

## Computerized Saccadic Eye Movement Therapy to Improve Oculomotor Control during Reading and Reading Rate in Adult Japanese Readers

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### ABSTRACT

**Background:** This study is aimed at determining whether reading rate and oculomotor control during reading, could be improved in adults with home-based computerized saccadic eye movement therapy.

**Methods:** Sixteen Japanese foreign students in the U.S. served as subjects and were randomly divided into two groups; a computerized eye movement training (CEMT) group and a control group. Subjects in the CEMT group received 5 weeks of home-based computerized saccadic eye movement training while subjects in the control group received no comparable training or intervention, other than diagnostic evaluations.

**Results:** CEMT group demonstrated significant improvement in all Visagraph II measurement parameters after intervention, except for duration of fixation and reading comprehension. Subjects in the control group demonstrated no significant pre-post differences.

**Conclusions:** These results suggest that CEMT, without supplementary reading instruction or educational intervention, can improve reading oculomotor performance with adult Japanese readers.

**Keywords:** Oculomotor, Visagraph II, Computerized Eye Movement Training, Vision Therapy, Reading

### Introduction

It has been well documented in past research that both children and adults with reading disability or dyslexia demonstrate poorer oculomotor control and saccadic quality than do their non-reading disabled counterparts.<sup>1-6</sup> A relatively recent intervention for oculomotor problems is computerized eye movement therapy (CEMT). We do not currently know how effective CEMT is as a treatment for improving oculomotor control, however. In a well-designed study of elementary school children with reading difficulties (RD) as subjects, Solan found that PA/VE and Guided Reading therapy improved eye movement skills which resulted in significant gains in reading comprehension, as measured by the Visagraph II.<sup>7</sup> Powers and Grisham reported that web-based on-line computerized visual skill training with the Gemstone Dynamic Vision Training (DVT) program (including saccade, pursuit, vergence, and accommodation training) improved reading performance in children and adults.<sup>8,9</sup> Similar research has also indicated the use of the Taylor Reading Plus™ on-line computerized eye movement training program (which consists of scanning and flash activities), shows promise as an effective tool to enhance oculomotor efficiency with

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adult non-disabled readers.<sup>10,11</sup> Although not all experts agree<sup>14-16</sup>, previous computerized eye movement research suggests that reading performance improves secondary to the training. Interestingly, results from our literature search uncovered only studies with native-English speaking subjects. An appropriate question is whether there would be any benefit from CEMT who speak other languages besides English, such as Japanese? In other words, would Japanese reading performance improve after CEMT—even though it requires distinctly different eye movement pattern than English?

Although previous research has documented improvement in oculomotor skills and reading comprehension with eye movement therapy<sup>7-13</sup>, a complicating factor in trying to tease out oculomotor benefit is that the eye movement therapy mentioned in the previously cited research was not limited only to eye movement training in isolation. In the aforementioned investigations, different mixtures of visual skills were often incorporated into the therapy, including accommodation, vergence, tachistoscopic recognition, and letter/word recognition—in addition to saccades. If eye movements and reading performance improve more as a result of full-scope optometric vision therapy than eye movement training used in isolation, then this would suggest that multiple factors are involved in overall oculomotor performance.

It would not be unreasonable to expect that reading performance with a language utilizing more complex graphemes (written letters) than English might have a different reliance upon eye movement skills during reading. Unlike English, the Japanese language is composed mainly of two kinds of symbols: Kanji and Kana. Kanji are logographic or symbolic characters developed from pictures used by the Chinese several thousand years ago to represent the world around them. Each Kanji character has a meaning by itself. Kanji also can be combined in Kanji compounds to form new meanings, much as root words, prefixes, and suffixes are combined in English. Approximately 4,500 Kanji are generally used in Japanese newspapers and other printed material (there are 1,945 official listed Kanji characters). A requirement for all elementary schools in Japan by the Ministry of Education is that by the end of the sixth-grade, 1,006 Kanji characters must be taught.

In addition to Kanji characters, phonetic symbols called Kana are also necessary to read modern Japanese. Kana characters can be subdivided into two

subtypes, Hiragana and Katakana. Each syllabary (characters of a language representing syllables) of 46 characters represents the same sounds. The cursive Hiragana is used to write words not normally written in Kanji and for verb endings and parts of speech. The angular Katakana is used for emphasis and to write words and names not of Japanese or Chinese origin<sup>21</sup>. Traditionally, Japanese is written vertically in columns going from top to bottom and ordered from right to left, with each new column starting to the left of the preceding one. Because of the influence of European languages such as English, it has also become common for Japanese to be written horizontally, from left to right, with successive rows going from top to bottom. It could be argued that Japanese reading eye movement development might be different from English because of the different requirements needed to read Japanese. Additionally, the duration of fixation would be expected to be longer than that for English because of the increased information density/visual complexity of the Kanji characters. Surprisingly, we were unable to find reported differences in eye movement characteristics between reading Japanese and English.

The underlying question that prompted this investigation was: given the obvious characteristic differences between these two languages, would CEMT generalize and result in improved Japanese reading eye movement performance following intervention?

Although previous studies had demonstrated improved eye movement skills with native English readers, could CEMT saccadic eye movement therapy alone be effective in improving reading oculomotor performance and reading rate with native Japanese readers?

## Subjects and Methods

Sixteen Japanese foreign students volunteered to be subjects for our study. All had graduated from high schools in Japan, and all were currently attending schools in the U.S. Subject age ranged from 21 to 34 years old. Six were male (mean age, 24.2 years; SD, 3.1) and 10 were female (mean age, 26.2 years; SD, 2.5). All participants denied ever having been diagnosed as reading disabled or dyslexic; and all read at a level sufficient to have completed high school in Japan. Each subject demonstrated a visual acuity of at least 20/30 near Snellen equivalent at 40 cm (with correction if required). All subjects gave informed consent for their participation in this study.

This study was designed to compare two groups of subjects: a CEMT group and a matched control group. The 16 Japanese students, who agreed to participate, were given a complete eye examination and found to be free of any vergence or accommodative problems. All were randomly assigned to either the CEMT group or the control group. Subjects in the CEMT group were to receive 5-weeks of home-based computerized eye movement training designed to enhance saccadic eye movement skills for reading. The principal investigator monitored training compliance for the CEMT group by telephone. Each CEMT participant was called once a week and encouraged to complete the prescribed home computer training assignment. Check sheets were used to verify home training compliance for CEMT subjects. The completed check sheets indicated that all 8-participants performed their prescribed training at least 4 times a week on average. All of the subjects in the CEMT group successfully completed the training protocol. Subjects in the control group received no comparable training or intervention, other than diagnostic evaluations.

Eye movement characteristics during reading, and reading rates for all subjects were evaluated at the beginning and at the end of the 5-week study period with the Visagraph II (Huntington Station, New York; modified to measure eye movement performance with Japanese text). Data from the three groups were analyzed for: fixations, regressions, span of recognition, duration of fixation, reading rate with comprehension, and reading comprehension (based upon the number of the correct answers to the ten comprehension questions following the eye movement recording).

For diagnostic eye movement recording purposes, three Visagraph level 10 paragraphs were professionally translated from English into Japanese. Stories 89 (titled: "Braille"), 90 (titled: "Roebing"), and 93 (titled: "Paganini") were chosen from the Taylor/Visagraph level 10 paragraphs and randomly used for all subjects. The three stories were selected primarily for translation and story content reasons. Not only could all of the words be accurately and easily translated from English to Japanese, but also the story content for those three stories was judged as having equal familiarity for the Japanese students. The professional translator adjusted some sentences in order to make the translated expressions more natural and readable in Japanese. The final translated paragraphs were 12-lines long, and single-spaced

typed on white bond paper using 12-point Times font (approximately 20/70 near Snellen equivalent), to closely match the original English version of the Visagraph II paragraphs. No extra spaces were added to the Japanese text, to accurately mimic natural Japanese text.

In order to adjust the difference between Japanese and English texts for the number of words per paragraph, raw scores of Visagraph II were converted to calculated scores by using the data in Table 3 that shows the number of words and characters in each paragraph.<sup>22</sup> We used characters, instead of words, for the adjusted data of Japanese paragraph because, unlike English, we do not use space between words in Japanese. We also use Kanji, which can demonstrate one meaning with one character because we believed that characters were more important units in Japanese rather than words.

Instructions to each subject followed the protocol listed in the Visagraph II manual and Taylor paragraph booklet.<sup>23-25</sup> After orientation to the Taylor Visagraph II system, each subject was comfortably seated and asked to hold the Taylor text 40 cm from the eyes at an angle of approximately 30 degrees downwards from primary gaze. Goggles were placed over the subject's near correction (when indicated) and the inter-pupillary distance was adjusted by centering the pupils through the apertures while subjects viewed a near target. Subjects were allowed to read each paragraph silently with no time limit. After reading the paragraph, the subject answered 10 standard comprehension questions (translated into Japanese) about the content of the paragraph. Comprehension questions were presented on white bond paper.

To enhance reliability, we mimicked past Visagraph II studies by first administering a practice-run measurement for each evaluation session, prior to obtaining the actual recording used for data analysis.<sup>26</sup> For each practice-run, the story-1 paragraph was used. (This level-1 story titled "Pony Ride" was translated into Japanese so it could be used for Visagraph II measurement practice.) Instructions to each subject followed the specified protocol listed in the Visagraph II Manual. If fewer than seven questions were answered correctly for any selection, an additional recording with a different story was added. The first trial reading selection, was necessary to validate the reading level, as well as to familiarize the subjects with the feel of the goggles. The trial story was read either silently or aloud but was excluded from any data

**Table 1.** Pre test comparison.

	Converted value	Control		CEMT		t	p
		Mean	SD	Mean	SD		
<b>FIX</b>	fixations/ 100 characters	37.8	11.8	48.6	23.2	1.18	0.257
<b>REG</b>	regressions/ 100 characters	4.1	3.8	8.8	6.2	1.79	0.095
<b>SPAN</b>	characters/ fixation	2.8	0.6	2.5	1.0	-0.88	0.395
<b>DUR</b>	(sec.)	0.29	0.03	0.27	0.02	-1.07	0.304
<b>RATE</b>	characters /min	602.0	147.4	550.4	211.9	-0.57	0.581
<b>Question</b>	% of correct answer	85.0	5.3	77.5	8.9	-2.05	0.064

**Table 2.** Post test least square means adjusting for the mean corresponding pre-test scores. The results were analyzed with analysis of covariance.

	Converted value	Control			CEMT			F	p
		Mean	Lower 95%CI	Upper 95%CI	Mean	Lower 95%CI	Upper 95%CI		
<b>FIX</b>	fixations/ 100 characters	39.32	36.37	42.28	30.93	27.97	33.88	17.97	0.001
<b>REG</b>	regressions/ 100 characters	5.0	3.5	6.4	2.0	0.6	3.5	8.63	0.012
<b>SPAN</b>	characters/ fixation	2.8	2.5	3.2	3.7	3.3	4.1	11.22	0.005
<b>DUR</b>	(sec.)	0.28	0.26	0.29	0.27	0.25	0.28	0.97	0.3419
<b>RATE</b>	characters / min	603.14	530.73	675.56	786.86	714.44	859.27	14.85	0.002
<b>Question</b>	% of correct answer	78.25	69.8	86.7	84.25	75.8	92.7	0.88	0.240

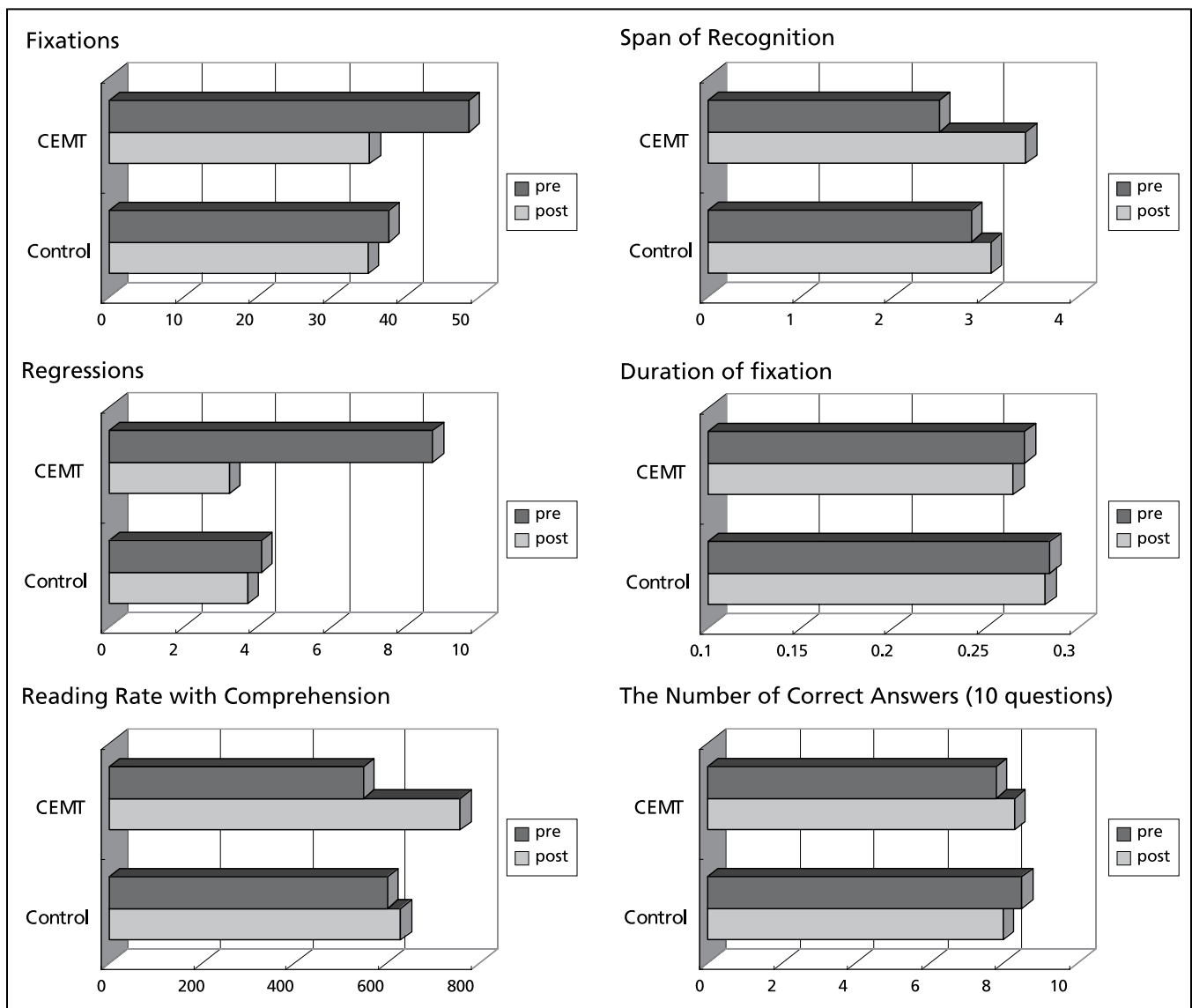
**Table 3.** The number of words and characters in each text (in 7 lines analyzed for data).

Text No.	The title of paragraph	Level	English		Japanese	Ratio
			Words	Characters	Characters	
89	BRILLE	10	100	290	481	1.65
90	ROEBLING	10	99	290	510	1.75
93	PAGANINI	10	100	292	484	1.66

analysis. Subjects were directed to read the second selection silently. Eye movement recordings from the last reading were collected and analyzed.

Our principal investigator used Microsoft PowerPoint to create the custom-computerized saccadic eye movement-training program. (This program is not currently commercially available.) The program very briefly displays letters of the alphabet sequentially from left to right. Similar to the Taylor Reading Plus program, five letters are sequentially displayed on the 10 lines. Subjects were directed to find and count

specific target letters from all letters displayed from the screen of the personal computer. Therapy was conducted using a wide variety of personal computers with different displays. The therapy program has ten different levels of difficulty. The subject chose the appropriate level of difficulty in order to maximize the effectiveness of therapy and to keep their motivation high. The speed increases and the font size become smaller with each successive higher level attained. Subjects in CEMT group were directed to do this therapy for at least 10-minutes per day and encouraged



**Figure 1.** Graphs for pre/post Visagraph II average data of each group. Fixations, regressions, span of recognition, duration of fixation; plus reading rate with comprehension.

to achieve as high a level as possible by the end of the study period. For the CEMT program, alphabet letters were used as the stimuli, however Japanese text was used for the diagnostic evaluations to eliminate the potential concern of language skills interaction with the eye movement training.

The pre-test measures are reported with means and standard deviations and compared across groups with a t-test. Post-test measures are reported with least squares means and 95% confidence intervals. The change following intervention was tested with analysis of covariance adjusting for pre-test measures. Alpha was set at 0.05 with no adjustment for multiple comparisons.

## Results

Visagraph II calculated means, standard deviations, and p-values for the groups with pre test measures are shown on Table 1 and Figure 1. Post-test least square means adjusting for the mean corresponding pre-test scores are shown on Table 2. The CEMT group resulted in a statistically significant decrease in fixation and regression and a statistically significant increase in span and rate.

## Discussion

Previous research from both clinical and laboratory settings has indicated that eye movement therapy results in improved eye movements and reading performance<sup>7-13</sup>. As noted previously, Solan

found significant improvement with elementary school children using a computer program.<sup>7</sup> Powers and Grisham reported that web-based on-line computerized visual skill training including saccade, pursuit, vergence, and accommodation training, improves reading performance in children and adults.<sup>8,9</sup> Other investigators have also found reading eye movement improvements from the use of the Taylor Reading Plus™ on-line computerized eye movement therapy program.<sup>10</sup>

A key difference between this study and past eye movement intervention research is that reading performance in previous studies was only assessed using the English language. In this current CEMT study, the training stimuli were English alphabet letters, but pre and post reading performance was measured by having subjects read Japanese (the subject's native language)—a language using two kinds of symbols: Kanji and Kana, which is graphically very different from English. Results suggest that CEMT using English letters generalizes to improved eye movement performance while reading Japanese text. Further, our results appear to support the use of home-based computerized saccadic therapy alone without traditional optometric vision therapy techniques or other visual skills therapy, visual perceptual therapy, letter/word recognition training, reading instruction, or educational intervention being utilized.

In viewing graphs of our results, it is important to note that pre-intervention reading performance of the CEMT only group (especially for fixations and regressions), appears to be qualitatively poorer than the vision therapy group in the beginning. However, t-test revealed that there were no significant differences between the groups for all of the pre-intervention parameters shown. Pre-intervention performance data from one subject in the CEMT group was much poorer than from the other 15 subjects, and well below the mean of CEMT group overall. Without this one subject, the averages for the three groups would have been nearly equal for all parameters. We feel that this noticeable (but not significant) pre-intervention difference between groups is the result of a small sample size outlier, rather than an originally problematic but more responsive to intervention CEMT group.

It was noted that the duration of fixation did not improve in the experimental group. Tran's research noted that the duration of fixation was significantly improved<sup>10</sup> using tachistoscopic training and saccadic

therapy; it would be interesting to see if tachistoscopic training could improve the duration of fixation.

Even though our results indicate the effectiveness of saccadic eye movement therapy for improving reading performance, it does not mean saccadic eye movement training alone would be enough for reading remediation for reading disabilities or normal readers who want to improve their reading performance. A combination of some methods could lead to better results for those people wishing to improve reading performance. In addition, the best choice of therapeutic methods for reading remediation might depend on the type of reading anomalies encountered. Since there was no placebo group in this study, additional research is required.

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## Appendix

The information described below was cited from the website: [www.readingplus.com](http://www.readingplus.com)

VISAGRAPH III® (All levels) - The Visagraph® Eye-Movement Recording System provides a detailed measurement of the efficiency of students foundational silent reading fluency skills which determine the effectiveness of all reading activities. It consists of a pair of goggles fitted with infra-red sensors that record the eye-movements of the reader as they read a short selection of text. The reports generated by the Visagraph® provide an objective measure of a student's existing reading ability, as well as the gains made during and after the completion of the Reading Plus® instructional programs.

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## COVID FUTURE MEETING DATES

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