Original Paper

Folia Phoniatrica et Logopaedica

Folia Phoniatr Logop 2017;69:219–225
DOI: 10.1159/000484139

Published online: March 20, 2018

Effects of Spectral Overlays on Reading Performance of Brazilian Elementary School Children

Ana Carla Oliveira Garcia[a] Teresa Maria Momensohn-Santos[a]
Douglas de Araújo Vilhena[b]

[a]Graduate Program on Speech Language Pathology Studies, Pontifical Catholic University of São Paulo, São Paulo, Brazil; [b]Graduate Program on Psychology: Cognition and Behavior, Federal University of Minas Gerais, Belo Horizonte, Brazil

Keywords
Reading · Intervention · Education · Spectral overlays · Visual stress

Abstract
Objective: To investigate the effects of spectral overlays on reading performance of Brazilian elementary school children. ***Methods:*** Sixty-eight children (aged 9–12 years) enrolled in the 5th and 6th grade were included in the study. The Rate of Reading Test (RRT – Brazilian Portuguese version) was used to evaluate reading speed and the Irlen Reading Perceptual Scale was used to allocate the sample according to reading difficulty/discomfort symptoms and to define the optimal spectral overlays. ***Results:*** A total of 13% of the children presented an improvement of at least 15% in reading speed with the use of spectral overlays. Pupils with severe reading difficulties tended to have more improvement in RRT with spectral overlays. Children with severe reading discomfort obtained the highest gains in RRT, with an average of 9.6% improvement with intervention, compared to a decrease of –8.2% in the control group. Participants with severe discomfort had an odds ratio of 3.36 to improve reading speed with intervention compared to the control group. ***Conclusion:*** The use of spectral overlays can improve reading performance, particularly in those children with severe visual discomfort.

Introduction

Vision is the main sensory system to assimilate information from our surroundings. To be able to process and interpret the information contained in visible light, the eye provides 70% of all sensory input fibers to the brain, mobilizing a comprehensive neural network of 32 cortical areas to process contrast, color, movement, direction, textures, three-dimensionality, contextualization, and memorization, among others [1]. Thus, reading ability can be perceived as the most difficult and complex visual-cognitive task, linking visual perception, eye movement, visual-auditory association, auditory recognition, phonological processing, oral expression as well as visual and auditory memory [2].

Some individuals may experience a variety of neurovisual processing problems that may hinder the reading process. A survey of 267 third-grade pupils in Ecuador [3]

E-Mail karger@karger.com
www.karger.com/fpl

Ana Carla Oliveira Garcia
Department of Speech Language Pathology and Audiology
Pontifical Catholic University of São Paulo (PUC-SP)
Rua Ministro Godói, 969, Perdizes, São Paulo, SP 05015-000 (Brazil)
E-Mail anacarlagarciausa@gmail.com

found that the most frequent indicators of reading difficulty were the use of a finger or a marker (38%), reading slowly or the need to take breaks often when reading (33%), and approaching or moving away from the page (19%). The most frequent indicators of reading discomfort were moving closer or further from the page (19%), under fluorescent lights (18%), eyes wide open (15%), frequent blinking (15%), dry, sandy, scratchy, or itchy eyes (13%), and eye ache or burning sensation (13%).

Such difficulties reduce the learning opportunities essential for development and may serve to restrict occupational opportunities [4]. Reading intervention requires a multidisciplinary approach that involves educators, psychologists, physicians, and speech therapists. Assistive technologies can aid readers to overcome a visual-perceptual difficulty, but this technology needs to be validated for an appropriate inclusion as an educational intervention.

Spectral overlays, colored transparent sheets placed upon texts, have been in use for three decades to help children and adults with reading difficulties related to the visual system's neurological processing, but very few studies have investigated this assistive technology in Brazil. By reducing visual stress symptoms during reading, spectral overlays improve letter and number recognition, reading speed, and text comprehension [5–15]. One out of 10 children in the general population reports a perceptual improvement in text clarity with the use of overlays [6, 8, 9, 11–13].

The purpose of the present study was to replicate past studies demonstrating the positive effects of spectral overlays on reading performance by applying this technique to Brazilian elementary school children.

Methods

The sample comprised 82 Brazilian Portuguese native speakers, of whom 14 children were excluded from the sample due to history of hearing loss or optical problems. The remaining sample (n = 68) consisted of 36 boys and 32 girls. The children ranged in age from 9 to 12 years (mean = 11.2 years) and were enrolled in either the 5th (n = 24) or 6th grade (n = 44) of a State Elementary School in the city of Jacareí, SP, Brazil. In a regional assessment, the school obtained a performance in Portuguese and Mathematics superior to the goals determined by the State Regional Board Of Education. All children and their parent/guardians signed an informed consent form for the research, and the Ethics Committee from the Pontifícia Universidade Católica de São Paulo approved the study.

Instruments

The Irlen Reading Perceptual Scale (IRPS) [16] was used to evaluate reading problems and to select the optimum spectral overlay, being divided into 2 sections. Section 1 had 2 scales with 16 questions each: (1) Reading Difficulty Questionnaire: investigates reading and educational problems (skipping or rereading lines, misreading words, losing place, poor comprehension, and slow reading), and (2) Reading Discomfort Questionnaire: perceptual or physical disturbances while reading (eye strain, fatigue, headaches, excessive blinking and squinting, and dry, itchy, or burning eyes). Section 2 involved different visual tasks with high-contrast images designed to increase visual stress (counting the number of lines in specific rows on 2 grid pattern cubes, counting symbols, sustained visualization of musical lines) to allow a more precise selection of the optimum spectral overlay (10 different colors of the Irlen Spectral Overlays set). Participants were asked if they presented with symptoms of visual stress and/or perceptual distortions during and after each visual task. Patients may identify illustrations of 11 types of text distortions (blurry, floating letters, halo, ripple, rivers, seesaws, shaky, Star Wars, swirl, washout, wavy) that usually manifest in situations of prolonged visual effort (Fig. 1).

The Wilkins Rate of Reading Test (RRT – Brazilian Portuguese version) was used to evaluate the effects of spectral overlays on reading speed [12]. The test has 5 distinct lists (1 training, 4 tests), each composed of 15 high-frequency words randomly repeated in each of the 10 lines, presented in Times New Roman font, size 9, simple spacing, printed with black color ink on a white A4 paper. The RRT has low linguistic difficulty, focusing on the visual aspect of reading. Past research has demonstrated the reliability of the original English version of the RRT (RRT-en), ruling out the hypotheses of placebo and training effect [7, 9, 10]. The reading gains with the use of spectral overlays cannot be explained by refractive or orthotic problems [5–7]. The 5% improvement in RRT-en is considered a good index of sustained use of spectral overlays, as it predicts 60–73% of the readers who will continue to use them for at least 3 months after their prescription [8, 12, 14]. However, the 5% improvement in reading rate with a preferred overlay may be considered too lax. If the test is used in isolation in the assessment of children, the criterion of a 15% increase in reading rate is recommended, as it represents an improvement beyond the range of intra-individual variability [17].

Procedure

Assessments were administered during school hours, in a quiet room of the institution. The room was lit by natural and fluorescent lights. Two certified Irlen clinic screeners conducted the IRPS followed by RRT assessments. One speech therapist administered Section 1 of the IRPS and one pedagogue administered Section 2. The second professional was masked to the outcomes of Section 1. On a different day, all children were assessed by an ophthalmologist. If visual problems were identified, parents/guardians were informed to refer their child to their local eye clinic for treatment.

Answers to the 32 questions in Section 1 of the IRPS were scored as follows: frequently (1 point), sometimes (0.5 points), never and do not know the answer (0 points). In both questionnaires, samples were divided according to 4 criteria: no reading difficulty/discomfort (0 points), mild (1–3.5 points), moderate (4–7.5 points), or severe symptoms (8–16 points). In Section 2 of the IRPS, the Irlen Spectral Overlays were presented in a standard manner and sequence, in a process of elimination based on participants' subjective reports if the overlays produced more comfort and a clearer/sharper visualization of a text (written in Dutch to be meaningless to the participant). Two different overlays were used

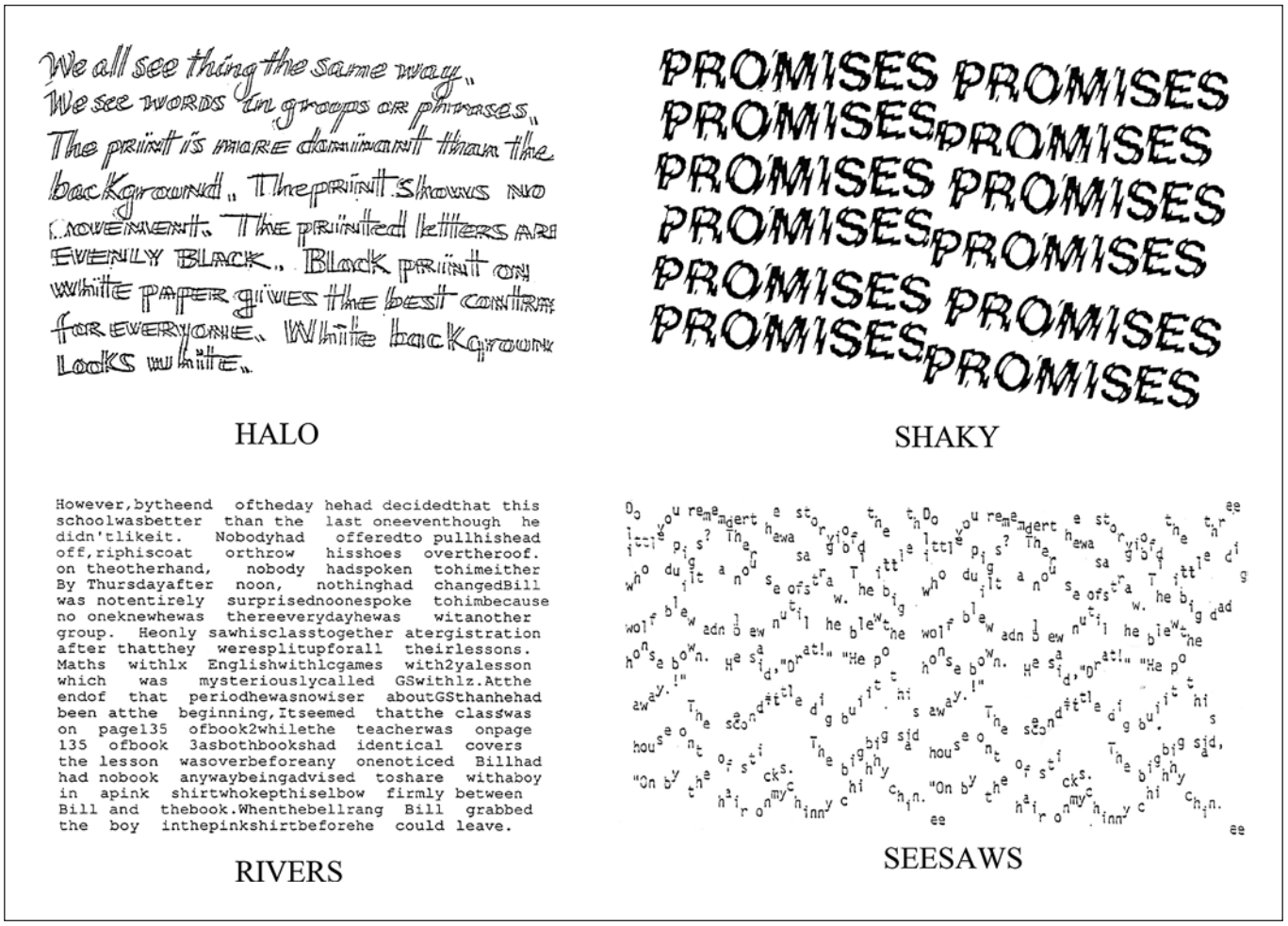

Fig. 1. Illustrations of types of text distortions. Source: Irlen [16].

at the same time, each covering half the page. Participants were asked to identify the preferred overlay, after which the less preferred one was replaced by the next overlay. Once a single overlay was chosen, combinations of overlays were then introduced in the same manner. The process was repeated until a final preferred overlay, or combination of overlays, was determined. Fifty-six pupils selected a spectral overlay (13 aqua, 12 blue-gray, 10 purple, 9 turquoise, 8 gray, 2 green, 1 peach, 1 goldenrod). For the 12 participants who did not have a color preference, a random overlay was issued (4 turquoise, 3 purple, 3 gray, 2 blue-gray).

Participants were asked to read aloud each RRT list as quickly as possible. A 30-second training list was used to make the participant more familiar with reading sequences of random words. In the 4 test lists, the examiner recorded any errors and instructed the child to stop reading after 1 min. The number of correct words read in 1 min was calculated for each list (to determine accuracy rate). The first test list was read with spectral overlays, followed by the second and third list without overlays, and the fourth with overlays (an ABBA design to control for learning and fatigue effects). The difference of words per minute between reading with and without spectral overlay was calculated as percentage in the following way. The average number of words without overlays ([list 2 + list 3] ÷ 2) was subtracted from the average number of words read with overlays ([list 1 + list 4] ÷ 2). This value was then multiplied by 100 and divided by the average without overlays.

Data Analysis

Groups were classified according to the Irlen criteria: none (0 points), mild (1–3 points), moderate (4–7 points), and severe (8–17 points) on the Irlen Perceptual Reading Scale (IRPS). Since this study aims to screen for potential cases of neurovisual disorder, without a comprehensive diagnostic protocol, the sample was divided into 2 groups: (1) Group 1: those with low to moderate probability of having visual stress (score <8 points on IRPS); and (2) Group 2: those with high probability of having visual stress (≥8 points). The difference between Group 1 and Group 2 was analyzed using independent two-tailed *t* tests. To determine the clinical significance of the differences, Cohen's *d* value was calculated: results equal to 0.2 are considered to be of small effect, 0.5 of moderate effect, and >0.8 as having a large statistical effect [17].

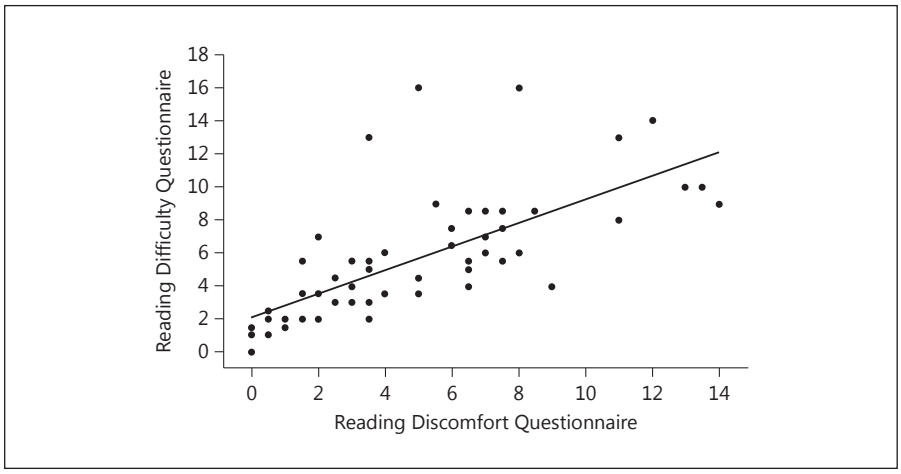

Fig. 2. Scatter plot between the Reading Difficulty Questionnaire and the Reading Discomfort Questionnaire from the Irlen Reading Perceptual Scale.

Table 1. Frequency distribution and RRT scores (mean gain ± standard deviation) in IRPS Section 1 questionnaires of reading difficulties and discomfort

Statistical grouping	Symptoms	Reading Difficulty Questionnaire		Reading Discomfort Questionnaire	
		n (%)	RRT	*n* (%)	RRT
Group 1	None	1 (1.5)	–1.2±0.0	4 (5.9)	–2.9±6.5
	Mild	25 (36.8)	0.8±8.6	33 (48.5)	–9.5±9.1
	Moderate	29 (42.7)	–0.1±10.0	20 (29.4)	0.7±7.7
Group 2	Severe	13 (19.1)	6.3±13.0	11 (16.2)	9.6±14.8

Results

In the Reading Difficulty Questionnaire, the majority of the current sample (62%, 42/68) reported a difficulty in reading between moderate to severe (Table 1). In the Reading Discomfort Questionnaire, the absence or mild presence of visual discomfort during reading occurred in 54% of the sample; 29% presented moderate symptoms and 16% had severe symptoms (Table 1). The scatter plot (Fig. 2) demonstrates that the variables of reading difficulty and reading discomfort have a moderate positive association ($r = 0.69$, $p < 0.001$).

Separating the sample according to the Reading Difficulty Questionnaire, the 13 children with severe reading difficulties (Group 2) tended to have more improvement in RRT with spectral overlays than the readers in Group 1 ($t_{(66)} = 1.94$, $p = 0.057$; Cohen's $d = 0.54$), with a 6.3% gain in reading speed compared to the average of 0.3% from the other 55 children. In the Reading Discomfort Questionnaire, children with severe reading discomfort obtained the highest gains in RRT, with an average of 9.6% (±14.8) improvement in reading speed with intervention, compared to a decrease of –8.2% (±8.4) in Group 1 ($t_{(66)} = 5.60$; $p = 0.0001$; $d = 1.49$). Participants with severe discomfort (Group 2) had an odds ratio of 3.36 (95% confidence interval = 0.90–12.64) to improve reading speed with intervention compared to the participants of Group 1.

Out of the 68 children analyzed in the current study, 9 (13%) presented an improvement of at least 15% in the RRT with the use of spectral overlays, with an average increase of 21% (±6%) in reading speed, with 2 participants increasing their performance by 28.8% and 30.8% (Table 2; Fig. 3). The same proportion of patients (31%) increased their reading speed by 5% or decreased by –5% after the use of spectral overlays (Fig. 3). Thus, analyzing the intervention effect in the whole sample ($n = 68$), participants read on average the same number of words per minute before (95.0 ± 21.6) and after intervention (95.8 ± 21.4) ($p = 0.476$), as spectral overlays have a negative, neutral, and positive effect depending on the reader's neurovisual processing. There was no difference in the perfor-

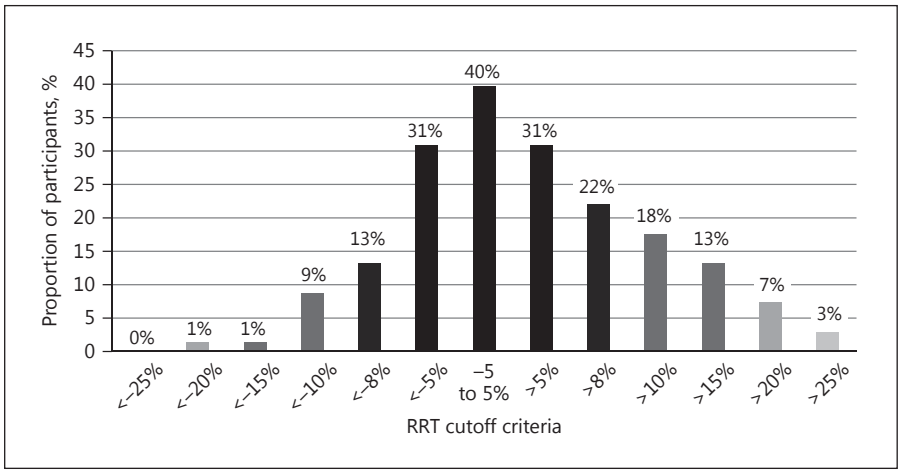

Fig. 3. Proportion of patients affected by the use of spectral overlays, according to different cutoff criteria in RRT.

Table 2. Results of the current sample (*n* (%) and mean gain values ± standard deviation) and gain proportion in different studies [8, 12, 21, 22]

	Improvement in reading rate								
	<–15%	<–5%	–5% to <5%	>5%	>8%	>10%	>15%	>20%	>25%
This study									
Frequency, *n* (%)	1 (1)	21 (31)	27 (40)	21 (31)	15 (22)	12 (18)	9 (13)	5 (7)	2 (3)
Mean gain, %	–22	–9±4	0±3	14±8	17±7	19±6	21±6	24±5	30±1
Gain proportion in different studies, %									
Wilkins et al. [12]				19					
Wilkins et al. [8]				36					5
Kriss and Evans [22]				25	22	13			3
Singleton and Henderson [21]				30	18	14			

mance of RRT between boys and girls before intervention ($t_{(66)}$ = 1.13, p = 0.262), after intervention with spectral overlays ($t_{(66)}$ = 1.37, p = 0.174), and gain of reading (with overlay relative to without overlay) ($t_{(66)}$ = 0.53, p = 0.595).

Discussion

This study investigated the effect of spectral overlays on the reading rate of 68 Brazilian elementary school children. Their reading performance was evaluated via RRT, an objective tool sensitive to participants' ability, as the readers are immediately compared to their own performance, without the need of a population standard. It was rare for the children to report an absence of signs and symptoms in the Reading Difficulty Questionnaire (1.5%) and Reading Discomfort Questionnaire (6%). Based on the Reading Difficulty Questionnaire, 6 out of 10 children had moderate to severe signs, such as frequent skipping or rereading lines, misreading words, and negative attitudes toward reading. Approximately one-third of the children reported no relevant difficulty with reading. Unfortunately, these results are in agreement with the below-average performance on international evaluations of the Brazilian educational system, with the country's mean reading performance unchanged from the years 2000 to 2015 [18]. Although not statistically significant, children with severe self-reported reading difficulties in IRPS had a tendency to slightly improve their reading speed with the use of spectral overlays, when compared to the other participants.

In the Reading Discomfort Questionnaire, 16% of the children had severe symptoms, with frequent eye strain (e.g., asthenopia) while reading, such as fatigue, headaches, nausea, excessive blinking, and pain in or around the eyes. Another 6% had no discomfort symptoms, 49%

had mild symptoms, and 29% had moderate symptoms. These values are similar to those found with 267 third-graders in Ecuador [3], where 5% had no discomfort symptoms, 46% mild symptoms, 36% moderate symptoms, and 13% severe symptoms. When compared to the rest of the sample, children with severe discomfort had the greatest gains in reading after spectral intervention. Participants with severe discomfort had a 3-times higher chance (odds ratio = 3.36) of improving reading speed with spectral overlays than the other participants. These results support that RRT is a valid tool for screening Brazilian patients with visual stress while reading.

These reading speed gains in participants with severe discomfort are in agreement with the literature, as spectral overlays are designed to increase visual comfort by reducing specific wavelengths and frequencies of the white light spectrum to which the person is sensitive, while decreasing visual-perceptual distortions and abnormal brightness. For example, Smith and Wilkins [19] verified that, when compared to a white page, overlays significantly decrease the number of visual stress symptoms. Allen et al. [20] verified that individuals with moderate to severe visual discomfort improved reading rate when using spectral overlays, whereas the low-discomfort group did not.

With spectral overlays, one-third of the current sample increased their reading speed more than 5% in the RRT. If we consider the more rigorous criterion of 15% gain in reading rate, which represents an increase beyond the range of intra-individual variability, 1 in every 10 children will likely show a significant improvement during reading tasks. Thus, spectral overlays change the interaction with printed material for these readers, allowing visual information to be received by the primary visual cortex without distortions.

The present sample of children read on average 95 words per minute, a value between the range of 87–99 words per minute found in different studies [11, 19]. These similarities between current data and international studies provide evidence of external validity to the newly adapted RRT (Brazilian Portuguese version).

After intervention, the proportion of participants with decreased reading speed was the same as the proportion of those in which it increased, thus supporting evidence that a reduction of specific wavelength of the light spectrum might have a detrimental effect on visual performance in participants with normal neurovisual processing. Miller [23] reported that some adults described a distinct discomfort and even distortion of the page with overlays. So, although spectral intervention is an important assistive technology, it should not be used lightly in the educational system.

The use of color to treat reading difficulties remains controversial. A study by Ritchie et al. [24] is widely cited as demonstrating that colored overlays are of no benefit. These authors claimed no significant difference with the use of overlays in the reading performance of children with Irlen syndrome. However, the same proportion of children with at least a 5% improvement in reading was found by Ritchie et al. [24] (31%, 19/61). However, Ritchie et al. [24] focused on the analyses of children with Irlen syndrome, so it is possible that they overestimated the identification of individuals with visual stress, as 77% of individuals selected by their teachers as "below-average" readers were identified as having Irlen syndrome and half of the children (54.3%) had uncorrected optical problems. These findings showed an unusually high occurrence of visual stress among children with reading disorders. The current study showed at least a 5% of improvement on reading tests, but our exclusion criteria were that only children with good eyesight were included; thus, peripheral visual problems which may interfere with the children's performance on visual tests were excluded from the sample.

Conclusion

Our results support the conclusion that spectral overlays can offer an immediate improvement in reading rate, particularly among children with severe visual discomfort while reading. The current study also provided evidence of the external validity of the RRT (Brazilian Portuguese version) as an instrument useful to investigate readers with visual stress.

Disclosure Statement

The authors report no potential conflict of interest relevant to this article. The research was totally funded by a grant from CAPES – a federal nonprofit organization from the Brazilian Government. The authors have no commercial and business relationships with or any type of profit from the marketing of products used in this research.

LAPAN (Laboratory of Applied Research in Neurovision) is a nonprofit scientific research laboratory associated with the local University of Minas Gerais. The main line of research is applied neurovisual sciences to a clinical setting and the development of new equipment such as eye trackers and pupilometers to be used in large scale in the school age populations.

References

1 Felleman DJ, Van Essen DC: Distributed hierarchical processing in the primate cerebral cortex. Cereb Cortex 1991;1:1–47.
2 Etchepareborda MC: Intervention in dyslexic disorders: phonological awareness training. Revista Neurol 2003;36(suppl 1):S13–S19.
3 Bernal M: Prevalencia del síndrome Meares-Irlen/estrés visual que afecta la lectura en niños de tercer grado. Maskana 2015;6:69–78.
4 Harries P, Hall R, Ray N, Stein J: Using coloured filters to reduce the symptoms of visual stress in children with reading delay. Scand J Occup Ther 2015;22:153–160.
5 Monger L, Wilkins AJ, Allen PM: Identifying visual stress during a routine eye examination. J Optom 2015;8:140–145.
6 Scott L, McWhinnie H, Taylor L, Stevenson N, Irons P, Lewis E, Evans M, Evans BJ, Wilkins AJ: Coloured overlays in schools: orthoptic and optometric findings. Ophthalmic Physiol Opt 2002;22:156–165.
7 Bouldoukian J, Wilkins AJ, Evans BJ: Randomised controlled trial of the effect of coloured overlays on the rate of reading of people with specific learning difficulties. Ophthalmic Physiol Opt 2002;22:55–60.
8 Wilkins AJ, Lewis E, Smith F, Rowland E, Tweedie W: Coloured overlays and their benefit for reading. J Res Read 2001;24:41–64.
9 Wilkins AJ, Lewis E: Coloured overlays, text, and texture. Perception 1999;28:641–650.
10 Lightstone A, Lightstone T, Wilkins AJ: Both coloured overlays and coloured lenses can improve reading fluency, but their optimal chromaticities differ. Ophthalmic Physiol Opt 1999;19:279–285.
11 Jeanes R, Busby A, Martin J, Lewis E, Stevenson N, Pointon D, Wilkins AJ: Prolonged use of coloured overlays for classroom reading. Br J Psychol 1997;88(Pt 4):531–548.
12 Wilkins AJ, Jeanes RJ, Pumfrey PD, Laskier M: Rate of Reading Test: its reliability, and its validity in the assessment of the effects of coloured overlays. Ophthalmic Physiol Opt 1996;16:491–497.
13 Tyrrell R, Holland K, Dennis D, Wilkins AJ: Coloured overlays, visual discomfort, visual search and classroom reading. J Res Read 1995;18:10–23.
14 Northway N: Predicting the continued use of overlays in school children – a comparison of the Developmental Eye Movement test and the Rate of Reading test. Ophthalmic Physiol Opt 2003;23:457–464.
15 Noble J, Orton M, Irlen S, Robinson GL: A controlled field study of the use of coloured overlays on reading achievement. Aust J Learn Diffic 2004;9:14–22.
16 Irlen H: Irlen Reading Perceptual Scale (IRPS). Perceptual Development Corporation, 2003.
17 Cohen J: Statistical Power Analysis for the Behavioral Sciences, ed 2. Hillsdale, L. Erlbaum Associates, 1988.
18 OECD: Programme for International Student Assessment (PISA). Results from PISA 2015, Organisation for Economic Co-Operation and Development, 2016, pp 1–13.
19 Smith L, Wilkins AJ: How many colours are necessary to increase the reading speed of children with visual stress? A comparison of two systems. J Res Read 2007;30:332–343.
20 Allen PM, Gilchrist JM, Hollis J: Use of visual search in the assessment of pattern-related visual stress (PRVS) and its alleviation by colored filters. Invest Ophthalmol Vis Sci 2008; 49:4210–4218.
21 Singleton C, Henderson L-M: Computerised screening for visual stress in reading. J Res Read 2007;30:316–331.
22 Kriss I, Evans BJ: The relationship between dyslexia and Meares-Irlen Syndrome. J Res Read 2005;28:350–364.
23 Miller LS: Scotopic sensitivity and reading disability; unpublished Master of Education thesis. Los Angeles, California State University, 1984.
24 Ritchie SJ, Della Sala S, McIntosh RD: Irlen colored overlays do not alleviate reading difficulties. Pediatrics 2011;128:e932–e938.