Efficacy of visual sensory training in dyslexia

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Summary

Background: Dyslexia is a neurodevelopmental disorder. It is the most common type of specific learning disorders, defined by persistent and impairing difficulties with learning foundational academic skills in reading. The magnocellular theory of dyslexia attributes the deficits commonly found in dyslexics to defective function of the magnocellular dorsal (MD) pathway. Visual sensory training aims at enhancing the (MD) functions.

Aim: This intervention study aims to measure the effect of visual sensory training in improvement of reading performance in visual and mixed visual- phonological dyslexia as compared to conventional& home- based training.

Patients and methods: An intervention prospective study was carried out on a group of seven dyslexic children ages 9 to 12 years old attending the Special Needs Care Centre, Faculty of Postgraduate Childhood Studies, Ain Shams University. Cases were clinically diagnosed according to the DSM5 then assessed using Illinois Test of Psycholinguistic Abilities (ITPA)& the Modified Arabic Dyslexia Screening Test (MADST). Each child received 12 sessions of visual sensory training, together with Conventional dyslexia training in the dyslexia unit and home-based reading practice training. MADST was repeated after the sessions to compare reading speed& accuracy before& after training. Results: There was significant improvement in the subtests of rapid automatized naming, bead threading, one minute reading, 2 minutes spilling nonsense passage reading and one minute writing. Compliance to conventional sessions caused significant improvement in the subtests of one minute reading and one minute writing. While compliance to home- based practice caused non- significant improvement in all subtests.

Conclusion: Visual sensory training is effective in improving reading skills in dyslexic children, especially when used as a part of multidisciplinary management program including sensory training, cognitive functions training and academic training.

Keywords: Dyslexia, visual sensory training, magnocellular dorsal system.

فاعلية برنامج تدريب حسي بصري في حالات عسر القراءة (الديسلكسيا)

مقدمة: تعتبر الديسلكسيا (عسر القراءة) واحدة من صعوبات التعلم المحددة المندرجة تحت الاضطرابات النمائية لدى الأطفال وهي تعرف بصعوبة اكتساب المهارات اللازمة للقراءة رغم نسبة الذكاء الطبيعية والتعليم الجيد الذي يتلقاه الطفل. ومن النظريات الموضوعة لتفسير هذه الصعوبة ضعف الخلايا العصبية العظيمة (magnocells) المسؤولة عن توصيل المدخلات البصرية المتحركة والمتغيرة؛ ويعمل التدريب البصري الحسي على زيادة قدرات هذه الخلايا.

الهدف: تقييم فاعلية برنامج التدريب الحسي البصري في تحسين مهارة القراءة لدى الأطفال الذين يعانون عسر القراءة (الديسلكسيا) ومقارنته بفاعلية البرامج التدريبية التقليدية والتدريب المنزلي على القراءة.

المرضى وطرق البحث: تمت هذه الدراسة التدخلية على عدد سبع أطفال من المصابين بعسر القراءة المترددين على مركز رعاية ذوي الاحتياجات الخاصة بجامعة عين شمس، والذين تتراوح أعمارهم بين ٩ إلى ١٢ سنة من الجنسين. تم تشخيص هؤلاء الأطفال عن طريق المقابلة الاكلينيكية ومن ثم اجراء اختبار إلينوي للقدرات النفسية اللغوية، وكذلك اختبار مسح الديسلكسيا العربي المعدل. تلقى الأطفال ١٢ جلسة من التدريب الحسي البصري بالتوازي مع جلسات تقليدية لعلاج الديسلكسيا وكذلك التدريب المنزلي على القراءة والكتابة. ومن ثم تم إعادة اختبار مسح الديسلكسيا العربي المعدل لقياس مدى تأثير التدريب على سرعة القراءة لديهم.

النتائج: اظهرت النتائج تحسنا ملحوظا في جميع درجات الاختبارات الفرعية لاختبار مسح القراءة بعد التدريب البصري.

الخلاصة: ان التدريب الحسي البصري فعال في تحسين المهارات القراءة لدى الاطفال المصابين بعسر القراءة خاصة عند استخدامه كجزء من خطة علاجية متكاملة تشمل كذلك تدريب المهارات المعرفية والتدريب الأكاديمي.

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Background:

Dyslexia is a neurodevelopmental disorder characterized by difficulty in accurate or fluent word recognition, poor decoding, or poor spelling abilities, despite adequate intelligence and instructions with normal visual& hearing acuity. (American Psychiatric Association, 2013) The prevalence of dyslexia worldwide is about (10- 17)%. (Kuerten, et.al, 2019) An Egyptian study refers to prevalence 11.3% among primary school children in Cairo. (El Sheikh, et.al, 2016) Several theories were proposed to explain dyslexia and the common deficits that are usually associated with it. One of these theories is the magnocellular- dorsal stream deficit theory (MD theory) that attributes most of these difficulties to defective magnocellular- dorsal pathway of the visual system. This stream is responsible for perception of changes in the visual field, motion perception, smooth pursuit eye movement, attentional shifting, temporal processing of visual stimuli, visual search and visual detection of emotional expressions. All these functions were found to be defective in dyslexic children. (Stein, J. 2019)

Visual sensory training aims to train visual perception by enhancing the magnocellular dorsal pathway. This was performed by different screen- based programs, including action video games, coherent dot motion and texture discrimination training. (Gori& Facoetti 2014, Lawton 2016)

In this study we hypothesize that visual sensory training; which is a part of the sensory integration therapy; is effective in improving reading performance regarding reading fluency and speed.

Methodology

Design:

This prospective intervention study was held in the Special Needs Care Center affiliated to the Faculty of Postgraduate Childhood Studies, Ain Shams University.

Sample Selection:

Seven children, (4 boys), 9 to 12 years old, were included in this study. Children were clinically diagnosed in the child psychiatry clinic as specific learning disability in reading (dyslexia), according to the DSM 5. Exclusion criteria included comorbid ADHD (attention deficit hyperactivity disorder) diagnosis, visual or auditory deficits, pure phonological dyslexia and any neurological disorder.

Assessment Tools:

Children were assessed using:

1. IQ test using Stanford- Binet Intelligence Scale V5, The Arabic version, (Abu El-Neil, 2011).
2. Illinois Test of Psycholinguistics Abilities, the Arabic version (El-Sady, et.al, 1996). This test measures and compares the visual and the auditory channels, including visual and auditory association, perception and memory, manual and verbal expression and grammatical& visual closure. It was used in this study to exclude children with pure phonological dyslexia, while children with visual or mixed visual and phonological dyslexia were included.
3. The Modified Arabic Dyslexia Screening Test (El Fiky, et.al, 2016): The test was developed as a screening tool to find dyslexic children using a quick and easily applied tool. In this study, the test was used to compare reading fluency and speed before and after training. The test includes 11 subtests:
   a. Rapid automatized naming test: scored as speed in seconds and number of correctly named items.
   b. Bead threading test: measures the number of beads threaded correctly in a duration of 30 minutes. It reflects the visual motor coordination of the child.
   c. One minute reading test: measures the number of correctly read words in one minute.
   d. Postural stability test: screens for body imbalance, which is commonly found in dyslexic children, pointing to a probable comorbid developmental motor coordination disorder. None of the children included in this study had abnormal postural stability test results.
   e. Phonemic manipulation test: It reflects the phonological awareness ability of the child.
   f. Two minute spelling test: measures the correctly written words in 2 minutes.
   g. The backward digit span test: reflects the child's audio attention, memory, and sequencing ability.
   h. Nonsense passage reading: measures the ability of the child to rapidly and accurately read a passage composed of real and pseudo words. The score includes both time in seconds and the number of correctly read real and pseudo words.
   i. One minute writing test: measurers the child's ability to copy a text in a rapid and correct way. It gives a sign about visual skills, visual motor coordination, sequencing and handwriting.
   j. Verbal fluency test: gives a sign about the child's phonological awareness.
   k. Semantic fluency test: gives a sign about the child's comprehension and word finding speed.

The used subtests to compare pre and post treatment skills were the Rapid naming duration, Bead threading, 1 min reading, 2 min spelling, Nonsense reading& 1 min writing.

Training Procedures:

1. Visual Sensory Training: All sensory training sessions were held in the Sensory Integration unit of the Special Needs Care Center affiliated to the Faculty of Postgraduate Childhood Studies, Ain Shams University. Each child received 12 sessions scheduled as one to three sessions per week. Each session’s duration was about 20 minutes. Sessions were applied by the researcher to give instructions and encourage the child to stay attentive to the devices. The following devices were used:
   a. Luminous Tunnel: for training depth perception and attentional shifting. Used for three minutes per session, one minute on each program.

b. The bubble Tube: to train the vertical motion perception both in central and peripheral vision. Used for three minutes per session.
c. Rotating mirror ball: to train eye tracking and pursuit eye movement. Used for two minutes per session.
d. Illumination Curtain: to train visual attention shifting, eye movement and visual attention to both central and peripheral stimuli, it was applied for seven minutes per session divided into seven programs.

2. Conventional dyslexia training: Held in the dyslexia unit of the Special Needs Care Centre, Faculty of Postgraduate Childhood Studies Ain Shams University. Children were trained on reading and writing together with visual and/or auditory skills; based on the type of dyslexia. Each child typically receives one 50 minute session per week.
3. Home base training: under the supervision of specialized psychologists in the dyslexia unit, parents are instructed to practice reading and writing with their children for about 15 to 20 hours weekly.

Ethical Considerations:

Ethical consideration according to the research ethics committee of both Ain shams University and institute of postgraduate childhood studies (IPGCS, 2014). Informed written and oral consents were obtained from parents and children after explanation of the study's aim and the procedures used in detail.

Statistical Analysis:

Recorded data were analyzed using the statistical package for social sciences, version 23.0 (SPSS Inc., Chicago, Illinois, USA). The quantitative data were presented as mean± standard deviation and ranges and the qualitative variables were presented as number and percentages. For comparing between two means, independent samples (t) test of significance was used while paired sample (t) test of significance was used when comparing between related sample. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the P- value was considered significant when< 0.05, highly significant when< 0.001 and non significant when> 0.05.

Results:

In this study, seven children 10.94±0.71 years old included; 57.1% boys and 42.9% girls (table 1). Two types of dyslexic children were included, three children with visual dyslexia (42.9%) and four children with mixed visual and phonological dyslexia (57.1%). Cases were also statistically analyzed about their compliance to home based reading& writing practice and their compliance to conventional dyslexia sessions table (2). Four cases (57.1%) were compliant to whom practice, while three cases (42.9%) were non compliant. Regarding compliance to conventional dyslexia sessions; four cases (57.1%) were compliant, while three cases (42.9%) were not compliant.

Table (1) Demographic data distribution among study group

Demographic Data		Total (n= 7)
Age (Years)	Range	9.7- 11.6
	Mean±SD	10.94±0.71
Sex	Male	4 (57.1%)
	Female	3 (42.9%)

Table (2) Compliance to conventional sessions and compliance to home training distribution among study group

		No	%
Compliance To Conventional Sessions	Yes	4	57.1%
	No	3	42.9%
Compliance To Home Training	Yes	4	57.1%
	No	3	42.9%

Table (3) shows the difference between the scores of MADST between before and after training. In rapid naming duration test scores, cases showed significant improvement. The Bead threading test also showed a significant increase in the number of beads threaded in 30 seconds. In the one minute reading test, cases showed significant improvement in the number of correctly read words. The 2 minute spelling test also showed a significant increase between pre and post training number of correctly written words. Also, there was a significant increase in the number of correctly read real words in the nonsense reading test, while there was non significant difference about the number of correctly read pseudowords and the duration of passage reading in the same test. Finally, there was a very significant improvement in the one minute writing test.

Table (3) Comparison between pre and post according to different parameters

Parameters	Pre	Post	Paired Sample T-Test		
			Md±Se	T-Test	P- Value
Rapid Naming Duration	28.71±7.80	19.86±3.98	8.86±2.88	2.242	0.012*
Bead Threading	9.00±1.53	10.43±1.51	-1.43±0.29	-4.804	0.003*
1 Min Reading	17.14±9.25	23.29±12.82	-6.14±1.41	-4.374	0.005*
2 Min Spelling	3.14±2.19	4.29±1.98	-1.14±0.40	-2.828	0.030*
Nonsense Reading Duration	189.43±206.02	158.57±179.00	30.86±24.58	0.692	0.515
Pseudowords	4.86±1.95	5.86±2.79	-1.00±0.49	-2.049	0.086
Real Words	19.86±8.93	25.00±10.13	-5.14±0.63	-8.118	<0.001**
1 Min Writing	10.14±3.44	12.57±3.78	-2.43±0.37	-6.584	<0.001**

p- value >0.05 is insignificant; *p- value <0.05 is significant; **p- value <0.001 is highly significant

This table shows statistically significant difference between pre and post according to rapid naming duration, Bead threading, 1 min reading, 2 min spelling, Real words and 1 min writing, with P- value (P<0.05); while there is no statistically significant difference between pre and post according to Nonsense reading duration and Pseudowords, with P- value (p> 0.05).

The comparison between the two groups of dyslexia, visual versus mixed dyslexia, in improvement on different subtests is presented in table (4). The visual Dyslexia Group showed significant improvement in the subtests of one minute reading and one minute writing as compared to mixed dyslexia group. While there was no significant difference in the other subtest scores.

Table (4) Comparison Between Visual Dyslexia And Mixed Dyslexia According To Different Parameters.

Amount Of Change About Parameters	ITPA				T-Test	P- Value
	Visual Dyslexia		Mixed Dyslexia			
	Mean	±Se	Mean	±Se		
Rapid Change	-15.33	10.73	-4.00	2.74	-1.188	0.288
Bead Change	1.67	0.33	1.25	0.48	0.660	0.538
1min Reading Change	9.00	0.00	4.00	1.83	2.315	0.049*
2 Min Spelling Change	0.67	0.28	1.50	0.29	-1.025	0.352
Nonsense Reading Duration Change	16.00	9.54	-26.00	17.14	0.895	0.412
Pseudowords Change	1.33	0.67	0.75	0.45	0.557	0.602
Real Words Change	5.67	0.33	4.75	1.11	0.684	0.525
1 Min Writing Change	3.33	0.33	1.75	0.25	3.895	0.011*

Using: (t) Independent Sample (t) test for Mean±SD;.P- value >0.05 is insignificant; *P- value <0.05 is significant; **P- value <0.001 is highly significant

This table shows statistically significant difference between visual dyslexia and mixed dyslexia according to 1min reading change and 1 min writing change, with P- value (P< 0.05); while the other parameters have insignificant difference, with P- value (p> 0.05).

When compliance to conventional sessions was taken as a variable in improvement of MADST subtests scores, table (5) only one minute reading subtest showed significant improvement in compliant versus non compliant group.

Also, when compliance to home based practice was measured as a variable table (6), there was no significant difference between the compliant and non compliant groups in any subtest.

Table (5) Association Between Compliance To Conventional Sessions According To Different Parameters

Amount Of Change About Parameters	Compliance To Conventional Sessions				T-Test	P- Value
	Visual Dyslexia		Mixed Dyslexia			
	Mean	±Se	Mean	±Se		
Rapid Automatized Naming Change	-11.50	8.50	-5.33	3.38	-0.590	0.581
Bead Threading Change	1.75	0.25	1.00	0.58	1.324	0.243
1min Reading Change	8.75	0.25	2.67	1.76	4.042	0.010*
2 Min Spelling Change	0.75	0.63	1.67	0.33	-1.153	0.301
Nonsense Reading Duration Change	6.50	5.65	-8.67	7.10	1.961	0.138
Pseudowords Change	1.75	0.63	0.00	0.00	2.351	0.065
Real Words Change	6.00	0.41	4.00	1.15	1.852	0.123
1 Min Writing Change	3.00	0.41	1.67	0.33	2.390	0.062

Using: (t) Independent Sample (t) test for Mean±SD; P- value> 0.05 is insignificant; *P-value< 0.05 is significant; **P-value< 0.001 is highly significant

This table shows statistically significant association between compliance to conventional sessions with 1 min reading change, with P- value (P< 0.05); while the other parameters have insignificant association, with P- value (p>0.05).

Table (6) Association Between Compliance To Home Training AccordingTo Different Parameters

Amount Of Change About Parameters	Compliance To Home Training				T-Test	P- Value
	Visual Dyslexia		Mixed Dyslexia			
	Mean	±Se	Mean	±Se		
Rapid Automatized Naming Change	-12.25	8.19	-4.33	3.84	-0.775	0.473
Bead Threading Change	1.25	0.48	1.67	0.33	-0.660	0.538
1min Reading Change	7.25	1.75	4.67	2.40	0.895	0.412
2 Min Spelling Change	0.75	0.63	1.67	0.33	-1.153	0.301
Nonsense Reading Duration Change	-11.25	9.54	9.67	7.23	-0.759	0.482
Pseudowords Change	1.00	0.58	1.00	0.60	0.286	0.832
Real Words Change	5.25	0.48	5.00	1.53	0.179	0.865
1 Min Writing Change	3.00	0.41	1.67	0.33	2.390	0.062

Using: (t) Independent Sample (t) test for Mean±SD; P- value> 0.05 is insignificant; *P- value <0.05 is significant; **P- value <0.001 is highly significant

There is no statistically significant association between compliance to home training with Rapid naming duration Change, Bead threading Change, 1 min reading Change, 2 min spelling Change, Nonsense reading duration Change, Pseudowords Change, Real words Change and 1 min writing Change, with P- value (p>0.05).

Discussion:

Good fluent reading needs the precise integration of many sensory& cognitive functions. To simplify, a new reader needs first to recognize the letter sounds (phonemes)& letter shapes (graphemes), then to lock both together so that every letter has a distinctive sound. The following stage of reading acquisition is good, timely identification of each letter and its associated sound; the formation of grapheme- phoneme pairs. Later, the reader needs to visually perceive a sequence of letters and recruit the phoneme of each one, then blend those phonemes sequentially in the correct sequence. Another more advanced step is to read sequence of words in a short time so that they can be fitted in the span of the reader's working memory, leading to good understanding of the sentence. Based on this simplified description of the reading process, we can point to many of the basic prerequisites of fluent reading. In the first stage, the child needs good visual and auditory attention, perception and memory so that he can identify letters and their sounds. He also needs good fine- tuned audio- visual integration to lock each phoneme to its graphene making grapheme phoneme pairs instantly ready to be used in the later stages. In the second stage, the reader needs to correctly perceive a sequence of letters visually and then use the pre- prepared grapheme phoneme pairs to produce a correct phoneme sequence to read the word. This needs a good sequencing ability both on the visual and auditory channels, as well as good working memory to blend the phonemes correctly. This also needs excellent smooth eye movement between subsequent letters to put the letters in the correct sequence and to perceive the space between subsequent words. Again, visual- auditory integration is mandatory to complete this step of reading. The third stage, where the reader needs to read a sequence of words to make a sentence, needs basically good achievement in the previous stages so that reading a word is no longer a hard or slow process. Then the reader needs to move his eyes smoothly on the sequence of words and lines so that each word is visually perceived in its correct position in the sentence. It also needs good working memory to keep the first words while reading the following ones to understand the meaning of the sentence. Another important skill is the good, planned shift of visual attention between the sequential words and the sequential lines to read every word and every line in the passage.

From this very simplified view of reading acquisition and the reading process, we can understand why there are very wide range of dyslexia theories. Where any deficit of one of the previously mentioned prerequisites can lead to dyslexia. This also gives a clear understanding of the several classifications of dyslexia.

From the different theories of dyslexia, we choose the MD deficit theory to focus on in this research, being one of the theories described as etiological rather than descriptive theories of dyslexia. The MD stream of the visual pathway is proved to be responsible for allocation of the visual attention, shifting of attention, smooth pursuit, eye movement, detection of motion, including both focal motion within the visual field or global motion, which means the motion of the whole visual field through eye movement. A function that is highly related to good perception of visual sequence. When moving eyes through a line to read a sentence. All these functions are essential for fluent reading. Previous studies found improvement in reading fluency after training of the MD stream using action video games (Franceschini, et.al, 2017) direction discrimination training, (Lawton 2008) coherent motion training (Qian& Bi 2015) and Texture discrimination training. (Stein 2019)

All these studies used computer screens for visual training. In our study, we take advantage of the wide visual field training available in the Sensory Integration Room to train several functions of the MD system, namely the smooth pursuit eye movement, the visual attentional shifting, the motion perception; both localized and global, depth perception as well as stimulation of the MD stream using flickering lights. Theoretically, training these functions can enhance the MD pathway which will be reflected on improvement of the visual skills, visuo- motor integration and hence the reading and writing performance.

Results of this study showed significant improvement in the bead threading scores which reflects improvement of the visual motor coordination. Also, the duration children needed to sequentially name a group of familiar pictures (Rapid Automatized Naming) was significantly shorter in the post training assessment. This denotes faster and smoother eye movement between the sequential pictures, taking in consideration that all children were able to name all the pictures sequentially before and after training and the difference was only in the duration of this task completion. Cases also showed significant improvement in the reading speed presented as the number of correctly read words in one minute and the number of correctly read words in the nonsense passage reading test. Regarding the visual motor integration and the writing speed, children also showed a significant increase in the number of written words in 2 minutes. An interesting finding was the very significant improvement in the number of correctly copied words in one minute. This task especially reflects the smooth eye movement and the good allocation of visual attention functions that are highly specific to MD.

Our results are consistent with previous studies on the effects of MD training on reading fluency. Franceschini and colleagues used the Action Video Games as a training procedure for MD stream. This technique, in contrast to ours, also included sounds together with the moving pictures. In the post training assessment, authors found significant improvement in the speed of word recognition and visuospatial attention. These functions are also relevant to MD stream. In their study, they also found improvement in the phonological short- term memory, phoneme blending and visual to auditory attentional shifting. (Franceschini, et.al, 2017) These results can be related to phonological skills improvement as a result of the sound to picture synchronization in action video games, that's not a part of our training procedure.

Another training procedure to improve MD function is the direction discrimination training. This method was used by Lawton in 2008 on a group of dyslexic children and another group of normal reader children. Each child received a 10 minute training session twice weekly for 15 weeks, with no other added reading training. The direction discrimination training in this study caused significant improvement in reading fluency of dyslexia, but not in normal reader group. On the other hand, a third group of dyslexia received conventional reading training only with no direction of discrimination training. This group showed non significant improvement in reading fluency. These results add to the evidence of poor direction discrimination in dyslexia, a function of MD stream.

Another training procedure to train the MD stream is the coherent motion detection training. This was used by Qian& Bi in 2015. And their results showed significant improvement in reading fluency of dyslexia children after 10 sessions of coherent motion detection training, visual search training and visual tracking training; all were collectively named MD Based Visual Training. The post training assessment of their sample showed improvement in reading fluency. Further, this improvement was correlated to the participant's improvement of coherent motion detection threshold.

Conclusion:

Visual sensory training is effective in improving reading fluency in dyslexic children.

Recommendations:

Clinically, adding sensory training to the protocol of dyslexia is recommended to enhance reading. Also, in the field of dyslexia research, much research is needed to make evidence- based sensory training protocols in different developmental disorders.

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