



Sustainability of the effect of optical intervention on the reading performance of children with dyslexia

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ABSTRACT

Background: Dyslexia is a learning disability associated with reading difficulties in children. Due to the potential of poor school outcomes interventions have been employed to help students with dyslexia read. This study was aimed at identifying the sustainability of the effect of combined Visual Tracking Magnifier (VTM) and Ministry of Education (MOE) interventions and MOE intervention alone on the reading performance of school children with dyslexia after discontinuation of intervention.

Methods: This prospective, interventional study was conducted on primary school children with dyslexia aged 8 – 11 years. The participants underwent comprehensive ophthalmic and optometric examinations and were categorized into groups A, B, and C, comprising primary school children at level 1 or 2. Groups A and B received combined VTM and MOE interventions for 12 and 24 weeks, respectively, and group C received MOE intervention alone. The reading performance was assessed at baseline and 12, 24, and 36 weeks post-intervention.

Results: Both components of the reading performance improved significantly for school children at both levels in all study groups (all $P < 0.05$). However, the reading performance improvement was only approximately 28% in group C and 38% – 50% in groups A and B. In group A, students at level 1 showed significantly improved reading speed from baseline to 12 weeks post-VTM intervention and reading rate from baseline to 24 weeks post-VTM intervention (both $P < 0.05$). Students at level 2 showed significantly improved reading speed and rate from baseline to 12 and 24 weeks post-VTM intervention (all $P < 0.05$). In group B, students at both levels showed significantly improved reading speed and rate from baseline to 24 and 36 weeks post-VTM intervention (all $P < 0.05$). Students at level 2 showed significantly improved reading speed 12 weeks after cessation of intervention (at 36 weeks post-VTM intervention) compared to 24 weeks post-VTM intervention ($P < 0.05$). The improvement remaining stable 12 weeks after discontinuation of intervention indicated a sustained effect.

Conclusions: Combined or individual intervention improved the reading performance of school children with dyslexia at levels 1 and 2. However, combined intervention showed a better reading improvement effect. Improvement in the reading performance was maintained after discontinuation of the VTM intervention. Further interventional studies with a longer study period after discontinuation of this optical intervention are required to confirm the long-term sustainability of its positive effects on the reading performance of school children with dyslexia.

KEYWORDS


dyslexia, optical device, visual aid, reading, educational early intervention, children, student, primary school, school

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INTRODUCTION

Dyslexia is a learning disorder associated with reading difficulties in children [1]. Children with dyslexia have normal intelligence and intact sensory abilities but difficulty in recognizing alphabets, reading accurately or fluently, and spelling [2]. It is a neurological condition that interferes with an individual's ability to store, process, or produce information [3]. Family environment and parenting factors are significantly associated with dyslexia in children. Children with dyslexia show personalities of psychoticism, neuroticism, introversion, and other behavioral problems. The quality of life of children is significantly impacted by dyslexia [4].

The estimated worldwide prevalence of dyslexia ranges from 4% to 10% [5-7]. Boys are more likely to develop dyslexia compared to girls [1]. In Malaysia, almost 7% of grade 3 students and 4% of university graduates are at risk of developing dyslexia [8].

Reading is integral to the learning process in children. Without adequate reading skills, comprehension and understanding abilities may be affected in children with dyslexia [9]. Therefore, improving the reading performance is essential. Reading performance is quantified objectively as reading speed and rate [10]. Using specific reading aids can help children with dyslexia read and process text easier. These aids also facilitate their learning sessions at school [11].

In a recent optical intervention study, the reading performance of school students with dyslexia improved with Visual Tracking Magnifier (VTM) intervention by 2.5 times compared to the use of telescope and magnifier and other interventions. VTM intervention yielded the highest improvement in the reading performance after 12 weeks [12]. Despite this observed improvement in the reading performance, sustainability of the effect after cessation of the intervention remains unknown. Therefore, the aim of the present study was to identify the sustained effect of combined VTM and Ministry of Education Malaysia (MOE) interventions and MOE intervention alone on the reading performance of children with dyslexia after discontinuation of intervention to ensure durability of the improved reading performance.

METHODS

This prospective, interventional study was conducted on primary school children with dyslexia aged 8 – 11 years from September 2019 to July 2020 selected from Special School Dyslexia Programs by MOE, Malaysia. The sample size was calculated for the two-way repeated-measures analysis of variance (ANOVA) using G*Power software version 3.1.9.4 [13]. Ethical approval was obtained from the Research Ethics Committee of Universiti Kebangsaan Malaysia (approval no.: UKM1.5.3.5/244/NN-070-2012). The study was performed in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained 2 weeks before commencement of the study from the parents or legal guardians of the children.

Children with dyslexia [14] were selected randomly from schools conducting the Dyslexia Program in Klang Valley, Malaysia. Inclusion criteria were the diagnosis of dyslexia, age of 8 – 11 years, normal intelligence quotient (IQ), best-corrected distance visual acuity of 6/9 or better, and best-corrected near visual acuity of N6 or better. Children with dyslexia with systemic diseases that can potentially interfere with the reading performance or ability to handle VTM intervention and those with convergence problems were excluded. MOE, Malaysia, defines level 1 as the primary school children aged 7 – 9 years and level 2 as the primary school children aged 10 – 12 years. Students from year 1 or 6 were not included, because students from year 1 had started school while those from year 6 were preparing for a special examination called the Primary School Achievement Test (Ujian Penilaian Sekolah Rendah).

All recruited children underwent thorough dyslexia screening [15], followed by the Raven's Colored Progressive Matrices Test for IQ [16], monocular and binocular unaided and aided visual acuity measurements at 6 m and 40 cm [17, 18], near point of convergence measurement [19], amplitude of accommodation measurement [19], ophthalmoscopy [20], retinoscopy, and subjective refraction [21]. Participants who fulfilled the inclusion criteria were evaluated for the reading performance [12, 22] based on the reading speed and rate. Reading speed was defined as the time taken to read a text and expressed as words/min (wpm). The reading rate was calculated by dividing the number of words correctly read by the reading duration and also expressed as wpm.

The reading performance of each participant was determined using the related world reading text designed by Omar et al. [10]. Optical intervention was performed with VTM using the 18.9-D powered COIL brand (COIL, Desa Pandan, KL, Malaysia) with a 1.7 × magnification power, a 7-mm reading aperture at the center, and a 143 × 104-mm-wide viewing area. In addition, the VTM has a semicircular grey filter at the top and bottom that plays

a key role in increasing the text's reading contrast and reducing the distortion of the text image. Furthermore, the pointer of VTM helps users maintain eye position at the readable lines of the text.

Participants were allocated into three groups, and each group had students at both levels. All school children with dyslexia were randomly selected using a table of random numbers. The reading speed was categorized into very slow, slow, and normal for children at both levels based on the previously published range [10]. Participants in group A received combined VTM and MOE interventions for 12 weeks, followed by discontinuation of the VTM intervention. The reading performance was measured at baseline, after 12 weeks of the VTM intervention, and at 24 weeks, i.e., 12 weeks after discontinuation of the VTM intervention. Participants in group B received combined VTM and MOE interventions for 24 weeks, followed by discontinuation of the VTM intervention. For group B, the reading performance was measured at baseline, 24 weeks, and 36 weeks, i.e., 12 weeks after discontinuation of the VTM intervention. The time interval between discontinuation of the VTM intervention and re-evaluation of the reading performance was 12 weeks in both groups. Group C, or the control group, included school children with dyslexia who received the MOE intervention alone. For group C, the reading performance was evaluated at baseline, 12 weeks, 24 weeks, and 36 weeks. Figure 1 shows the study flowchart.

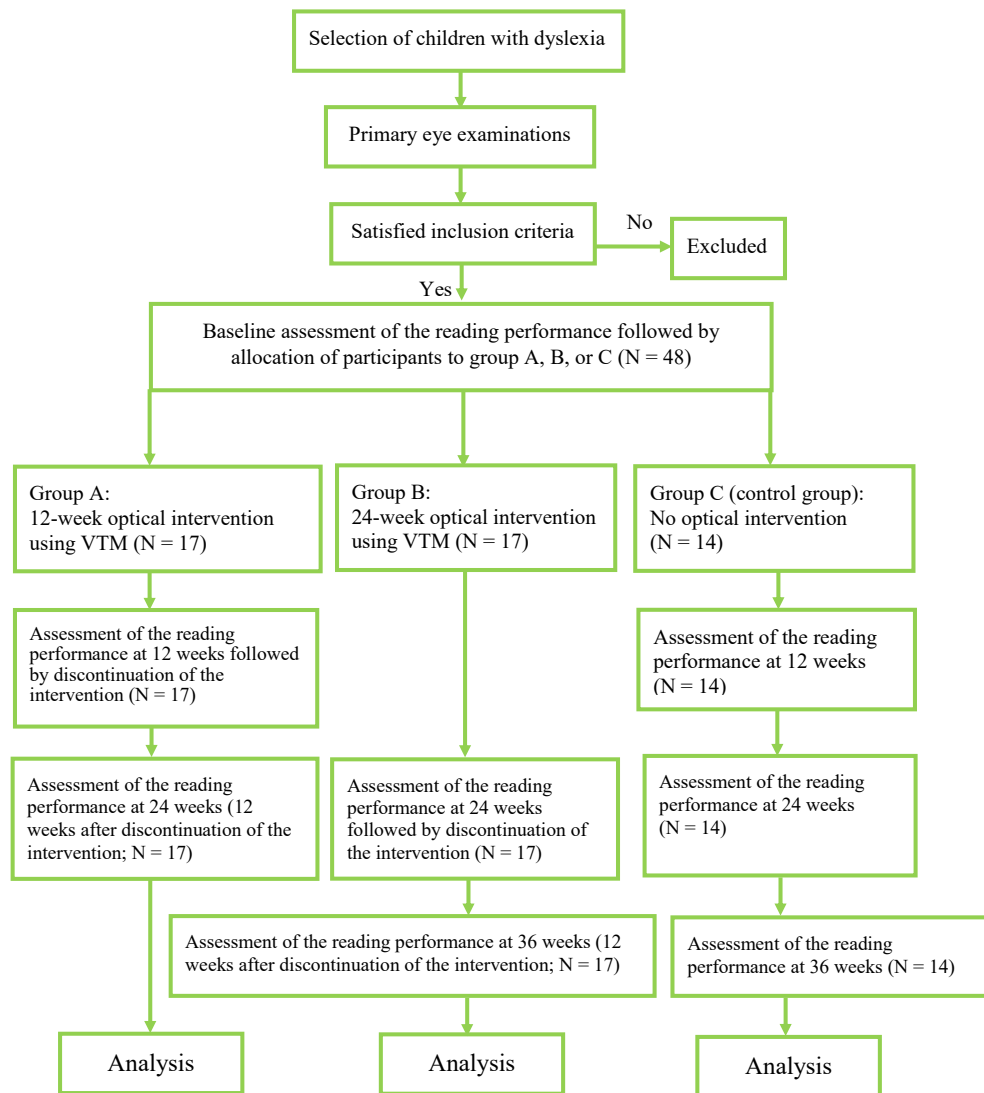


Figure 1. Study flowchart. Note: Included children with dyslexia were allocated to group A, B, or C. Group A, received optical intervention with the Visual Tracking Magnifier (VTM) and Ministry of Education (MOE) interventions for 12 weeks; Group B, received VTM and MOE interventions for 24 weeks; Group C, or the control group, received the MOE intervention alone; The reading performance constituted the reading speed and rate; The reading speed was defined as the time taken to read the text and expressed as words/min; The reading rate was calculated by dividing the number of words correctly read by the reading duration and expressed as words/min.

Statistical analyses were performed using IBM SPSS Statistics for Windows (version 21.0, IBM Corp., Armonk, NY, USA). Normality of data distribution was tested with the Shapiro – Wilk test. Based on the normality test results, a parametric test was performed. The reading performance (reading speed and rate) was compared among groups A, B, and C for children at levels 1 and 2 with the repeated-measures one-way ANOVA, followed by a post-hoc analysis with the Bonferroni test for pairwise comparisons. The homogeneity of variance was checked using Levene's test. Bonferroni correction was performed to avoid type I error. Furthermore, the change in the reading speed or rate in groups A and B in each post-intervention measurement from its corresponding baseline values were compared with those in group C. A *P*-value of < 0.05 was considered to indicate statistical significance.

RESULTS

We enrolled a total of 48 school children with dyslexia, including 40 (83%) boys and eight (17%) girls, with age ranging from 8 to 11 years. Participants in level 1 were 20 children with dyslexia, with age ranging from 8 to 9 years, while those in level 2 were 28 children with dyslexia, with age ranging from 10 to 11 years. In children with dyslexia, the mean descriptive data obtained from vision tests conducted before the optical intervention were within normal limits, and the mean (SD) IQ was 30.5 (23.3). All participants in each group and at each level showed a similar baseline level of reading performance. The baseline reading speed at level 1 was categorized as slow while that at level 2 was categorized as very slow. Table 1 shows the reading performance at levels 1 and 2 for all groups.

Table 1. Improvement in the reading performance of children with dyslexia according to the duration of intervention

Study Group	School level (n)	Measurement time	Reading performance			
			Reading speed (words/min)		Reading rate (words/min)	
			Mean ± SD	<i>P</i> -value	Mean ±SD	<i>P</i> -value
Group A	Level 1 (n = 6)	Baseline	28.47 ± 20.07	0.016	25.80 ± 20.46	0.009
		12-week	44.40 ± 21.54		42.03 ± 22.75	
		24-week	56.18 ± 27.44		54.59 ± 27.25	
	Level 2 (n = 11)	Baseline	41.54 ± 14.40	0.001	38.68 ± 15.06	< 0.001
		12-week	58.04 ± 22.07		56.29 ± 22.68	
		24-week	65.61 ± 27.48		64.39 ± 28.22	
Group B	Level 1 (n = 6)	Baseline	28.07 ± 13.35	0.007	26.23 ± 13.30	0.005
		24-week	46.89 ± 12.00		45.74 ± 12.55	
		36-week	55.05 ± 20.07		54.73 ± 20.16	
	Level 2 (n = 11)	Baseline	35.91 ± 16.23	< 0.001	34.19 ± 16.86	< 0.001
		24-week	58.77 ± 29.97		57.55 ± 30.04	
		36-week	63.05 ± 28.64		62.17 ± 28.10	
Group C	Level 1 (n = 8)	Baseline	28.73 ± 22.18	0.001	27.05 ± 23.06	0.003
		12-week	36.53 ± 21.58		35.01 ± 21.85	
		24-week	39.46 ± 23.04		37.82 ± 23.33	
		36-week	39.88 ± 23.61		38.44 ± 23.57	
	Level 2 (n = 6)	Baseline	39.86 ± 22.19	0.004	38.11 ± 22.63	0.011
		12-week	57.14 ± 30.25		53.24 ± 30.82	
		24-week	66.72 ± 33.75		58.72 ± 32.76	
		36-week	67.29 ± 32.58		67.01 ± 32.61	

Abbreviations: n, number of students; min, minutes; SD, standard deviation. *P*-values < 0.05 are shown in bold. Note: Group A, received optical intervention with the Visual Tracking Magnifier (VTM) and Ministry of Education (MOE) interventions for 12 weeks; Group B, received VTM and MOE interventions for 24 weeks; Group C, or the control group, received the MOE intervention alone; The reading performance constituted the reading speed and rate; The reading speed, was defined as the time taken to read the text and expressed as words/min; The reading rate, was calculated by dividing the number of words correctly read by the reading duration and expressed as words/min; Level 1, 20 primary school children with dyslexia with age ranging from 8 to 9 years; Level 2, 28 primary school children with dyslexia with age ranging from 10 to 11 years.

Table 2. The Bonferroni post-hoc analysis results of improvement in the reading performance of school children with dyslexia according to the duration of intervention

Study Group	School Level	Measurements time				Reading Performance				
		Mean Difference	SEM	95% CI Difference	P-value	Mean Difference	SEM	95% CI Difference	P-value	
Group A	Level 1 (n = 6)	Baseline versus 12-week	-15.92	4.43	-31.60 – -0.25	0.047	-16.23	5.25	-34.79 – 2.32	0.081
		Baseline versus 24-week	-27.70	8.05	-56.16 – 0.75	0.055	-28.79	7.72	-56.08 – -1.50	0.040
	Level 2 (n = 11)	12-week versus 24-week	-11.78	7.37	-37.83 – 14.27	0.513	-12.56	7.22	-38.08 – 12.96	0.427
		Baseline versus 12-week	-16.50	4.07	-28.19 – -4.80	0.007	-17.60	3.82	-28.59 – -6.61	0.003
		Baseline versus 24-week	-24.07	5.91	-41.05 – -7.08	0.007	-25.70	5.83	-42.45 – -8.95	0.004
		12-week versus 24-week	-7.57	3.65	-18.06 – 2.92	0.196	-8.09	3.68	-18.68 – 2.48	0.158
Group B	Level 1 (n = 6)	Baseline versus 24-week	-18.82	4.98	-36.43 – -1.21	0.039	-19.51	4.94	-36.99 – -2.03	0.033
		Baseline versus 36-week	-26.98	7.01	-51.77 – -2.19	0.036	-28.50	6.95	-53.09 – -3.92	0.028
	Level 2 (n = 11)	24-week versus 36-week	-8.16	3.65	-21.06 – 4.74	0.227	-8.99	3.66	-21.95 – 3.96	0.173
		Baseline versus 24-week	-22.85	4.94	-37.03 – -8.66	0.003	-23.35	4.73	-36.95 – -9.75	0.002
		Baseline versus 36-week	-27.13	4.72	-40.69 – -13.57	0.001	-27.98	4.39	-40.59 – -15.36	<0.001
		24-week versus 36-week	-4.28	1.39	-8.28 – -0.28	0.035	-4.62	1.61	-9.26 – 0.02	0.051
Group C	Level 1 (n = 8)	Baseline versus 12-week	-7.79	2.25	-15.99 – 0.39	0.063	-7.95	2.43	-16.79 – 0.89	0.082
		Baseline versus 24-week	-10.72	2.31	-19.14 – -2.30	0.014	-10.76	2.71	-20.65 – -0.88	0.033
	Level 2 (n = 6)	Baseline versus 36-week	-11.14	2.34	-19.67 – -2.61	0.012	-11.39	2.75	-21.39 – -1.38	0.026
		12-week versus 24-week	-2.92	0.99	-6.54 – 0.68	0.129	-2.81	0.96	-6.31 – 0.68	0.133
		12-week versus 36-week	-3.35	0.96	-6.87 – 0.17	0.064	-3.43	0.99	-7.04 – 0.17	0.063
		24-week versus 36-week	-0.42	0.47	-2.15 – 1.31	1.000	-0.62	0.70	-3.19 – 1.95	1.000
Level 2 (n = 6)	Baseline versus 12-week	-17.27	5.55	-40.73 – 6.18	0.160	-15.13	5.47	-38.24 – 7.98	0.238	
	Baseline versus 24-week	-26.85	6.26	-53.27 – -0.43	0.047	-20.61	8.47	-56.35 – 15.13	0.355	
	Baseline versus 36-week	-27.43	5.75	-51.72 – -3.13	0.030	-28.89	5.70	-52.94 – -4.84	0.023	
	12-week versus 24-week	-9.58	2.26	-19.13 – -0.02	0.049	-5.47	7.29	-36.26 – 25.31	1.000	
Level 2 (n = 6)	12-week versus 36-week	-10.15	2.65	-21.33 – 1.02	0.073	-13.76	2.98	-26.36 – -1.15	0.035	
	24-week versus 36-week	-0.57	1.42	-6.59 – 5.44	1.000	-8.28	5.00	-29.40 – 12.83	0.953	

Abbreviations: SEM, standard error of mean; CI, confidence interval; n, number of students; min, minutes. P-values <0.05 are shown in bold. Note: Group A, received optical intervention with the Visual Tracking/Magnifier (VTM) and Ministry of Education (MOE) interventions for 12 weeks; Group B received VTM and MOE interventions for 24 weeks; Group C, or the control group, received the MOE intervention alone; The reading performance constituted the reading speed and rate; The reading speed was defined as the time taken to read the text and expressed as words/min; The reading rate was calculated by dividing the number of words correctly read by the reading duration and expressed as words/min; Level 1, 20 primary school children with dyslexia with age ranging from 8 to 9 years; Level 2, 28 primary school children with dyslexia with age ranging from 10 to 11 years.

Both components of the reading performance improved significantly at both levels in all study groups (all $P < 0.05$; Table 1). However, the improvement in the reading performance was only approximately 28% in group C and ranged from 38% to 50% in groups A and B. These findings indicate that any form of intervention for children with dyslexia to read better was effective. Using combined VTM and MOE interventions showed better improvement in the reading performance.

The Bonferroni post-hoc analysis for pairwise comparisons was performed on the long-term effect of the VTM intervention in groups A and B at 24 and 36 weeks post-VTM intervention (Table 2). For group A, the VTM intervention was discontinued at 12 weeks, and the measurement was obtained at 24 weeks. Children at level 1 showed a significantly improved reading speed from baseline to 12 weeks post-VTM intervention and reading rate from baseline to 24 weeks post-VTM intervention (both $P < 0.05$). Children at level 2 showed significantly improved reading speed and rate from baseline to 12 and 24 weeks post-VTM intervention (all $P < 0.05$). In group B, children at both levels showed significantly improved reading speed and rate from baseline to 24 and 36 weeks post-VTM intervention (all $P < 0.05$; Table 2). This improvement was maintained in both groups after discontinuation of the intervention as shown by the lack of statistically significant difference between 12 and 24 weeks post-intervention in group A in the reading performance at both levels and between 24 and 36 weeks post-intervention in group B in the reading performance at level 1 and reading rate at level 2 (all $P > 0.05$; Table 2).

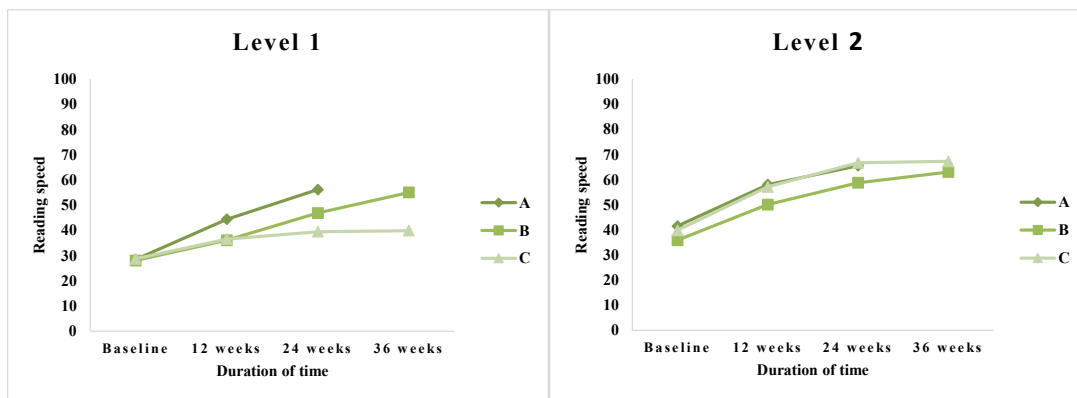


Figure 2. Trend of the reading speed from baseline to post-intervention for children at levels 1 (left) and 2 (right) in all study groups. Note: A, Group A received optical intervention with the Visual Tracking Magnifier (VTM) and Ministry of Education (MOE) interventions for 12 weeks; B, Group B received VTM and MOE interventions for 24 weeks; C, Group C, or the control group, received the MOE intervention alone; The reading speed was defined as the time taken to read the text and expressed as words/min; Level 1, 20 primary school children with dyslexia with age ranging from 8 to 9 years; Level 2, 28 primary school children with dyslexia with age ranging from 10 to 11 years.

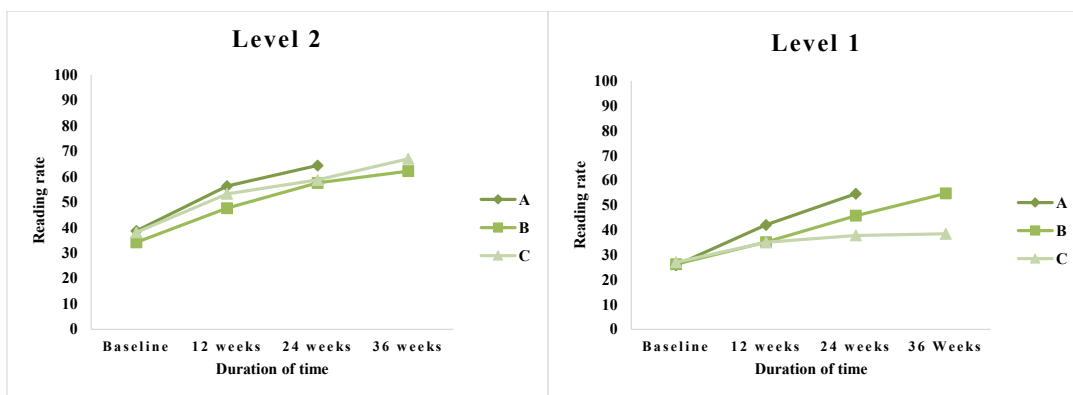


Figure 3. Trend of the reading rate from baseline to post-intervention for children at levels 1 (left) and 2 (right) in all study groups. Note: A, Group A received optical intervention with the Visual Tracking Magnifier (VTM) and Ministry of Education (MOE) interventions for 12 weeks; B, Group B received VTM and MOE interventions for 24 weeks; C, Group C, or the control group, received the MOE intervention alone; The reading rate was calculated by dividing the number of words correctly read by the reading duration and expressed as words/min; Level 1, 20 primary school children with dyslexia with age ranging from 8 to 9 years; Level 2, 28 primary school children with dyslexia with age ranging from 10 to 11 years.

Children at reading level 2 showed significantly improved reading speed 12 weeks after discontinuation of the intervention (at 36 weeks post-VTM intervention) compared to 24 weeks post-VTM intervention ($P < 0.05$; Table 2). This finding indicated sustained improvement in the reading performance even after discontinuation of the VTM intervention.

In group C with MOE intervention alone, children at both levels showed significantly improved reading speed and rate from baseline to 24 and 36 weeks post-intervention (all $P < 0.05$), except for the reading rate from baseline to 24 weeks at level 2 ($P > 0.05$; Table 2). However, the improvement in the reading performance was lesser compared to that in children with dyslexia who underwent combined VTM and standard MOE interventions. This improvement was observed with delay as shown by the lack of significant difference in the reading performance between baseline and 12 weeks post-intervention in group C (Table 2). These findings indicated that long-term improvement in the reading performance could occur without the VTM intervention but with delay. It may require more time for the sustainability effect. Thus, the combined VTM and standard MOE interventions showed a sustained, long-term improvement in the reading performance in children with dyslexia.

Figures 2 and 3 demonstrate the trend of improvement in the reading speed (Figure 2) and rate (Figure 3) from baseline to post-intervention for children at both levels. The reading speed of children at level 1 improved from baseline to 24 weeks in group A by 97%, to 36 weeks in group B by 96%, to 24 weeks in group C by 37%, and to 36 weeks in group C by 39%. At level 2, the reading speed improved from baseline to 24 weeks in group A by 58%, to 36 weeks in group B by 76%, to 24 weeks in group C by 67%, and to 36 weeks in group C by 69%. These findings indicate that a combined intervention was more beneficial in improving the reading speed compared to the MOE intervention alone at level 1. However, at level 2, both interventions were equally beneficial for improving the reading performance. At level 2, the VTM intervention applied for a longer duration revealed a greater improvement in the reading speed.

The reading rate (Figure 3) in children at level 1 improved from baseline to 24 weeks in group A by 112%, to 36 weeks in group B by 109%, to 24 weeks in group C by 40%, and 36 weeks in group C by 42%. The reading rate in children at level 2 improved from baseline to 24 weeks in group A by 66%, to 36 weeks in group B by 82%, to 24 weeks in group C by 54%, and to 36 weeks in group C by 76%. Combined VTM and standard MOE interventions improved the reading rate more than the MOE intervention alone.

Table 3 shows the comparison results of all intervention groups with the control group in the change in the reading speed and rate, reflecting the change in the reading speed and rate at each post-intervention measurement from its corresponding baseline value that did not differ significantly (all $P > 0.05$).

Table 3. Comparison results for each intervention group with the control group in changes in the reading speed and rate

Change between	Group A (n = 17)	Group C (n = 14)	P-value	Group B (n = 17)	Group C (n = 14)	P-value
Baseline - 12 weeks reading speed (words/min), Mean \pm SD	53.22 \pm 22.24	45.36 \pm 26.73	0.378	-	-	-
Baseline - 24 weeks reading speed (words/min), Mean \pm SD	62.28 \pm 27.00	51.14 \pm 30.33	0.288	54.57 \pm 25.31	51.14 \pm 30.33	0.733
Baseline - 36 weeks reading speed (words/min), Mean \pm SD	-	-	-	60.23 \pm 25.58	51.63 \pm 30.11	0.139
Baseline - 12 weeks reading rate (words/min), Mean \pm SD	51.26 \pm 23.08	42.82 \pm 26.65	0.353	-	-	-
Baseline - 24 weeks reading rate (words/min), Mean \pm SD	60.93 \pm 27.44	46.78 \pm 28.65	0.172	53.38 \pm 25.44	46.78 \pm 28.65	0.502
Baseline - 36 weeks reading rate (words/min), Mean \pm SD	-	-	-	59.55 \pm 25.18	50.68 \pm 30.38	0.382

Abbreviations: n, number of students; min, minutes; SD, standard deviation. P-values < 0.05 are shown in bold. Note: Change, is the change in the reading speed or rate in each post-intervention measurement from its corresponding baseline values; Group A, received optical intervention with the Visual Tracking Magnifier (VTM) and Ministry of Education (MOE) interventions for 12 weeks; Group B, received VTM and MOE interventions for 24 weeks; Group C, or the control group, received the MOE intervention alone; The reading performance constituted the reading speed and rate; The reading speed was defined as the time taken to read the text and expressed as words/min; The reading rate was calculated by dividing the number of words correctly read by the reading duration and expressed as words/min; Level 1, 20 primary school children with dyslexia with age ranging from 8 to 9 years; Level 2, 28 primary school children with dyslexia with age ranging from 10 to 11 years.

DISCUSSION

The reading performance of all children with dyslexia had improved significantly after 12 weeks of interventions, indicating a sustained effect of the interventions. The reading speed reached the normal category from the slow category for children at level 1 in groups A and B but not in group C (control group). The reading speed improved in all groups from the very slow category to the slow category for children at level 2. These findings indicated that interventions, either combined or individual, are useful to assist children with dyslexia to improve their reading performances. However, the combined intervention showed a higher reading performance. This proved that the combination intervention is more effective than the individual intervention for children at both levels. Of all interventions, 24 weeks of the combined VTM and MOE intervention was the most consistent and effective in improving the reading performance of children with dyslexia.

In a previous study, clinical assessment of the VTM intervention was performed as part of the overall intervention to improve the reading performance of children with dyslexia [12]. The findings of the Barton Intervention Program showed significantly improved reading fluency of students with dyslexia [23], similar to the findings of the present study. The previous study supported that the reading performance can be improved using aids such as VTM for school children with dyslexia [12]. Observation and focus group discussions with teachers and children with dyslexia can provide a better understanding of the outcome of the VTM intervention.

Although VTM has been indicated as the simplest method of both assessing and treating dyslexia [24, 25], other than a previous [12] and the present studies, to the best of our knowledge, no study has investigated the efficacy or sustainability of this optical intervention in improving the reading performance of children with dyslexia. Both studies revealed positive effects of the optical intervention using VTM [12]. This positive effect was sustainable despite discontinuation of the intervention at or before 3 months. Follow-up studies involving the same group of students should be performed to examine the durability of the observed positive effects of this intervention for a longer term, i.e., after entering the upper elementary grades. This would clarify more aspects of the effectiveness of this intervention in the reading performance of children with dyslexia.

The social burden of dyslexia is high in magnitude. College students with dyslexia showed a higher rate of depressive symptoms compared to those without dyslexia [26]. Dyslexia significantly affects the quality of life of children [4]. Therefore, many studies have been aimed at investigating various interventions for improving the reading performance of children with dyslexia. Studies using multitude of interventions [27, 28] reported positive effects on the reading and writing skills of children with dyslexia. Similarly, in the present study using VTM as an optical intervention, the reading speed and rate improved significantly for children at level 1 from baseline to 24 weeks post-intervention in group A and 36 weeks post-intervention in group B. The reading speed at level 1 improved from baseline to 24 weeks in group A by 97%, to 36 weeks in group B by 96%, to 24 weeks in group C by 37%, and to 36 weeks in group C by 39%. The reading rate at level 1 improved from baseline to 24 weeks in group A by 112%, to 36 weeks in group B by 109%, to 24 weeks in group C by 40%, and 36 weeks in group C by 42%. These findings indicate that the combined intervention was more beneficial in improving the reading speed and rate compared to individual intervention for children at level 1.

The durability [29] or sustainability [30] of the positive effects of intervention on the skills of school children with dyslexia are equally important. Therefore, despite confirmed positive effects of optical intervention using VTM in our previous experience [12], in the present study, we investigated the sustainability of the positive effects of VTM on the reading performance of children with dyslexia. In both groups A and B, the improvement was maintained after discontinuation of the intervention as shown by the lack of significant difference between 12 and 24 weeks post-intervention in the reading performance for children at both levels in group A and between 24 and 36 weeks post-intervention in the reading performance for children at level 1 and reading rate for children at level 2 in group B. Children at level 2 showed significantly improved reading speed 12 weeks after discontinuation of the intervention (at 36 weeks post-VTM intervention) compared to 24 weeks post-VTM intervention.

To the best of our knowledge, this was the first study investigating the sustainability of the positive effects of combined VTM and MOE interventions in comparison with the MOE intervention alone on the reading performance of children with dyslexia after discontinuation of the intervention to ensure the durability of the improved reading performance. However, we failed to include other interventions, such as cognitive training or the multisensory method, for comparisons, which would have yielded more robust conclusions. Moreover, we failed to examine the durability of the observed positive effects on the reading performance of children with

dyslexia after entering the upper elementary grades, and follow-up studies would clarify more aspects of the effectiveness of this intervention. Including students without dyslexia along with those with dyslexia in future interventional studies with a longer follow-up after discontinuation of the VTM intervention could provide more conclusive results regarding the sustainability of the positive effects.

CONCLUSIONS

The combined and individual interventions improved the reading performance of school children with dyslexia at both levels. However, the combined VTM and MOE intervention yielded a better reading improvement effect. Furthermore, the reading performance improvement could be maintained after discontinuation of the VTM intervention, indicating a sustainability of its positive effects. The 24-week intervention period with VTM could be recommended because the reading performance sustainability was more consistent. Further interventional studies with a longer period after discontinuation of this optical intervention are required to confirm the long-term sustainability of the positive effects on the reading performance of school children with dyslexia.

ETHICAL DECLARATIONS

Ethical approval: Ethical approval was obtained from the Research Ethics Committee of Universiti Kebangsaan Malaysia (approval no.: UKM1.5.3.5/244/NN-070-2012). The study was performed in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained 2 weeks before commencement of the study from the parents or legal guardians of the children.

Conflict of interest: None.

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