ARTICLE

The Effect of the King-Devick Reading Acceleration Program on Reading Fluency and Comprehension: A Summary of Randomized Clinical Trials

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ABSTRACT

Background: Reading performance is essential to a child's academic success. Reading is a complex task involving the integration of language, attention and information processing including eye movements. Efficient eye movements provide a physical foundation for proficient reading and these skills can be improved as multiple studies have reported successful outcomes following training. Data from these studies are summarized and presented to examine the effect of the training program across a wide demographic and large student population. Subgroup analyses further lend insight to ideal timing and length of training.

Methods: Data from five investigations of in-school training programs were combined and analyzed. Study participants were randomized into treatment or control groups. Students 1st through 4th grade (n=611, 7.0 ± 0.8 years) underwent eighteen, 20-minute sessions utilizing King-Devick (K-D) Reading Acceleration Program (RAP). Reading fluency and comprehension was assessed pre- and post-treatment.

Results: The treatment group had significantly greater improvement compared to the control group in fluency (8.9% vs. 5.9%, p<0.001) and comprehension (9.1% vs. 3.1%, p<0.001). A separate group of high-needs students (n=111) also improved significantly in fluency (p<0.001) and comprehension (p<0.001). An extra-training group, who received an average of 11 additional treatment sessions, improved significantly in fluency and comprehension following extra-training (p=0.003, p=0.013). There was a greater improvement in reading comprehension for students receiving intervention in the fall as compared to the spring (10.9% vs 8.1%, p<0.001).

Conclusions: Improving reading skills in youth is essential to building the foundations for future academic success. Efficient eye movements are one necessary component of proficient reading that integrate with visual processing, word decoding and attention span. K-D RAP improves aspects of reading that are not currently addressed in schools. Based on the positive reading outcomes there is increasing evidence to support the inclusion of teaching the physical act of reading in the early education curriculum nation-wide.

INTRODUCTION

Reading performance as it relates to learning is one of the most important predictors in academic success. Children who read proficiently in 3rd grade are significantly more likely to graduate from high school and achieve greater economic success later in life.[1] Two thirds of 4th grade students are not proficient in reading in the United States.[1,2] Additionally, poor readers tend to have more behavioral and social issues in school and higher rates of repeating grade levels.[3] Learning difficulties that lead to dropping out of high school result in fewer students participating in higher education, which could have long-term consequences on the nation's economic success.[2]

The transition from 3rd to 4th grade is substantial as students shift from 'learning to read' to 'reading to learn' and deriving meaning from text.[4] If reading performance is below-expected by 4th grade, a child's future success and contributions on a larger scale are at risk. Students would greatly benefit from a program that facilitates the process of learning to read early on.

Reading involves the integration of language, attention, information processing, vision, and eye movements. Three oculomotor functions that are essential to reading efficiently include: 1) saccades, a fast movement from one target, or word, to the next, 2) convergence, inward movement of the eyes to sustain binocular alignment at near, and 3) accommodation, focusing and maintaining clarity of the target. More than 50% of the brain is related to visual function.[5] Brain areas involved in fast eye movement control include the frontal eye fields, supplementary eye field, dorsolateral prefrontal cortex, parietal lobes, superior colliculus, oculomotor nuclei in the brainstem, and the cerebellum.[5,6] These neurological areas also control aspects of visual attention and processing,[7] which are integral to proficient reading.

Eye movement control involves numerous neurological pathways and synchronization with extraocular muscles for precise muscle movement. Oculomotor function has been shown to be an effective performance measure in monitoring the quality of life in individuals with multiple sclerosis,[8,9] Parkinson's Disease,[10] Alzheimer's disease,[11,12] and amyotrophic lateral sclerosis.[13] Decrements in saccadic performance can be seen in hypoxia[14,15] and extreme sleep deprivation.[16] Multiple studies provide evidence of oculomotor dysfunction secondary to mild traumatic brain injury.[17-19]

Given the complexity of efficient, accurate reading-related eye movements, these may not be fully developed when a child is learning

to read, resulting in inaccurate saccades, longer fixation, and slower reading rates.[20-22] Furthermore, children with reading disabilities demonstrate reduced saccadic accuracy and speed compared to normal readers.[23,24] Eye movement skills can be trained and improved,[25-28] and multiple studies reported successful outcomes following training.[25-29] Eye movement training should be an integral part of rehabilitation following acquired brain injury.[27-30] A recent study of individuals diagnosed with oculomotor dysfunction following mild traumatic brain injury observed more accurate saccades, faster reading rates, reduced symptoms, and improved visual attention following six weeks of oculomotor rehabilitation, which included saccadic, vergence, and accommodative training.[28]

Research has studied the impact of an in-school eye movement training program on reading performance.[25,26,31,32] An early study examined reading fluency in grade school students 2nd through 4th grade before and after eye movement training. Students demonstrated a significant improvement in reading fluency, using the Wechsler Individual Achievement Test Third Edition (WIAT). A similar study looked at reading performance changes after six weeks of eye movement training and found significant improvements in reading fluency as measured by the Scholastic Reading Fluency Assessment.[32] Furthermore, the study demonstrated that 2nd graders had the greatest average increase in reading fluency and concluded that there may be an ideal time frame for eye movement training.

Subsequent studies examined the effect of the oculomotor training program on student reading performance across a larger population. In 2014, *Clinical Pediatrics* published a study that assessed reading performance pre- and post-training and at a one-year follow-up assessment. After six weeks of in-school eye movement training, students who received active eye movement training had significantly improved reading fluency scores compared to the students who had not received eye movement training. At the one-year follow-up, students demonstrated an average reading improvement of 17 percentile rank points from pre-treatment scores from the previous year. Follow-up assessments showed that the reading gains remained after two years.[25]

These studies implemented and evaluated the program at urban grade schools in Chicago, Illinois, and represented a limited demographic of mostly African American students. Additionally, reading performance outcomes were limited to fluency only. In order to gain more information on how the program may be useful in other demographic populations and examine other aspects of reading ability, the training program was further studied in two rural schools and incorporated reading comprehension as an outcome measure. First and second grade students (n=327) were enrolled in the oculomotor training program during the spring semester of the academic school year.[31] This study differed from prior studies by including a subgroup analysis of "high-needs" students who were enrolled in an Individualized Education Plan (IEP), reading recovery program, or English Language Learners (ELL) as well as explored extended, extra training sessions beyond the standardized amount to investigate dose ranges. Similar to previous studies, the treatment group had significantly greater reading fluency outcomes following training as compared to the control group. In addition, there was a significant improvement in reading comprehension after treatment. The high needs subgroup and subgroup of students enrolled in extra training achieved improvements to a greater degree than the overall treatment group.

Given that all previous studies were conducted during the spring semester of the academic school year, a subsequent study alternatively examined the impact of the implementation of the eye movement training program in the fall semester. One hundred and

eighty students in 1st through 3rd grade from rural schools performed six hours of oculomotor training and were assessed with identical protocols to the spring study, which included the WIAT Reading Fluency and Comprehension Assessments and the King-Devick Eye Movement Test for Reading. There was a significant improvement in reading performance for the treatment group compared to the controls. The change in pre- and post-reading measures was significant and even greater than improvements seen in the spring study.

Based on the positive impact of each study, the studies were combined to analyze the significance of the eye movement training program across a wide demographic and large student population.

METHODS

Study Participants

Subjects in the studies were elementary school students in Illinois and Wisconsin. Students (n=611) in 1st, 2nd, 3rd, and 4th grade were enrolled in the Spring or Fall season. Subjects were excluded if they could not identify or read numbers aloud. Recruited subjects were assigned to two intervention groups in a 3:1 ratio: treatment and placebo, using a random number generator. A separate group of high-needs students (n=111) included students with IEPs, reading recovery programs, or ELL were identified prior to the studies, underwent the treatment protocol, and were analyzed as a separate group. Extended treatment students were analyzed as a separate group as well. We obtained each participant's assent, along with a written informed consent from a parent or guardian.

Outcome Measures

A total of five studies exploring the effect of the in-school saccadic training program were combined in order to examine how in-school saccadic eye movement training improved reading performance on a large scale, at both rural and urban elementary schools, within diverse populations. Each study used the King-Devick RAP computerized software for the saccadic eye movement training. Each study utilized pre- and post-training assessments measuring reading and rapid number naming performance. *Allen et al*[26] and *Wethe et al*[32] assessed reading fluency with the Scholastic Fluency Formula Assessment, and the more recent three studies assessed reading performance using the WIAT Reading Fluency Subtest. In addition to reading fluency, two studies performed WIAT Reading Comprehension Assessments. The materials for each study include the King-Devick RAP Software, the King-Devick Test, the WIAT Reading Fluency and Comprehension Subtests or the Scholastic Fluency Formula Assessment.

King-Devick (K-D) Test

The King-Devick (K-D) Test is based on performance of rapid number naming. Better performance on the K-D Test has been correlated with higher reading fluency scores[26] and achievement test scores. Worse performance predicts lower academic status.[33] Standardized instructions require the student to read aloud a series of randomized single digits, zero through nine, in a left to right, top to bottom direction as quickly and accurately as possible. The test contains one demonstration card and three test cards which increase in difficulty. The total cumulative time and the total number of errors on the three test cards constitute the summary score. The time and errors are compared to age-based norms.[33] Criteria for below-expected performance on the K-D Test was scoring beyond one standard deviation from the age-based average on time and/or errors.

Reading Fluency and Comprehension Assessment: The Wechsler Individual Achievement Test Third Edition (WIAT)

The Reading Fluency and Reading Comprehension subtests of the WIAT (Pearson, San Antonio, TX) were used for the standardized reading assessment. In the Reading Fluency

subtest of the WIAT, participants are timed while reading aloud two grade-level-specific passages. Reading Fluency assesses and scores the subject's reading speed and accuracy, and reflects overall reading performance. Total time, number of words read, and word errors are recorded. The score is based on an average number of words read correctly per minute. A standard score (SS) and percentile ranking (PR) by grade level are determined. SS is based on a scale with a mean (average) of 100 and a standard deviation of 15. If a student's SS is 100, the student performed average. PR represents the student's relative standing to other students who are the same grade. A PR of 50 indicates that the student performed better than 50% of children in the same grade.

In the Reading Comprehension subtest of the WIAT, participants read three grade-level-specific passages and then answer a series of questions. Reading Comprehension measures literal and inferential reading comprehension skills using a variety of item sets. The student responses to comprehension questions are scored on accuracy. A SS and PR by grade level is then determined.

Scholastic Fluency Formula Assessment

The Scholastic Fluency Formula Assessment (Scholastic Press, New York, New York) is an individually administered Oral Fluency Assessment measured in words read correctly per minute (WCPM). Participants read three grade-level passages aloud each for one timed minute. The total number of words read and the number of errors are recorded. The score is based on an objective average words read correctly per minute (WCPM) measurement. Baseline reading assessments using Benchmark Passages were completed one week before initiating the in-school training. Reading assessments using Progress Monitoring passages were completed one week after the in-school training. Each score was converted to percentile rank and standard score by grade level.

Intervention

King-Devick RAP presents single randomized numerical targets zero through nine, in a left to right and top to bottom direction to simulate reading-related eye movements. K-D RAP is performed on a desktop or laptop computer with standard screen size. The subjects are instructed to read aloud the number targets as they appear dynamically on the screen. The speed at which the number targets appear is increased over time based on the student's ability and progress. The speed is measured in numbers per minute and varies from 10 to 500. The aim is to perform the training at the fastest speed possible without errors.

Treatment Protocol

Four of the five studies were prospective, participant-masked, randomized, controlled, cross-over design. The fifth study, which had the smallest population, Wethe et al[32] (n=9), administered treatment only without the placebo group, and the treatment group went through the same treatment protocol as other studies.

All testing and training was conducted at the subjects' schools by trained administrators and training was masked to students and school personnel. For the studies performed in 2015, objective assessments included: 1) the WIAT Reading Fluency, 2) WIAT Reading Comprehension and 3) the K-D Test. In 2014, Leong et al used objective assessments 1) the WIAT Reading Fluency and 2) the K-D Test. Wethe et al[32] and Allen et al[26] studies administered 1) Scholastic Fluency Formula Assessment and 2) the K-D Test as pre- and post-training assessments.

Treatment protocol consisted of eye movement training with RAP. All treatment sessions were carried out in the subjects' school. Each student participated in 18 training sessions of 20-minutes each, for a total of six hours of training. The total training length

Table 1. Enrollment Demographics (n=611)

	Control (n=122)	Treatment (n=378)	High Needs (n=111)	Extra-Training (n=58)
Age (yrs), mean (SD)	6.9 (0.8)	7.1 (0.9)	6.8 (0.8)	7.2 (0.7)
Male (%)	50	53	51	54
Grade 1 (%)	61	50	62	54
Grade 2 (%)	34	36	35	46
Grade 3 (%)	5	11	3	–
Grade 4 (%)	–	3	–	–
Race (%)				
Caucasian	79	74	85	88
African American	18	24	7	9
Asian/Pacific Islander	2	1	2	0
American Indian/ Alaskan	0	0	1	0
Other	1	1	5	3
Hispanic (%)	7	7	23	14

ranged from five to six weeks depending on the study, and the total six hours of training was consistent across the studies. Dodick et al[31] extended treatment for an average of 11 sessions, two weeks longer for students who failed the rapid number naming test at the post-training assessment.

The control group read aloud single, randomized numeric targets zero through nine, positioned in the center of the screen which did not change positions and did not simulate the left to right saccadic eye movements used during reading. The speed of presentation could be varied from 10 to 500 numbers per minute. The speed of presentation was similarly increased as subjects' ability improved.

After the 18 sessions, subjects in both treatment and control group were reassessed with the standardized assessments. All testing procedures were identical to pre-treatment testing. The control groups were then crossed-over to complete the same 18 session treatment protocol of the treatment group and assessed post-treatment. Another post-assessment was performed for the extended treatment group, who went beyond 6 weeks of training.

Statistical Analysis

Statistical analyses were performed using the Stata 12.0 software (StataCorp, College Station, Texas). Percent change between individual pre- and post-treatment scores was calculated. Descriptive statistics of mean and standard deviation were used to summarize the continuous measures of the cohort. Normality assumption for variables of interest was checked using Shapiro Wilk test. Pre- and post-treatment scores were compared using paired t-tests. Percent changes between groups were compared using two sample t-tests. Two of the studies obtained access to student information including enrollment in an IEP or students enrolled in reading assistance. Students identified in this high needs subgroup were analyzed separately. Four studies were conducted in the spring semester and one in the fall semester, therefore comparisons between outcomes from these studies were conducted. Statistical significance was set at $p < 0.05$.

RESULTS

Characteristics of the study cohort (n=611) are displayed in Table 1. Age, gender, grade level, and racial background were similar between the treatment and control groups. The high-needs (n=111) and extra-training (n=58) group characteristics are also displayed in Table 1.

Reading Fluency

The control and treatment groups had similar pre-treatment scores for reading fluency. Both groups demonstrated a significant improvement in fluency ($p<0.001$, Table 2); however, the treatment group had a greater improvement in fluency compared to the control group ($p<0.001$, Table 2). The treatment group achieved a significant change from the 55th percentile rank pre-treatment to the 69th percentile rank post-treatment ($p<0.001$, Figure 1).

Table 2. Wechsler Individual Achievement Test Third Edition (WIAT) Reading Fluency Score by Group

Reading Fluency (n=500)							
	Percentile Rank, mean (SD)			Standard Score, mean (SD)			
	Pre-Treatment	Post-Treatment	*P*	Pre-Treatment	Post-Treatment	Change	*P*
Control (n=122)	56th (28)	68th (26) P < 0.001[a]	P = 0.008[b]	104 (15)	109(15)	5.9%	P < 0.001[b]
Treatment (n=378)	55th (30)	69th (28) P < 0.001[a]		103 (17)	112 (17) P < 0.001[a]	8.9%	

[a] Pre-treatment vs. Post-treatment comparison using paired t-test
[b] Control vs. Treatment group percent change comparison using two sample t-test

Table 3. Wechsler Individual Achievement Test Third Edition (WIAT) Reading Comprehension Score by Group

Reading Comprehension (n=393)							
	Percentile Rank, mean (SD)			Standard Score, mean (SD)			
	Pre-Treatment	Post-Treatment	*P*	Pre-Treatment	Post-Treatment	Change	*P*
Control (n=104)	66th (20)	72nd (19) P < 0.001[a]	P = 0.001[b]	108 (10)	111 (11) P < 0.001[a]	3.1%	P < 0.001[b]
Treatment (n=289)	62nd (22)	78th (17) P < 0.001[a]		106 (10)	115 (11) P < 0.001[a]	9.1%	

[a] Pre-treatment vs. Post-treatment comparison using paired t-test
[b] Control vs. Treatment group percent change comparison using two sample t-test

Table 4. High-Needs Group Fluency and Comprehension WIAT Subscale Scores

High-Needs Group (n=111)					
	Percentile Rank, mean (SD)		Standard Score, mean (SD)		
	Pre-Treatment	Post-Treatment	Pre-Treatment	Post-Treatment	Change
Fluency	23rd (19)	37th (25) P < 0.001[a]	85 (13)	94 (13) P < 0.001[a]	11.2%
Comprehension	37th (24)	53rd (27) P < 0.001[a]	93 (13)	99 (19) P < 0.001[a]	7.6%

[a] Statistically Significant Pre-treatment vs. Post-treatment comparison using paired t-test

Reading Comprehension

Both groups also demonstrated improvements in reading comprehension. This was statistically significant for the treatment and control groups (p<0.001, Table 3). Similar to reading fluency, the treatment group had a greater improvement in comprehension as compared to the control group (SS 9.1% vs. 3.1%, p<0.001, Table 3).

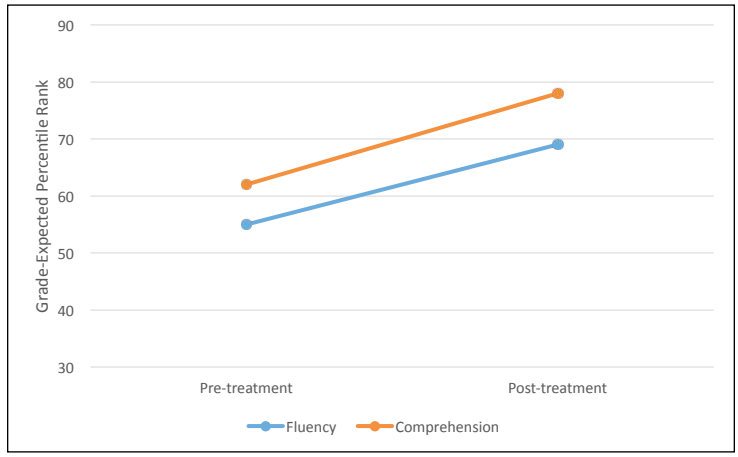

Figure 1: Figure 1. Treatment Group Reading Performance Measures

High Needs Subgroup

Reading outcomes of the high-needs student group (n=111) are displayed in Table 4. These students had significantly lower initial reading scores compared to the rest of the treatment group (26th PR reading fluency vs. 67th, p<0.001; 40th PR reading comprehension

Table 5. Extra-Training Sub Group Fluency and Comprehension Scores

Extra-Training Sub-Group (n=58)							
	Percentile Rank, mean (SD)			Standard Score, mean (SD)			
	Pre-Treatment	Post-Treatment	Post-Extra Training	Pre-Treatment	Post-Treatment	Post-Extra Training	Change
Fluency	36th (26)	48th (29)	56th (31) p<0.001[a]	92 (15)	99 (14)	104 (18) p = 0.003[a]	13.1%
Comprehension	47th (25)	63rd (28)	68th (23) p=0.015[a]	98 (12)	103(24)	109 (12) p = 0.013[a]	11.2%

[a] Statistically Significant Post-Treatment vs. Post-Extra Training comparison using paired t-test

Table 6. Fall vs Spring Wechsler Individual Achievement Test Third Edition (WIAT) Reading Comprehension Score by Group

Reading Comprehension (n=393)						
	Percentile Rank, mean (SD)		Standard Score, mean (SD)			
	Pre-Treatment	Post-Treatment	Pre-Treatment	Post-Treatment	Change	*P*
Spring **Control (n=69)** **Treatment (n=188)**	65th (22) 63rd (21)	70th (20) 78th (17) p = 0.005[a]	108 (11) 106 (10)	110 (11) 114 (10)	2.5% 8.1% P < 0.001[a]	P < 0.001[b]
Fall **Control (n=35)** **Treatment (n=101)**	68th (18) 59th (23)	76th (16) 79th (17) P = 0.006[a]	108 (9) 105 (11)	113 (11) 116 (12)	4.5% 10.9% P < 0.001[a]	

[a] Control vs. Treatment group percent change comparison using two sample t-test
[b] Spring vs. Fall percent change comparison using two sample t-test

vs. 63rd, p<0.001) and demonstrated significant PR and SS improvements in fluency and comprehension during the treatment period (Table 4).

Extended Treatment

Treatment group students who performed below age expectations on the K-D Test and continued on for extra training (n=58) received an average of 11 additional sessions. These students saw significant improvements in reading fluency and comprehension both in the initial treatment period as well as following the extra training (p=0.003 fluency, p=0.013 comprehension, Table 5). Overall these students demonstrated a 13.1% change in SS for reading fluency and an 11.2% change in SS for reading comprehension.

Fall vs. Spring Training

A comparison between Fall and Spring seasons of training was performed. While students in both fall and spring significantly improved post-treatment in reading comprehension, there were greater improvements in reading comprehension in the fall across both control and treatment groups however the treatment group demonstrated the greatest improvement in the fall compared with spring (change in SS: 10.9% vs 8.1%, p<0.001, Table 6).

During the course of the training there were 15 students (2.4% of the entire cohort) following treatment who did not improve in reading fluency and 60 students (12% of the entire cohort) who did not improve in reading comprehension.

Students who had below expected performance (beyond one standard deviation of age-based norms[33]) on the K-D Test assessment also scored significantly lower in reading fluency (p<0.001, Table 7) and comprehension (p<0.001, Table 7) in their pre-treatment reading assessments compared to students who scored at or above expected K-D test performance. Dodick et al found that students in the treatment group who performed significantly below expectation on the K-D

Table 7. Performance on the King-Devick Test

Performance on the Pre-Treatment King-Devick Test			
	Below Expected K-D Performance (n=156)	**At or Above Expected K-D Performance (n=171)**	***P***
Fluency Percentile Rank, mean (SD)	39th (28)	60th (30)	$p < 0.001$a
Fluency Standard Score, mean (SD)	94 (16)	105 (16)	$p < 0.001$a
Comprehension Percentile Rank, mean (SD)	51st (25)	63rd (22)	$p < 0.001$a
Comprehension Standard Score, mean (SD)	100 (13)	106 (11)	$p < 0.001$a

[a] Statistically Significant Below Expected vs. At or Above Expected K-D Performance comparison using two sample t-test

assessment (n=133) had a significantly greater improvement in fluency following treatment compared to students who performed at or above expectation on the K-D Test (73% vs. 31% increase in fluency respectively, p<0.001). There was a similar improvement in reading comprehension scores across both groups (54% improvement in comprehension for the below K-D Test expectation group and 51% improvement for the group that performed at or above expected on K-D Test).

DISCUSSION

Collectively, the studies of eye movement training intervention provide evidence that K-D RAP significantly improves reading fluency and comprehension performance in grade school students. Pre- and post-treatment assessments from five different schools showed that reading fluency and comprehension scores significantly improved following treatment. The comparison between the treatment and control groups was significant, demonstrating that the treatment had an effect on reading performance compared to placebo training. When the control group was crossed-over into active treatment, they achieved significant gains in reading fluency and comprehension as well.

There was an overall increase in reading fluency and comprehension performance in both the treatment and control groups, which was expected since students were concurrently continuing to learn to read in school for the duration of the studies. The control group's reading improvement may also be attributed to the placebo protocol of rapid number naming task which involve aspects of visual attention and processing speed. Both tasks have been shown to have a positive effect on reading performance.[34,35]

Reading comprehension was included as an outcome measure in the study by Dodick et al. Comprehension is the main purpose of reading, and the additional testing demonstrated that eye movement training could impact comprehension. These results were similar to a previous study that had also examined the effect of eye movement training on reading comprehension.[34] This study assigned 6th grade students with reading difficulties to undergo eye movement therapy, then reading comprehension therapy or vice versa. The results showed that both eye movement and reading comprehension therapy significantly improved reading comprehension and eye movement efficiency. The authors attributed the improvement to changes in visual attention, while Dodick et al attribute the changes to processing speed and oculomotor efficiency, in addition to visual attention.

To further explore dose ranging and better determine the optimal length of treatment, Dodick et al also included extra training for students who were below average in eye movement performance following the standard 6-week training. With an average of 11 additional sessions, the group demonstrated

continued gains in reading fluency and comprehension with the additional training. These improvements suggest that some students may realize increased benefits from longer training programs. This is an area for future research to further understand the ideal training duration for reading improvement. Reading improvements persisted at the one-year follow up for students enrolled in the study by Leong et al. Continued longitudinal studies would provide information on the lasting effects beyond one year. Additionally, the evaluation of standardized academic testing before and after training would allow for further insight into how eye movement training affects overall academic performance.

Students who scored below age expectation on the K-D Test based on normative data[33] scored significantly lower average fluency and comprehension scores compared to students who performed at or above expected norms for the K-D Test. The K-D Test may be used as a quick and easy to use, screening tool to identify students who are below average in reading performance and may benefit the most from eye movement training. It is important to note that average and above average students significantly improved in reading as well.

A high needs student subgroup was examined by Dodick et al.[31] The high needs student group demonstrated the largest improvement in reading fluency compared with the overall treatment group. The high needs group improved, however to a lesser degree than the overall treatment group in reading comprehension. This difference may be due to students acquiring reading fluency skills prior to realizing reading comprehension improvements. Reading comprehension is a more difficult task and may develop later for this group. Since the high needs students achieved an 11.2% improvement compared to 9.2% for the overall treatment group in reading fluency standard score following treatment, this population may benefit the most from eye movement training. Future longitudinal studies would be beneficial to understanding how reading performance changes over time in this population.

A fall study was performed to examine eye movement training at the start of the academic school year. All prior studies were performed in the spring. Treatment had a significant effect on reading performance during both time points in the academic school year; however, students improved to a greater degree in the fall lending insight into a potential ideal window for implementation of eye movement training within the school year. Further study to examine optimal timing of training administration is warranted.

Each study was valuable in providing a new insight on K-D RAP in the school curriculum. There was a diverse population of racial background and socio-economic demographics when all studies were combined. Despite there being a broad and large student population, limitations existed in these studies. Comprehensive visual evaluations were not conducted as part of these investigations. Therefore, other aspects of visual processing may also affect reading performance measurements. The Hispanic population in the control and treatment group was less than the national average of 17%.[36] However, there were more Hispanic students in the high needs group than the national average, which may be explained by enrollment in ELL. The testers were not masked to the group allocation of the students and also represents a study limitation. Future studies should consider masking reading fluency and comprehension test administrators. Comparing academic test scores before and after K-D RAP would provide further insight into how this type of eye movement training may translate into overall academic success. Future research is needed to explore appropriate length and timing of training in order to maximize reading outcomes. Long term follow-up for the students in each study is not yet available. Prior studies

have shown reading performance stability over the course of one and two year follow-up,[25] therefore ongoing follow-up of this cohort will provide useful longitudinal information regarding reading fluency and comprehension and the effectiveness of K-D RAP. Despite the limitations, these studies provide increasing evidence that implementing eye movement training in the grade school curriculum is beneficial in early reading performance.

The positive reading outcomes following the training protocol with K-D RAP may be attributed to the repetitive practice of eye movements, shifting visuospatial attention, and visual processing. These tasks are components of the physical act of reading. Saccades, vergence, and accommodation tasks are all engaged while performing K-D RAP. The data on accommodative and convergence training provides further evidence that eye movement skills can be trained and improved.[25-28,32,37] The results of this study show that early reading skills improved with the implementation of K-D RAP, an in-school eye movement training, to teach the physical act of reading. Early education widely accepts teaching the physical act of writing through practicing fine motor movements, in-hand manipulation, and visual-motor control.[38] Similarly, teaching the physical act of reading through increasing the efficiency of eye movements should also be considered[39] as improving reading skills in youth is essential to building the foundations for future academic success.

CONCLUSION

There is a national need to examine ways of improving grade school reading performance in the United States. The eye movement training program, K-D RAP, resulted in significant improvements in reading fluency and comprehension. The program was flexibly incorporated into the daily classroom schedule for each school over a five to six-week period and an eight-week period for extended treatment. Efficient eye movements are one necessary component of proficient reading that integrate with visual processing, word decoding and attention span. Cognitive processing also contributes to successful reading. K-D RAP improves aspects of reading that are not currently addressed in schools. Based on the positive reading outcomes found in this summary, there is increasing evidence to support the inclusion of teaching the physical act of reading in the early education curriculum nation-wide.

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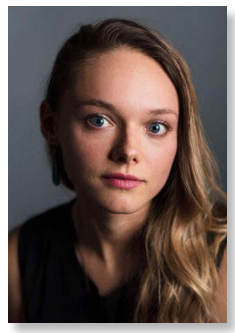

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