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Research Article

An Investigation of the Visual Function and the Effect of Colored Filters on Reading Ability of Dyslexic Children

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Abstract

Purpose: The aim of the present study was to evaluate the effect of colored filters on the reading ability in dyslexic children.

Method: Twelve children with dyslexia and twelve age and gender matched non-dyslexic children between second and fifth grade were recruited. Visual acuity assessment, refraction and binocular examinations including far and near heterophoria, near point of convergence and accommodation, stereopsis, and near fusional reserves were performed for all participants. Afterwards, both the colored filters and transparent ones were used in dyslexic group. Children were asked to choose one filter which enhances the clarity or perception of the text and then the reading ability was measured with and without filters.

Results: The mean age of all subjects was 8.42±1.06 years. The results showed that fusional reserves significantly reduced in dyslexic children compared to normal individuals, although no statistically significant difference was reported in other visual functions. Moreover, it has been shown that reading ability of dyslexic children was significantly improved with colored filters.

Conclusion: The results of the present study showed that fusional reserves decreased in dyslexic children. Moreover, speed and accuracy of the reading increased significantly in dyslexic children with color filters. It would be recommended that in dyslexic children, in addition to a thorough assessment of binocular vision, using color filters is beneficial.

Keywords: Dyslexia; Binocular vision; Magnocellular system; Colored filters; Colored overlays

Introduction

Reading and writing are the most important issues for learning especially in today's computer-based society. Any disorder or disability which affects children proficiency to read or write is classified as a learning disability and may result in negative effects on educational, emotional and either social functions [1,2]. One of the most common learning disabilities is dyslexia which is characterized with debility in reading [2-4]. It has been estimated that 3% [5] to 13.67% of school-aged children are dyslexic [6]. Considering the visual system, significant association have been found between magnocellular pathway involvement and dyslexia incidence [7,8]. The main hypothesis for this association is magnocellular theory, according to which most of children with dyslexia have defect in magnocellular pathway [9]. Moreover, it has been agreed that any disorder in eye movement could be a leading cause for dyslexia [10]. Binocular instability is the most common visual sign in dyslexic patients, which is distinguished by the low fusional reserve and vergence instability [11]. Patients with binocular instability usually suffer from blur vision, diplopia, asthenopia and visual distortion [12]. Kriss and Evan reported that visual stress, which was defined as any disability to see comfort and without distortion, is more prevalent in dyslexic children compared with normal population [13].

It has been approved that decreasing the font size, using colored filters and reducing the contrast could improve the reading ability in dyslexic patients, and relieve visual symptoms through increasing patient's perception [1,14]. Color filters, was firstly introduced by Irlen International Association [15], who suggested applying filters as an effective remedy for visual symptoms-co-occurring dyslexia and stated that the color of the therapeutic filter is different from person to person, therefore, it may not have any effect if an appropriate color does not prescribed [16]. According to previously published studies, colored filters or overlays could improve the symptoms of visual stress and reduce the asthenopia symptoms and consequently improve the reading ability in dyslexic children [17-19]. This study is proposed to assess the effectiveness of colored filters on reading speed in dyslexic children.

Methods

Study population

Twelve dyslexic children and twelve age- and gender- matched normal individuals (age range: 7 to 10 years of age) were recruited for this study according to inclusion criteria as follows: normal mean intelligence quotient between 90 and 110 (Wechsler intelligence test), being healthy without any physical problems, parents' consent, lack of acute vision and hearing problems and no psychological problems. Children with any ocular pathology were excluded from the study population. All patients were referred by a specialist to the dyslexia comprehensive center. It is important to keep in mind that dyslexia is not a disease or an identifiable physical condition. Rather, it is a

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Table 1: Filters physical characteristics.

Filter	Wave length (nm)	Absorbance (Abs)
X1	432	1.661
X2	226	3.706
X5	677.9	0.877
X6	476.1	1.922
X7	228.1	0.294
X8	449.9	0.660
X9	288	2.176
X10	224	3.954
X12	566	0.532
X13	426	1.246
X14	567.9	0.726
X15	674	0.137
X16	609.9	0.640

Table 2: Means and standard deviations of visual factors in dyslexic and normal groups.

Factor	Normal	Dyslexia	Total	P-value
Refractive error OD	0.66±0.45	0.58±0.60	0.62±0.52	0.64
Refractive error OS	0.68±0.54	0.60±0.56	0.64±0.54	0.68
Visual acuity OD	9.92±0.28	9.83±0.38	9.88±0.33	0.54
Visual acuity OS	9.92±0.28	9.83±0.38	9.88±0.33	0.54
Visual depth perception	40.00±0.00	40.83±2.88	40.42±2.04	0.31
Distance heterophoria	3.17±3.56	0.83±1.58	2.00±2.94	0.06
Near heterophoria	3.00±2.76	4.83±3.01	3.92±2.97	0.19
Near point of accommodation	8.25±1.28	10.33±4.18	9.29±3.21	0.46
Near point of convergence	6.08±1.16	8.25±4.02	7.17±3.10	0.42

Table 3: Mean of binocular vision in dyslexic and normal groups.

Factor	Normal	Dyslexia	Total	P-value
B.I FusionalVergence	16.50±1.24	14.00±2.82	15.36±2.42	0.02
B.O FusionalVergence	24.50±2.71	15.00±2.86	20.18±5.55	P<0.001
B.I Recovery	13.83±1.33	10.00±2.30	12.09±2.65	P<0.001
B.O Recovery	21.83±2.48	11.00±3.01	16.91±6.13	P<0.001

BI: Base In; BO: Base Out.

learning style that could be assessed through a profile to show whether the child has a typical pattern of strengths and weaknesses, coupled with other assessments to rule out other possible causes of symptoms, such as vision or hearing problems.

A diagnostic assessment is the most comprehensive kind of assessment. Definitive diagnosis of dyslexia has been confirmed using psychological tests, math performance tasks, sequential memory tests, cognitive and emotional growth tests and also speech therapy examination. All tests were performed by an experienced psychologist. Patients with any history of dyscalculia, attention-deficit/hyperactivity disorder, attention deficit disorder, ocular pathology, and amblyopia or color vision deficient were excluded from the study. Demographic data were collected for each subject and detailed visual examinations were performed including: visual acuity, refractive error, distance and near heterophoria, positive and negative fusional reserves and depth of vision.

Ethical consideration

Informed consent of a parent/guardian was obtained after explanation of the nature and possible consequences of the study. The experiment followed the tenets of the Declaration of Helsinki and was approved by the Research Ethics Committee of Mashhad University of Medical Sciences.

Visual function assessment

Subjective and objective refractions were carried out using retinoscope (Heine Beta 200 retinoscope, HEINE Optotechnic, Germany, http://www.heine.com/) and auto refractometer (Topcon RM8800, Topcon Corporation, Japan, http://global.topcon.com/). Visual acuity was measured monocularly with the Snellen chart at a distance of 6m. The cover test was done to confirm the presence of any far or near heterophoria and simultaneous prism and cover test was performed to estimate the amount of present heterophoria.

For assessment of the near point of accommodation, the correction was cited in trial frame and normal room illumination was used. Each patient observed the target at a distance of 40cm and was instructed to report the first sustained blurred, then the measured distance from the spectacle plane was converted to dioptric power. The same procedure was repeated for assessment of the near point of convergence, while the patient was instructed to report the first diplopic image of the target. All measurements were repeated for three times and average was recorded.

Positive and negative fusional reserves were evaluated using the prism bar at 40cm. Divergence or negative ranges (Base In) were tested before convergence or positive ranges (Base Out) due to possible vergence adaptation. For each section, the patient was instructed to report the blur, break and recovery of the target while adjusting the prism power.

Stereoacuity was measured in subjects using the Titmus circles test (Stereo Optical, Chicago, IL).

Reading ability

Reading ability was measured with the Decoding Skills Test (DST), which contains 10 experiments [20]. Reading ability was evaluated using three of sub tests including: reading words, reading non-words and chain of words. Hoseini et al [21] approved the validity and reliability of the reading tests. Total test time was 2 minutes. Each correct answer had one score and the highest score was 30. Raw scores are used to convert results into grade- level scores. Additionally, level score shows how the patient performs and if he or she could proceed to the next level. Thirteen filters with different colors and intensity, which were defined using UV Visible Spectrophotometer, were used. Table 1 shows the physical characteristic of each filter. Wilkins method was used to choose filters [22]. Reading skill was evaluated with and without filters. The current study was a blind study and information about the efficacy of filters was masked from the participants to eliminate the bias until after a trial outcome was known.

Statistical analyses

All statistical analyses were performed using the SPSS software version 11.5 (SPSS Inc, Chicago, IL, USA). The normality of the quantitative variables was checked using the Kolmogorov Smirnov test. Mann-Whitney U test, Wilcoxon and Friedman tests were conducted to check the efficacy of filters and comparing the means. The level of significance was set at 0.05.

Results

Twenty-four children (12 dyslexic children and 12 normal children) were included in this study. Mean age of participants was 8.42±1.16 years in dyslexic group and 8.42±0.99 years in control group.

Visual factors

Comparing dyslexic and normal children, no significant differences were noted with regards to refractive errors, visual acuity, visual depth perception, distance and near heterophoria, near point of accommodation and near point of convergence (Table 2).

There was a statistically significant difference between two groups in fusional reserves (Table 3); the mean of dyslexic children was significantly lower than the mean value of normal children ($p<0.001$). The values of positive fusional reserves for break and recovery fell outside the normal range in dyslexic children, while in negative fusional reserves the minimum amounts of break and recovery ranges were similar to the normal values.

Colored filters

Five filters of thirteen exciting filters were chosen, which included: X1 (yellow filter), X8 (yellow filter), X13 (red filter), X2 (transparent filter) and X15 (transparent filter). The most chosen filters were X2 (41.7%) and X1 (33.3%). The remaining three filters were chosen just once (8.3%).

Reading speed

Assessing the reading ability of dyslexic children, four factors were evaluated with and without filters. The factors included: total read words, correct read words, raw score and level score. There was a statistically significant difference in mean value for four reading ability factors with and without filter (Table 4).

One common criteria to assess the efficacy of colored filter is an improvement of 5% in reading ability which is defined as a cut-off point [17]. Therefore, to evaluate filters efficacy, the mean values of three tests with and without filters were compared, and percentage change was obtained (Table 5).

For further study of efficacy, filters were categorized into two groups: 1. Colored filters (X1, X8 and X13) 2. Transparent filters (X2 and X15). The difference between these two groups is shown in Table 6.

Based on our results the colored filters could significantly (8.67%) improve the word reading ability in comparison with transparent filters.

Discussion

This study examined the efficacy of colored filters on reading ability of dyslexic children. The author's attention concentrated not only on color filter effectiveness, but also on visual function in dyslexic children. This study showed that fusional reserves in dyslexic children were significantly lower than normal group. These results are in good agreement with Evans and Kapoula experiments [23,24]. Adequate vergence is fundamental for maintaining the visual direction and also is a basic requirement for reading. According to Jainta and Kirkby experiments, dyslexic children suffer from binocular instability and fixation disparity while reading [11,25]. Evaluation of fusional reserve is the most appropriate test to assess the binocular instability in dyslexic patients [26]. This test can be performed at any distances using prism bar, however, as reading is usually more relevant with near vision measurement, test is performed at close distance in dyslexic children. Fusional reserve training would simply improve binocular instability. The present results are consistent with results of Evans study [27], which found no correlation between visual factors and reading ability, indeed the deficiency in reading ability is not relevant to visual disorders. Our results showed that filters remarkably improved the reading skill by 5.67%. Red and yellow filters could improve the reading ability by 8.67%. The results further indicated that transparent filters improved the chain of word reading ability (5.2%) than the colored filters. Although the improvement was not statistically significant, but clinically it reached the significant level and cause a 5.2% (cut off point 5%) improvement. Our results support the hypothesis that colored filters are more profitable for those patients with extensive reading disability [17]. The results of our study concur with Wilkins, Bouldoukian, Northway, Ray and Lightstone studies, that colored filters are more effective in improving reading ability [17-19,28-30]. It should be noted that previous studies had some limitations, for example in most of these studies, sampling is biased and pre-determined [17,18], and patients had previously used filters and declared that filters had improved their ability. Ritchie [31] resolved this issue; however, his study included all patients with different types of learning disorders. In our study, these two limitations have been resolved and only the dyslexic children were participated with no history of filter usage. For this purpose, all the subjects underwent a comprehensive examination with and without filters. Although, this research was carefully prepared, there are some limitations. First, due to low cooperation of the dyslexic children few dyslexic children recruited in the study and second, accommodative tests are limited. Further study with concentration on accommodative disorders would be of interest.

Table 4: Reading ability with and without filter in dyslexic children.

Test	Without filter	With filter	P-value
Reading test (correct words)	88.08±23.01	92.25±21.05	0.04
Reading test (raw scale)	88.08±23.01	92.25±21.05	0.04
Reading test (level score)	74.08±22.25	79.75±19.04	0.03
Total score	252.50±33.10	262.50±29.53	0.04

Table 5: Colored filter efficacy.

Test	Mean without filter	Mean with filter	Efficacy percentage
Reading words (level score)	74.08	79.75	5.67%
Reading non-words (level score)	81.41	84.33	2.92%
Chain of words (level score)	88.80	92.70	3.90%

Conclusion

Finally, it can be concluded that dyslexic children do not have considerable difference in refractive errors, visual acuity, visual depth perception, distance and near heterophoria, near point of

Table 6: Effect of colored and transparent filters on reading ability.

Test	Colored filters (M±SD)			Transparent filters (M±SD)			p-value
	Without F	With F	Imp	Without F	With F	Imp	
Reading words (L.V)	65.66±25.74	74.33±23.81	8.67%	82.50±16.03	85.16±12.65	2.66%	0.0036
Reading non-words (L.V)	77.33±28.94	78.83±22.24	1.5%	85.50±10.85	89.83±13.87	4.33%	0.36
Chain of words (L.V)	88.20±7.85	90.80±7.49	2.6%	89.40±8.08	94.60±11.84	5.2%	0.12

F: Filter; Imp: Improvement; L.V: Level Score; M: Mean; SD: Standard Deviation.

accommodation and near point of convergence in comparison with normal children, except for fusional vergence which was significantly reduced in dyslexic children. Moreover this paper has clearly shown that applying filters could improve the reading ability in dyslexic patients and improved their skills.

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