects study was conducted. A 30-minute within-subjects study was then conducted on middle school students. Due to time restrictions and other limitations, only reading comprehension was examined in the middle school group. In both the high school and middle school groups, each student read two texts: one with block formatted text and the other with VSTF-based text, and answered content questions, from which objective data were obtained. This was followed by a questionnaire on how students felt using VSTF (details are explained in *Procedure*, below).

Materials

LiveInk® software was used with permission from LiveInk® company. Due to limited technological resources, the LiveInk® text was printed out with color as it is displayed in the actual program. Before students received the printed text, teachers demonstrated the use of LiveInk® to the students on projectors.

Four texts were prepared for the high school and middle school groups. To prevent students from utilizing their background knowledge, unfamiliar topics were chosen. High school students were given two English texts about science used from a 12th grade textbook

called *Provision* which was published by Kirihara-Shoten. Middle school students were given two texts about geography.

To ensure consistency of the English levels in these texts, we used the following reputable methods: the Flesch Reading Ease and the Flesch-Kincaid Grade Level tests (Yubune, Kanda & Tabuchi, 2007). These tests were developed by Rudolf Flesch and J. Peter Kincaid in 1942 and 1975 (Miller, 2017). The Flesch Reading Ease test scores are calculated out of 100 based on a text's readability. Larger number correlate to easier texts. A 12-year-old student can typically easily understand a text with a score of 60 or above. People who graduated from universities are capable of understanding texts with scores of 30 or below (McGovern, 2015). The formula used in the Flesch Reading Ease test is below.

$$206.835 - 1.015\left(\frac{\text{total words}}{\text{total sentences}}\right) - 84.6\left(\frac{\text{total syllables}}{\text{total words}}\right)$$

(Miller, 2017)

The Flesch-Kincaid Grade Level test determines English level based on the US school grade level, from first grade to university graduation (Miller, 2017). The following is the formula used in the Flesch-Kincaid Grade Level test.

$$0.39\left(\frac{\text{total words}}{\text{total sentences}}\right) + 11.8\left(\frac{\text{total syllables}}{\text{total words}}\right) - 15.9$$

(Miller, 2017)

The readability of the text used in this study is indicated in Table 1. Texts for the high school students were named TEXT A and TEXT B, and texts for the middle school students were named TEXT C and TEXT D. Since texts for middle school students were very short, it was inappropriate to use Flesch Reading Ease test.

Table 1. Text readability

	High school		Middle school	
	TEXT A	**TEXT B**	**TEXT C**	**TEXT D**
Words	345	338	46	45
Characters	1675	1692	225	213
Sentences	19	21	6	6
Words per sentence	18.1	16	7.6	7.5
Characters per word	4.7	4.8	4.7	4.5
Flesch reading ease	49.8	49.5	n/a	n/a
Flesch-Kincaid grade level	10.3	10.3	8.4	8.3

True or false questions were prepared for each text to determine the students' reading comprehension. For high school students, there were seven questions per text, and for middle school students, there were four questions per text. The questions were provided with block-formatted text.

Cloze tests were also only prepared for high school students to determine the retention of the texts. Cloze tests, which were invented by Wilson L. Taylor (1953) are a reputable

method for testing student retention or working memory (Kadota & Noro, 2001). In the cloze test, students were asked to produce missing words in the sentences and then reproduce missing words from their memory (Abu-Rabia & Siegel, 2002). For this test, three sentences were selected respectively from TEXT A and TEXT B. A blank was created for each sentence for students to fill in during the cloze test.

Questionnaire was prepared based on previous studies and their implications (Kanda, 2012; Park & Warschauer, 2016). These questions based on a scale of 1–7 addressed the students' subjective feelings about comprehension, retention, motivation and eye stress. The following list of questions was used in the experiment.

Questionnaire

Q1. Do you feel fewer eye regressions using VSTF-based text than block formatted text?
Q2. Do you think that VSTF-based text made the context easier to understand than the block formatted text?
Q3. Do you think that VSTF-based text is easier to remember than the block formatted text?
Q4. Do you think that VSTF-based text is easier to see and read than the block formatted text? Why do you think so? (supplemental)
Q5. Do you feel more motivated reading VSTF-based text than block formatted text?
Q6. Do you want to read more on VSTF-based text?

Procedure

Texts were distributed appropriately since there might be readability differences amongst the texts even after using Flesch Reading Ease and Flesch-Kincaid Grade Level tests to determine English level consistency. The high proficiency class (n=38) was divided into two groups: Group 1 and Group 2. Group 1 (n=19) read TEXT A with traditional block-formatted text and TEXT B with VSTF-based text. Group 2 (n=19) read TEXT A with VSTF-based text and TEXT B with traditional block formatted text. This was also performed in the lower English level class (n=38) which was partitioned into two groups: Group 3 and Group 4. Group 3 (n=19) read TEXT A with block-formatted text and TEXT B with VSTF-based text while Group 4 (n=19) read TEXT A with VSTF-based text and TEXT B with traditional block-formatted text.

In the middle school sample (n=56), there were no academic-level distinctions between the classes. In Class 1 (n=28), students read TEXT C with traditional block-formatted text and TEXT D with VSTF-based text while in Class 2 (n=28), students read TEXT D with traditional block-formatted text and TEXT C with VSTF-based text.

Students followed the steps below accordingly with the teachers' instructions. Students were told to wait until all students were finished with a section before moving on to the next step ensuring correct timing.

High school

i. Teachers explained about the research and how LiveInk® works.
ii. Students were timed while reading the traditional block formatted text. Group 1 and Group 3 read TEXT A first, while Group 2 and Group 4 read TEXT B first. The time was shown on the screen.
iii. Students answered seven true or false content questions that were related to what they read on (ii). (Note: Students were given the option to look back at the text.)
iv. Students were then timed while reading VSTF-based text as in (ii). Group 1 and Group 3 read TEXT B, while Group 2 and Group 4 read TEXT A.
v. Students answered seven true and false questions related to what they read in (iv).
vi. Students were given a seven-point scale questionnaire regarding their perceptions of the text difference.
vii. Students were given the cloze test. Students were not permitted to look back at anything.

Middle school

I. Teachers explained about the research and how LiveInk® works.
II. Students read the traditional block formatted text. Class 1 read TEXT C first while Class 2 read TEXT D first.
III. Students were given four true or false content questions related to what they read on step (II). (Note: Students were given the option to look back at the text, if needed.)
IV. Students read VSTF-based text. Class 1 read TEXT D, while Class 2 read TEXT C.
V. Students answered four true and false questions related to what they read in (IV).
VI. Students were given a seven-point scale questionnaire regarding their perceptions of the differences.

Results

Objective effects of VSTF on English reading literacy

The first research question addresses whether VSTF has a beneficial effect in Japanese high schools and middle schools, reading speeds, reading comprehension, reading efficiency and retention were determined. The student's answer sheets were divided into block-formatted text and VSTF-based text and calculated regardless of whether students read TEXT A or TEXT B, and TEXT C or TEXT D in each group (high proficiency in high school, low proficiency in high school and middle school groups) (Table 2).

Table 2. Objective comparison of VSTF-based text and block-formatted text among student groups

		High school students				Middle school students (n=56)	
		High proficiency (n=38)		Low proficiency (n=38)			
		block-formatted	VSTF-based	block-formatted	VSTF-based	block-formatted	VSTF-based
Reading time (WPM)	Mean	88.930	**96.493**	78.591	**85.290**		
	SD	24.727	22.649	25.270	46.330		
	Difference	7.563 (t=3.081, p=0.002***)		6.699 (t=1.575, p=0.062*)			
Reading comprehension (Pecentage of correct answers)	Mean	**60.740**	56.684	42.500	**49.579**	72.320	**73.660**
	SD	17.248	18.677	18.180	17.550	20.040	16.110
	Difference	−4.056 (t=−1.010, p=0.160)		7.079 (t=1.722, p=0.047**)		1.340 (t=0.364, p=0.718)	
Reading efficiency (WPM × Percentage of correct answers × 0.01)	Mean	54.205	**55.972**	34.020	**44.150**		
	SD	21.446	27.803	19.233	37.120		
	Difference	1.767 (t=0.379, p=0.354)		10.130 (t=1.775, p=0.042**)			
Reading retention (Percentage of correct answers)	Mean	16.553	**23.447**	6.947	**18.237**		
	SD	23.920	25.340	15.644	25.093		
	Difference	6.894 (t=1.530, p=0.068*)		11.290 (t=2.830, p=0.007***)			

Note: * indicates p<0.1, ** indicates p<0.05, *** indicates p<0.01

Reading time

The words-per-minute (WPM) were calculated from the number of words in the text that a student reads divided by their total reading time in minutes. The average WPM and a difference of mean test were used to establish whether the VSTF-based text effect on the reading time was significant or not.

High proficiency in high school. The data reveals that the average WPM ($\bar{x}$=96.493, SD=22.649) of VSTF-based text was 7.563 words higher than the average WPM ($\bar{x}$=88.930, SD=24.727) of block-formatted text. There was a significant difference between the WPM while using VSTF-based text and block-formatted text, which supports the hypothesis (t=3.081, p=.002***).

Low proficiency in high school. The average WPM $\bar{x}$=85.290, SD=46.330) of VSTF-based text was 6.699 words higher than the average WPM ($\bar{x}$=78.591, SD=25.270) of block-formatted text for low proficiency students. A t-test showed a significant difference between the WPM while using VSTF-based text and block-formatted text, thus supporting the hypothesis (t=1.575, p=.062*).

Reading comprehension

The percentages of correct answers on the true-or-false content questions were also calculated. The % correct (average percentage correct) and the difference of mean test were employed to determine whether the effectiveness on reading comprehension was significant or not.

High proficiency in high school. The average percentage of correct answers ($\bar{x}$=56.684%, SD=18.677) of VSTF-based text was found to be 4.056% points lower than the average percentage of correct answers ($\bar{x}$=60.740%, SD=17.248) of block-formatted text. No significant difference while using VSTF-based text and block-formatted text was reported, which does not support the hypothesis (t=-1.010, p=.160).

Low proficiency in high school. *On average,* VSTF-based text scored 49.579% (SD=17.550), which is 7.079% points higher than block-formatted text subjects ($\bar{x}$=42.500%, SD=18.180). VSTF-based text had significantly higher correct percentages than block-formatted text, which supports the hypothesis (t=1.722, p=.047**).

Middle school. The data reveals that the average percentage of correct answers ($\bar{x}$=73.660%, SD=16.110) *of* VSTF-based text was 1.340% points higher than the average percentage of correct answers ($\bar{x}$=72.320%, SD=20.040) of block-formatted text. There was no significant difference while using VSTF-based text and block-formatted text, which does not support the hypothesis (t=.364, p=.718).

Reading efficiency

Reading efficiency was shown by taking the product of WPM and % comprehension. This value was multiplied by 0.01. The average reading efficiency and difference of mean test were applied to see whether effectiveness on reading efficiency was significant or not.

High proficiency in high school. Reading efficiency was found to be 1.767 higher, using VSTF-based text ($\bar{x}$=55.972, SD=27.803) than block formatted text ($\bar{x}$=54.205, SD=21.446). There was no significant difference, which does not support the hypothesis (t=.379, p=.354).

Low proficiency in high school. *The average scores for reading efficiency with* VSTF-based text ($\bar{x}$=44.150, SD=37.120) were 10.130 points higher than block-formatted text ($\bar{x}$=34.020, SD=19.233) and demonstrated a significant difference, which supports the hypothesis (t=1.775, p=.042**).

Retention

The percentages of correct answers on the cloze tests were computed. The average cloze test score % and difference of mean test were used to examine whether VSTF-based text effect on retention was significant or not.

High proficiency in high school. The average percentage of correct answers on cloze test that students answered after reading VSTF-based text was ($\bar{x}$=23.447, SD=25.340) 6.894%

points higher than block-formatted text ($\bar{x}$=16.553, SD=23.920). A t-test showed a significance, which supports hypothesis (*t*=1.530, *p*=.068*).

Low proficiency in middle school. *The average percentage of correct answers on cloze test that students answered after reading* VSTF-based text ($\bar{x}$=18.237, SD=25.093) was 11.290% points higher than block formatted text ($\bar{x}$=6.947, SD=15.644). Differences between the scores of VSTF-based text subjects and block-formatted text subjects were very significant, supporting the hypothesis (*t*=2.830, *p*=.007***).

Comparison of measurements between proficiency levels in high school

The aim of research question 2 was to determine whether English level affects the outcomes of using VSTF through examining average score differences. Table 3 shows whether there are significant differences between the high proficiency group and low proficiency group in high school by using the average score difference (VSTF-based text – block-formatted text). The mean differences and standard deviations of each students' data are shown in Table 3. From the mean, standard deviation and degree of freedom, the t-statistics and p-values were calculated (* indicates *p*<.1, ** indicates *p*<.05, *** indicates p<.01).

Table 3. Comparison of measured added benefits of using VSTF between high proficiency students and low proficiency students

		High school students	
		High proficiency (n=38)	**Low proficiency (n=38)**
		VSTF-based – block-formatted	VSTF-based – block-formatted
Reading time (WPM)	Mean	**7.560**	6.705
	SD	15.128	26.240
	Difference	−0.855 (*t*=0.174, *p*=0.431)	
Reading comprehension (Pecentage of correct answers)	Mean	−4.053	**7.079**
	SD	24.725	25.335
	Difference	11.132 (*t*=1.938, *p*=0.028**)	
Reading efficiency (WPM × Percentage of correct answers × 0.01)	Mean	1.767	**10.122**
	SD	28.766	35.158
	Difference	8.355 (*t*=1.320, *p*=0.098*)	
Reading retention (Percentage of correct answers)	Mean	6.895	**11.289**
	SD	27.781	23.367
	Difference	4.394 (*t*=0.746, *p*=0.229)	

Note: * indicates p<0.1, ** indicates p<0.05, *** indicates p<0.01

Reading time. There was no significant difference in reading speed variation of the text structure methods (VSTF-based text & block-formatted text) between high proficiency students in high school and low proficiency students in high school (*t*=-.174, *p*=.431), *which does not support the hypothesis.*

Reading comprehension. There was a significant difference between high proficiency students in high school and low proficiency students in high school for average reading

comprehension score difference (VSTF-based text – block-formatted text) (t=1.938, p=.028**), which supports the hypothesis.

Reading efficiency. Using average reading efficiency score difference (VSTF-based text – block-formatted text), a significant difference was found between high proficiency students in high school and low proficiency students in high school (t=1.320, p=.098*), which supports the hypothesis.

Retention. When examining the average retention rate variation of the text structure methods (VSTF-based text & block-formatted text), no significant differences were found between high proficiency students and low proficiency students in high school (t=.746, p=.229), which does not support the hypothesis.

Students' subjective thoughts on effectiveness of VSTF

Research question 3 explored students' thoughts and feelings on the effectiveness of utilizing VSTF as compared to block-formatted text in reading. A questionnaire was used to examine Research question 3, and were analyzed by using percentages (agree responses/ total responses ×100%) and chi square tests to determine whether the differences between agree responses and disagree responses were significant or not (Table 4). Figure 2 represents the results of the supplemental questions that inquired about the reasons that students perceived VSTF-based text to be easier than block-formatted text.

Table 4. Subjective assessment of VSTF in high school (high and low proficiency) and middle school students

		Total	Agree	Disagree	Agree(%)	Chi scores	P-values
Fewer regressions than block-formatted text	High school; high proficiency	31	23	8	74.2%	7.258	0.007***
	High school; low proficiency	27	22	5	81.5%	10.704	0.001***
	Middle school	46	45	1	97.8%	42.087	<0.001***
Easier to understand than block-formatted text	High school; high proficiency	31	25	6	80.6%	11.645	0.001***
	High school; low proficiency	31	29	2	93.5%	23.516	<0.001***
	Middle school	46	44	2	95.7%	38.348	<0.001***
Easier to remember than block- formatted text	High school; high proficiency	28	21	7	75.0%	7.000	0.008***
	High school; low proficiency	30	27	3	90.0%	19.200	<0.001***
	Middle school	47	43	4	91.5%	32.362	<0.001***
Easier to see the text than block-formatted text	High school; high proficiency	35	28	7	80.0%	12.600	<0.001***
	High school; low proficiency	34	31	3	91.2%	23.059	<0.001***
	Middle school	45	42	3	93.3%	33.800	<0.001***
More motivated to read than block-formatted text	High school; high proficiency	20	11	9	55.0%	0.200	0.655
	High school; low proficiency	19	10	9	52.6%	0.053	0.819
	Middle school	34	24	10	70.6%	5.765	0.016***
Willing to use from now	High school; high proficiency	32	23	9	71.9%	6.125	0.013***
	High school; low proficiency	27	23	4	85.2%	13.370	<0.001***
	Middle school	46	37	9	80.4%	17.043	<0.001***

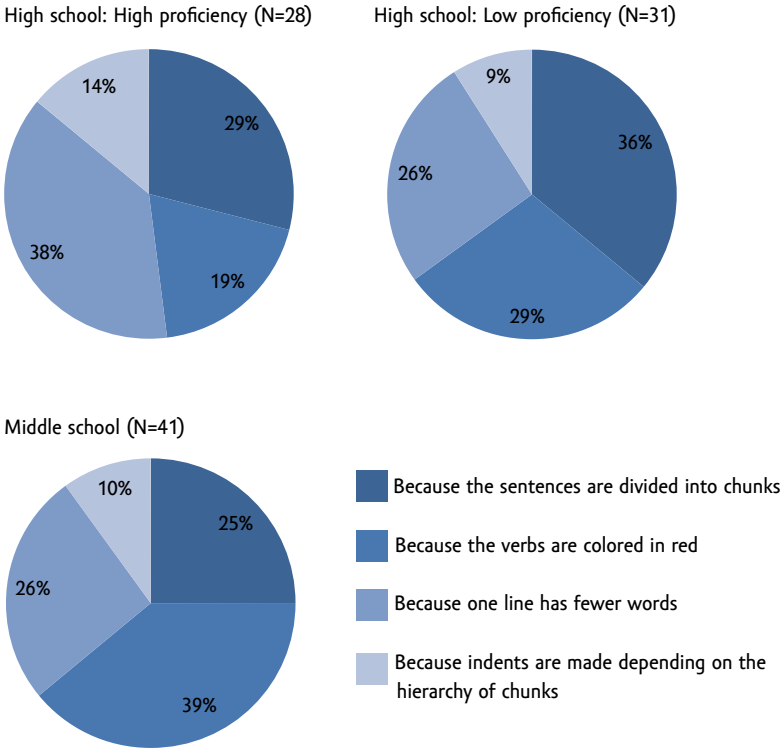

Figure 2. The reasons that students find VSTF easier to read

A remarkable finding is that on most of the questions, the percentages of the middle school students who agreed were the highest. This was followed by the low proficiency groups in high school, and finally, the high proficiency group in high school. Within the high school level, the most agreed categories were "easier to understand" (80.6% for high proficiency students and 93.5% for low proficiency students) followed by "easier to see the text" (80.0% for high proficiency students and 91.2% for low proficiency students), and finally, "easier to remember" (75.0% for high proficiency students and 90.0% for low proficiency students). Within the middle school level, "fewer regressions" was the most agreed category (97.8%), followed by "easier to understand" (95.7%) and lastly, "easier to see the text" (93.3%). In contrast, the least agreed category was "more motivated to use" (55.0 % for high proficiency students in high school, 52.6% for low proficiency in high school, 70.6% for middle school students).

A notable finding in the chi-squared tests was that within all the student groups, the agreed response was statistically significantly higher ($p<.05$) than the disagreed responses in all categories, with an exception for "more motivated to use from now" in the high school students (high and low proficiency).

There were also interesting results from the supplemental questions that provide insight on why VSTF-based text is easy to see for students. Within each level, the reasons that students provided were varied. For high proficiency students in high school, 38% of students answered that it was easier to see VSTF-based text because "one line has fewer words" than one line of block-formatted text. This was followed by the reasons: "the sentences are divided into chunks" (29%), "verbs are colored in red" (19%) and "indents are made depending on the hierarchy of chunks" (14%). For low proficiency students in high school, 36% of students agreed that seeing VSTF-based text is easy because "the sentences are divided into chunks". Following this, the reasons: "verbs are colored in red" (29%), "one line has fewer words" (26%), and "indents are made depending on the hierarchy of chunks" (9%) were chosen. In comparison, middle school students answered that seeing VSTF-based text is easy because "verbs are colored in red" (39%), "one line has fewer words" (26%), "the sentences are divided into chunks" (25%), and "indents are made depending on the hierarchy of chunks" (10%).

Observation

In order to support the objective data, teachers observed students' attitudes during and after this experiment, and they also received some institutional free comments from students. Both teachers in the high school and the middle school said that students participated in the experiment seriously, but for some students, especially middle school students, the prepared texts and quizzes seemed difficult and made them want to give up reading. The high school teacher also remarked that since the high school students who participated had only three months left until the national center examination, many of them wondered how long it would take to improve their reading skills when using VSTF. The middle school teacher observed that after finishing this experiment, some of the students started to visualize their texts and to care about the structure of English sentences, more. He further added that students started to color and visualize their textbooks of other subjects effectively, too.

Discussion

This study addresses three questions related to the effects of VSTF; (1) Does VSTF have a positive effect in Japanese high schools and middle schools, in terms of reading speeds, reading comprehension, reading efficiency and retention? (2) Do the effects on outcomes change depending on students' English levels? (3) Do students feel they are reading more effectively with VSTF-based text than traditional block-formatted text?

The first research question was answered by this study. The objective assessments demonstrated that high proficiency students in high school received a positive effect on reading speed and retention, but not on reading comprehension and reading efficiency. For the low proficiency students in high school, there were significant increases for all the variables: reading speeds, reading comprehension, reading efficiency and retention. In comparison, middle school students did not demonstrate any significant differences between VSTF and block-formatted texts.

The second research question was also answered by this experiment. When comparing low proficiency and high proficiency high school students, there were statistically significant differences in reading comprehension and reading efficiency, but not reading speed and reading retention. Middle school students were not compared with high school students

because of the differing test difficulty. Further, they did not demonstrate any differences between VSTF-based text and block-formatted text. The objective outcome suggests that the positive effect from VSTF was highest for low proficiency students in high school, followed by low proficiency students in high school and middle school students.

The third research question was also answered by the subjective questionnaire and implied several things about VSTF beyond objective data. Unlike the objective assessment, most of the students from all the grades gave more positive evaluations of using VSTF-based text than block-formatted text. Surprisingly, even though middle school students did not gain beneficial effects from using VSTF-based text on the objective outcomes, they had more positive opinions of VSTF than both groups of high school students. Between high and low proficiency high school students, low proficiency students felt more positive about VSTF than high proficiency students, which has no contradiction with objective outcomes. This suggests that lower English level students want to gain a higher level of English skills and seek an effective way to study.

Middle school students thought VSTF was very useful and were motivated to use it more, but VSTF was not objectively effective for reading middle school textbooks. It's known that motivation is one of the important factors for learners to improve their reading abilities. Considering the virtuous cycle of good readers that was suggested by Nuttall (2005), regularly using VSTF-based text might improve these learners' English abilities (Mizuno, 2015; Nuttall, 2005). Further, it would be beneficial for students to be concerned about text structures when reading even simple sentences, as reading style has implications toward their futures. As the middle school teacher observed that some students started to visualize the text, this suggests that these good habits would be a foundation for understanding higher levels of English.

Another important finding from the subjective questionnaire was that different levels of students had different reasons for why students perceived VSTF-based text to be easier to see. For example, a majority of the middle school students answered that they felt better at reading because the verbs were colored in red, whereas the reason why a majority of the high proficiency students in high school was that there were fewer words per line. This suggests that VSTF can help a wide range of levels of students learn in varied ways.

Limitations and future research

There were some limitations in this study that should be considered for future research. The first drawback of this study was that the experiment was conducted once and did not continue over a long period of time. There were comments made by students saying that since they were not able to adapt to reading VSTF-based text immediately, it was hard for them to focus. Previous studies say that it can take a year for students and teachers to become more adept with new interventions (Means *et al.*, 1995; Sandholz & Reilly, 2004). Since this study revealed that VSTF was effective for certain levels of students in a short-term period, future research should be conducted over a long duration to determine whether English ability can improve long-term and whether VSTF usage has side effects or not.

The second limitation in this study was that all the student participants read both the VSTF-based text and block-formatted text on paper. The primary benefit of using VSTF is applying it to natural language processing, so reading VSTF-based text on paper stands as an experiment. However, previous research suggests that when people read on computer screens, they read slower, learn less deeply and remember less (Myrberg & Wiberg, 2015).

Also, it should be considered that some learners hesitate to use new devices and face challenges using computers. Future research needs to determine whether reading VSTF-based text on the computer is truly beneficial or not.

Another interesting finding suggested in this research was that there might be different impact sizes depending on the students' major (i.e. science or liberal arts). In this study, experiments were conducted for the highest level of students group and lowest level of students group in high school. Nonetheless, the high proficiency group was a group of liberal arts students and the low proficiency group was a group of science students. Considering different chosen majors/fields of study in assessing VSTF could be an insightful variable, in which previous studies have not yet examined.

Conclusions

Despite these limitations, VSTF shows promising results as a method of improving English reading ability through empowering syntactic awareness, reducing eye regressions and utilizing working memory effectively. The study confirmed objectively that the use of VSTF in Japanese schools provided a benefit to high school students, especially to lower proficiency levels of students when reading complicated texts. However, few benefits are reported for middle school students who are still learning simple and short English sentences. Subjectively, most of the middle school and high school students agreed about the effectiveness of VSTF and were willing to use it more. These findings suggest that VSTF can be a viable option for students to learn and read English texts effectively both in-class and outside of class. Struggling English reading learners might show significant improvement if they use VSTF for a long period of time. As these results were promising and considering that e-books are expected to be increasingly popular in the near future, further long-term rigorous research on VSTF should be conducted on variety levels of learners using more varied texts.

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References

Bernhard, E. (2000). *Second language reading as a case study of reading scholarship in the 20th century.* Hillsdale, NJ: Lawrence Erlbaum.

Carpenter, P.A., & Just, M.A. (1988). *The role of working memory in language comprehension.* Hillsdale, NJ: Complex Information Processing.

Chun, D., & Plass, J. (2000). Networked multimedia environments for second language acquisition. In M. Warschauer & R. Kern (Eds.), *Network-based language teaching: Concepts and practice* (pp. 151–170). Cambridge: Cambridge University Press.

Cowan, N. (2012). *Working memory capacity.* New York: Psychology Press.

Cromer, W. (1970). The difference model: A new explanation for some reading difficulties. *Journal of Educational Psychology, 61,* 471–483. https://doi.org/10.1037/h0030288

Demb, J. B., Boynton, G. M., & Heeger, D. J. (1997). Brain activity in visual cortex predicts individual differences in reading performance. *Proceedings of the National Academy of Sciences, 94*(24), 13363–13366. https://doi.org/10.1073/pnas.94.24.13363

Funabashi, S. (1997). Wakingumemori no shinkeikiko [Neural mechanisms of working memory]. *Higher Brain Function Research*, (17), 126–133.

Garrod, S. (1992). *Reconciling the psychological with the linguistic in accounts of text comprehension.* Nordic Research on Text and Discourse (pp. 27–43). NORDTEXT Symposium, Espoo, Finland, May 10–13, 1990. Retrieved from https://eric.ed.gov/?id=ED359748

Gascoigne, C. (2006). Toward an understanding of incidental input enhancement in computerized L2 environments. *CALICO Journal, 24*(1), 147–162.

Gernsbacher, M. A. (1997). Two decades of structure building. *Discourse Processes, 23*(3), 265–304. https://doi.org/10.1080/01638539709544994

Ghasemi, B., & Hashemi, M. (2011). Foreign language learning during childhood. *Procedia – Social and Behavioral Sciences, 28,* 872–876. https://doi.org/10.1016/j.sbspro.2011.11.160

Grabe, W. (2009). *Reading in a second language: Moving from theory to practice.* Cambridge: Cambridge University Press.

Hzang, H. T., & Liou, H. C. (2007). Vocabulary learning in an automated graded reading program. *Language Learning & Technology, 11*(3), 83–106.

Ikeda, M., & Saida, S. (1978). Span of recognition in reading. *Vision Research, 18*(1), 83–88. https://doi.org/10.1016/0042-6989(78)90080-9

Jandreau, S., & Bever, T. G. (1992). Phrase-spaced formats improve comprehension in average readers. *Journal of Applied Psychology, 77*(2), 143–146. https://doi.org/10.1037/0021-9010.77.2.143

Kadota, S., & Noro, T. (Eds.). (2001). *How the mind works in EFL reading* (1st ed.). [In Japanese] Tokyo: Kuroshio Shuppan.

Kanda, A. (2012). Tentative use of VSTF for Japanese EFL students – evaluation and improvements. *Nihon E-Learning Gakkaishi, 12*.

Len, H., & Chun, T. (2007). Reading authentic EFL text using visual and advance organizers in a multimedia learning environment. *Language Learning & Technology, 11*(3), 83–106.

Loewen, S. (2005). Incidental focus on form and second language learning. *Studies in Second Language Acquisition, 27*(03). https://doi.org/10.1017/s0272263105050163

McGovern, F. (2015). Improve customer engagement – Use Flesch-Kincaid readability score. Retrieved from Visible Thread website: https://www.visiblethread.com/2015/04/improve-customer-engagement-use-flesch-kincaid-readability-scores/

Means, B., Olson, K., Ruskus, J., Quellmalz, E., Middleton, T., & Remz, A. R. (1995). *Technology's role in education reform findings from a national study of innovating schools.* Retrieved from https://www2.ed.gov/PDFDocs/techrole.pdf

Miller, R. (2017). *What is the Flesch Reading Ease Score?* Retrieved from http://www.roxifyonline.com/Rox/documentation/Flesch%20Reading%20Ease%20Score.pdf

Mizuno, K. (2015). From reading books to sharing books: Going beyond the virtuous circle of the good reader. *The JALT CALL Journal, 39*(2).

Myrberg, C., & Wiberg, N. (2015). Screen vs. paper: What is the difference for reading and learning? *Insights the UKSG Journal, 28*(2), 49–54. https://doi.org/10.1629/uksg.236

Nuttall, C. (2005). *Teaching reading skills in a foreign language.* Oxford: Macmillan Education.

OECD. (2018). Program for international student assessment. Retrieved from https://www.nier.go.jp/kokusai/pisa/index.html

Ormrod, J., Anderman, E., & Anderman, L. (2017). *Educational psychology: Developing learners* (9th ed.). New York: Pearson Education.

Oshio, A. (2018). *SPSS to Amos ni yoru kaiseki* (3rd ed.). Tokyo: Tokyo-Shoseki.

Park, Y., & Warschauer, M. (2016). Syntactic enhancement and second language literacy: an experimental study. *Language Learning & Technology, 20*(3), 180–199.

Park, Y., Xu, Y., Collins, P., Farkas, G., & Warschauer, M. (2018). Scaffolding learning of language structures with visual-syntactic text formatting. *British Journal of Educational Technology, 50*(4), 1896–1912. https://doi.org/10.1111/bjet.12689

Sandholtz, J. H., & Reilly, B. (2004). Teachers, not technicians: Rethinking technical expectations for teachers. *Teachers College Record, 106*(3), 487–512. https://doi.org/10.1111/j.1467-9620.2004.00348.x

Sell, D., & Ando, S. (1986). *Faster reading in English* (28th ed.). Tokyo: Eichousha-Shinsha.

Tate, T. P., Collins, P., Xu, Y., Yau, J. C., Krishnan, J., Prado, Y., Warschauer, M. (2019). Visual-syntactic text format: Improving adolescent literacy. *Scientific Studies of Reading, 23*(4), 287–304. https://doi.org/10.1080/10888438.2018.1561700

Walker, R., Gordon, A., Schloss, P., Fletcher, C., Vogel, C., & Walker, S. (2007). Visual-syntactic text formatting: Theoretical basis and empirical evidence for impact on human reading. *2007 IEEE International Professional Communication Conference.* https://doi.org/10.1109/ipcc.2007.4464068

Walker, R., Vogel, C., & Fletcher, C. (2004). Neurocognitive and classroom-based validation of computer-generated, visual-syntactic text formatting for college and high school reading. In *American Educational Research Association.* Retrieved from http://www.clipread.com/sbir/vstf_aera_2004.pdf

Walker, S., Schloss, P., Fletcher, C., Vogel, C., & Walker, R. (2005). *Visual-syntactic text formatting: A new method to enhance online reading online.* Retrieved from http://www.liveink.com/VSTF_ReadingOnline_IRA_2005_Walker.pdf

Warschauer, M., Park, Y., & Walker, R. (2011). Transforming digital reading with Visual-syntactic text formatting. *The JALT CALL Journal, 7*(3), 255–270.

Youngmin Park. (2017). Syntactic enhancement: Bootstrapping for second language reading. *Journal of Cognitive Science, 18*(4), 473–509. https://doi.org/10.17791/jcs.2017.18.4.473

Yubune, E. (2010). Functions of chunks and working memory in fluent reading. *Dialogue, 9*(1349–5135).

Yubune, E., Kanda, A., & Tabuchi, R. (2007). Effects of different computer display methods of reading units on learners' reading efficiency. [In Japanese] *Language Education & Technology, 44.* https://doi.org/10.24539/let.44.0_215