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Effects of MNRI Visual Reflex Neuro-Training on Visual and Academic Skills of Children with Autism

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Abstract

Background: The Masgutova Neurosensorimotor Reflex Integration (MNRI) Visual Reflex NeuroTraining (VRNT) program facilitates improvement in visual perception, fixation, mobility and saccades functionality in children with Autism Spectrum Disorder and supports their academic skills of reading, writing, and overall neurodevelopment.

Objective: Our objective was to determine the effectiveness of MNRI VRNT exercises on the eye tracking, ocular-vestibular and optokinetic visual reflex patterns (based on saccades) in children diagnosed with autism (Study Group, n=240). The research hypothesis was that training using these early visual sensory-motor patterns such as: binocular vision and visual fixation, convergence/divergence, eye tracking, ocular-vestibular and optokinetic will improve visual perception and processing resulting in a positive impact on academic skills particularly reading and writing for children with ASD.

Study Design: A controlled trial setting and participants - 360 individuals diagnosed with ASD of moderate severity from 7 to 10 years of age. Children attended the VRNT sessions at MNRI Family Conferences (Poland and USA). The study provided comparative analysis and correlation of results in visual competency depending on specific visual reflex patterns. A comparison of the Study Group and Control Group 1 and Control Group 2 was evaluated.

Study Group of children diagnosed with ASD (n=240) included boys (n=142); 7-8 year-old (n=58); 8-9 year-old (n=40); 9-10 year-old (n=44) and girls (n=98); 7-8 year-old (n=33); 8-9 year-old (n=28); 9-10 year-old (n=37); verbal (n=91) and non-verbal (n=54), with partial ability to pronounce limited amount of words (n=95).

1. Control Group 1: Included children diagnosed with ASD (n=120) included boys (n=83); 7-8 year-old (n=28); 8-9 year-old (n=31); 9-10 year-old (n=24) and girls (n=37); 7-8 year-old (n=12); 8-9 year-old (n=14); 9-10 year-old (n=11); verbal (n=47) and non-verbal (n=24), with a partial ability to pronounce a limited amount of words (n=49).

2. Control Group 2: Included typical children (n=260) with boys (n=120); 7-8 year-old (n=43); 8-9 year-old (n=38); 9-10 year-old (n=28) and girls (n=140); 7-8 year-old (n=52); 8-9 year-old (n=46); 9-10 year-old (n=42); verbal and with normal neurodevelopment markers (n=260).

At the first stage of the study all participants diagnosed with ASD (n=360) in the Study Group (n=240) and Control Group 1 (n=120) and Control Group 2 (n=260) of children with typical development had pre- and post-assessments of:

a) Visual reflexes (seven patterns total): Binocular single vision and visual fixation, convergence, divergence, horizontal eye tracking, physiological nystagmus, optokinetic and ocular- vestibular/vestibular-optic. (Children in the control groups did not have the MNRI I Visual Reflex NeuroTraining.)

b) Visual skills (Test): Convergence stability, directionality in perception, form perception/processing, eye tracking (pursuits and saccades), accommodation (eye- focusing), visual- motor integration, visualization, and other.

c) Academic abilities of reading and writing: (Standard School Performance Test - SPT) with age differentiation.

At the second stage of the study MNRI VRNT was given to the children in the Study Group (n=240). At the third stage of the study a comparative analysis of results on visual reflex patterns and visual skills was evaluated considering school competency in reading and writing of children diagnosed with ASD in the Study Group and both control groups compared to educational norms for reading and writing (SPT).

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Interventions: The MNRI – Masgutova Neurosensorimotor Reflex Integration therapeutic procedure was the main therapeutic intervention carried out during the 8-day training Conference of 6 hours daily in the Study Group (n=240) in which the VRNT procedure was done as therapy for visual modality.

The visual training for the Study Group was designed as one session for a 50-minute duration per day which equaled a total of 8 sessions during a Training Conference. The participants, children and their parents, were also trained with the exercises as part of them at-home program.

Main outcome measures: Reflex assessments of seven visual reflex patterns on Binocular single vision (fixation and visual field), convergence, divergence, eye tracking, physiological nystagmus, ocular-vestibular, and optokinetic a scale of 0 to 20 points was implemented. Comparative statistical analysis using ANOVA test and NewKrefft was used to ascertain the statistical significance of positive changes in visual skills development and academic abilities of reading and writing before and after the MNRI intervention.

Results: This study showed that children diagnosed with ASD (n=360) compared to those with neurotypical development (260) had: a) 85.71% of visual reflex patterns (6 out of 7) immature and dysfunctional; b) 80% of visual skills (12 out of 15 tested) at the dysfunctional level; and, c) academically, 73.6% of these children had an inability to read or poorly developed reading skills, and 79.7% had their writing abilities falling at the critical level.

Discussion: After the MNRI VRNT procedure was administered the Study Group (children diagnosed with ASD; n=240) showed a statistically significant and substantive improvement in all outcome measures. In a rather short time of 8 days of intensive training for 50 minutes each day, positive changes for all visual abilities and skills and their links with the academic skills of writing and reading were observed. After completion of this intensive training: 71.43% (5 out of 7) of their reflex patterns improved significantly (p<0.05) which was characteristic for every child. These improvements of reflex patterns allowed the children to improve their visual skills with 75% of them (9 out of 12) moving from dysfunctional to functional level, though to a very low functional level, and 25% (3 out of 12) moved to a marginal level between functional and dysfunctional. The scores for academic skills, particularly in their reading, improved in 43.33% of children in the Study Group (n=104) and for writing in 33.75% (n=62). It was also noted that their oral-motor skills, clarity of sound in pronunciation, speech, comprehension seen in use of more complicated language constructs, and typing improved. However, the significance of positive changes in all these areas was on a lower level than those in children with typical development, which shows the necessity for further corrective therapy of reflex patterns in children with ASD. There was no statistical significance of improvement in levels of development of visual reflex patterns and academic skills in Control Group 1 and Control Group 2 that did not go through the MNRI VRNT therapy.

Conclusion: MNRI Visual Reflex Neuro Training (VRNT) increases the level of visual reflex functionality for a range or variety of patterns of children diagnosed with ASD particularly visual convergence/divergence, horizontal eye tracking, ocular-vestibular and optokinetic which positively affects their academic skills of reading, writing, and overall neurodevelopment.

Keywords: Vision; MNRI; Reflex; Autism; Academic skills; Neurodevelopment; Eye tracking

Introduction

Studies on Autism

Individuals diagnosed with Autism Spectrum Disorder (ASD), first described by Dr. Leo Kanner [1] as an "inability to relate 'themselves' in the ordinary way to people and situations" are given this diagnosis when "deficits are involved into two following areas: 1) Social interactions and communications and 2) Restricted, repetitive patterns of behavior and interests [2]."

ASD disorders develop during early childhood [3,4]. The number of identified cases of ASD is rapidly increasing in many countries, especially in technologically developed countries [4-6]. In some states of the USA, one out of every 68 children (one out of 42 boys, and one out of 189 girls) is diagnosed with ASD [1-8]. This increase within two years went up 30% in comparison with 2012 [9].

Different aspects of main ASD symptoms have currently been intensively studied: behavioral, cognitive, academic-intellectual, speech and language, neurophysiological – perception patterns and brain coding-decoding functions, and medical/health. The scope of studies proposes a variety of evaluation and assistance/intervention tools; however, they are more conceptual, descriptive and hard for professionals and parents to realize in real activities and the lives of their children. Some tools became more frequently and systematically used however, and there are not many programs that target the study for the reasons for the disorder, especially on a neurophysiological, neurodevelopmental and reflex integration level [10,11] (Table 1).

Specialists and parents are mainly concerned with solutions for their children's deficits on a symptomatic level, and thus, for finding improvements in speech, communication, behaviour and the academic skills for reading, writing, math, and all aspects that are the outcome of executive functions of voluntary programming and control by the brain cortex.

There are some helpful studies that target specific areas that help to deal with the everyday problems of a child with ASD at school and home. These studies and intervention programs for the support of children with ASD are focused on school skills particularly on: - Reading such as: reading for sound and meaning [12,13]; reading and IQ relations in academic achievement [14,15]; integration of reading skill components - word recognition, non-word decoding, text reading accuracy and text comprehension [16-18], reading and cognitive profiles [19] "meaning-focused" reading [20], reciprocal questioning [21], remediation of a reading comprehension deficit [18] and others. The main deficit that these studies target is support of the comprehension process.

Writing: Teaching recognition of alphabet letters and numbers [22], spelling, also reading and spelling [23], spelling, also reading and spelling [23], letter concept formation, behavior and skills, phonological awareness, computer-assisted instruction [24,25] and PROMPT [26].

Groups	Boys			Girls			Speech
		Ages			Ages		**Total (n=240)**
	7-8	7-8	8-9	9-10	8-9	9-10	Verbal = 91
							Non-verbal = 53
Study (n=240)	**n=142**			**n=142**			Some speech = 95
	58	58	40	33	28	37	
Control 1 (n=120)	**n= 83**			**n= 83**			**Total (n=120)** Verbal = 47
	28	28	31	12	14	11	Non-verbal = 24
							Some speech = 49
Control 2 (n=260)	**n=120**			**n=120**			**Total (n=260)**
	43	43	38	52	46	42	Verbal = 260

Table 1: Demographic data on groups of children participated in study.

Each of these studies states that overall development of children diagnosed with ASD is delayed by 1-3 years or more in comparison with their peers [10] and that comprehension is a most challenging function [17] found comprehension difficulties in more than 65% of children with ASD who had measurable reading skills.

There is research showing a correlation between poor visual functions and the academic skills of reading [25], recognizing visual patterns, language and social ability delays showing a demonstrated difference in eye movement patterns of children diagnosed with ASD [27] and a greater effect of computer assistance *vs.* traditional book methods [28].

Visual and motor reflex patterns in infancy serve as the neurophysiological basis for future academic skills of school children [10,11,29,30]. The vision-based skills of reading and writing rely on the primary sensory-motor and reflex patterns of: binocular vision, eye tracking, focusing, convergence/divergence, figure-ground discrimination, ocular-vestibular and optokinetic, the head- righting reflex, and others which build upon the integration of overall neurodevelopment with manual skills, gross-motor coordination, central and peripheral vision integration, balance, stability, grounding, vestibular and auditory systems, including motivation and cognitive processes (attention, memory, thinking processes, language).

The activity of vision with automaticity (no conscious control) is poorly studied, though this translates into a big part of the problem for many functions, communication, behaviour, as well as reading, writing, and others. This research shows that the ocular-vestibular, optokinetic reflexes and physiological nystagmus (conducted by the work of neurons in the pretectum, tectum and tegmentum areas in the midbrain of the brain stem) must specifically be matured and myelinated to be able to serve the cognitive visual functions of voluntary academic skills. The main task in this area of the brain is to process the visual and auditory modality input and adjust them with proprioceptive-vestibular-motor programming and control directed by the cerebellum [31-35]. This adjustment allows for stabilizing, creating constancy, and maintaining visual dynamics, for example, for visual images dependent on ocular-vestibular and optokinetic reflex functions [31-33]. When these reflex patterns are delayed in development, then horizontal eye-tracking along a line when reading sentences, one after another, and 'jumping' from the end of one line to the beginning of the next line results in difficulties at a technical or functional level to comprehend the visually perceived text [36-38]. The peripheral (or ambient) vision serves to guide the saccades, which aims central vision). There must be simultaneous awareness of both the ambient visual system (also known as peripheral vision) and the focal visual system (also known as the central visual system) [39,40]. The ambient and focal visual systems follow separate pathways in the brain and respond to different stimuli [41]. In order to read smoothly and have accurate saccadic fixations, a person must use their peripheral vision to see the next word coming up on the right as they are reading the word they are looking at - as well as to see the beginning of the following line when they are at the end of a line of text. The ability to use both the ambient and focal visual systems simultaneously is often a very significant issue with ASD [42], similar to the difficulty that is observed when attempting to attend to the visual and auditory systems at the same time.

These specialists offer objective tests such as electronystagmography (ENG), Clinical Test of Sensory Organization and Balance (CTSIB), visual evoked potentials (VEP), and otoacoustic emission (OAE) tests.

This also negatively affects writing skills and the visual components of the entire writing action: acuity of hand-eye coordination, graph/manual abilities, and visual-motor imitation (decoding and coding), visual-auditory coordination, and vision-space-time orientation. Timely maturation and integration of the above reflexes enable children to avoid delays in both sensory-motor skills and academic achievement.

Specialists working with various MNRI reflex integration programs have consistently found a correlation between visual skills, reflex patterns, and learning challenges among children diagnosed with ASD [4,43,44]. This additionally causes insufficient function in various sensory modalities and motor-postural coordination which then inhibits development of other skills and neurodevelopment [35].

Initial study by MNRI researchers on the influence of visual and motor reflexes on visual skills serving reading and writing resulted in quantification of these correlations in a group of 360 (7-10 years old) children diagnosed with ASD. Another project focused on 240 children diagnosed with moderate ASD. The purpose of these studies was to determine whether MNRI vision training of the visual reflex patterns would influence the development of visual skills in these children and be reflected in improvement of their ability to read, write, and draw. This study documents our findings of the positive effects of this visual training using comparative analysis of data gathered from these two study groups.

Ethical Approval

Institutional Review Board (IRB) approval was granted by the New England IRB (85 Wells Ave., Ste 107, Newton, MA 02459) (IRB ll-173) under IORG Number IORG0000444. This study project is included within this research.

All participants were assigned codes to protect anonymity. Receipt of informed consent was received from all participants' parent or legal guardian. Visual tests were done by an ophthalmologist, optometrist, and licensed psychologist; the visual MNRI visual reflex assessments and therapy sessions were conducted by designated MNRI Core Specialists who have successfully completed the MNRI Continuing Professional Education requirements and clinical hours.

Materials and Methods

Visual Reflex Assessment (VRA)

The primary outcomes of interest were changes in the visual reflex patterns of children diagnosed with autism. Visual Reflex Assessments (VRA) were based on classic definitions of reflex patterns [5,29,30,31,33,45]. It was conducted prior to (pre-test) and after conferences (post-test) and the results analyzed through comparative analysis. Evaluations of visual patterns considered the child's age, neurological abnormalities, versus the normal status of inborn reflex patterns. Briefly, this entailed grading seven reflexes (diagnostic qualities coded X1-X7) using five parameters:

1) Sensory-motor circuit (correspondence of the response to the specific sensory stimulus);
2) Direction of the motion or sequence of the response;
3) Stability of the response (smooth eye movements, normal range of eye movements);
4) Timing (in tracking, the ability of the eyes to remain following a slow moving object in the center of their field of vision with the eyes neither lagging behind nor moving ahead; in oculovestibular and optokinetic reflexes including speed and head righting adjustment and number of saccades);
5) Symmetry of the response in both eyes.

The following additional parameters of the reflex pattern were also evaluated:

1) Efficiency of eye movements in terms of completion of the task, range of visual field, and ability to maintain binocularity in the mid-field;

2) Muscle tone (easy tracking, no tension, normal physiological nystagmus, appropriate blinking reflex, no staring reflex, easy breathing) [36]. Scores in the VRNT were assigned on a continuous scale of '0-4' points, with '4' indicating full display of a parameter, and '0' indicating the absence of the parameter display resulting for above five parameters in a maximum score of 20 for each reflex.

A summary of the scores are in Table 2 [7,36].

Visual Skills Assessment (VSA)

Participants were given tests prior to and after therapeutic intervention, done by qualified ophthalmologists and psychologists:

- Convergence stability
- Directionality in perception
- Form perception/processing
- Eye tracking (pursuits and saccades)
- Accommodation (eye-focusing)
- Orientation in "center-periphery";
- Orientation in "left" and "right"
- Eye tracking while reading
- To imitate drawing or move eyes in a line from left to right and vice versa
- To imitate drawing or move eyes in a shape of a circle in both directions – from left to right and vice versa
- Ability to hold a pen/pencil and control hand movements
- Ability to look at and follow hands (left and right) while moving them in a different direction (hand up–gaze up, hand down-gaze down, hand to side–gaze to side, hand to center-gaze to center)
- To look at a near and distant object (ability to follow instructions with demonstration)
- Ability to follow verbal and non-verbal demonstration instructions to look in different directions: up, down, to sides, and in center (visual midline).

The results were analyzed in relation to skill development and by percentage relationship to the group results. Each skill was evaluated on scale of '0-5', in which '0' – no skill is presented, and '5' – skill fully developed; overall maximum score that children could reach per a skill was 15 points with grades: '0-2' – no skill or very poor, '3-5' – fair level, '6-10' – moderate, '11-13' – good, '14-15' – fully developed. The pre- and post-test results were evaluated through comparative analysis. Correlative analysis between the visual reflexes and skills was also done and visual acuity was checked.

Academic Skills Assessment based on standardized testing was done by qualified school teachers. Participants diagnosed with ASD were asked to read and write for five minutes hands-on tasks (text).

Reading: A standard criterion for reading according to each age group was used. For example, at age of 7-8 (first grade in Europe and second in the USA) a child was expected to read the text of 27-32 phrases (=55-60 words), 8-9 (second grade) – 45-50 phrases (=90-100 words), and 9-10 (third grade) – 57-60 phrases (=114- 116 words). The criteria for rating the technical aspects of reading were: reading by syllables or complete words, errors in reading, number of words per minute, expressiveness, and comprehension. The speed of reading was measured depending on the child's age and school curriculum (whether at the beginning of the school year or second half) and by comparison of a child diagnosed with ASD with skills of a typical child. The scores were given from '2' to '5'. For example, at the beginning of the year a child is expected to read certain amount of words per a minute and was given points: '5' points (excellent) for 35 (55-60) words; '4'– 30-34 (49-54); '3' (fair) – 25-29 (40- 48); '2' points (very poor) – 25 (40) words. Writing. Their ability to write was tested and a graph representation of their writing was created and analyzed. All children were asked to re-write letters and sentences from an example text; the evaluation of their writing ability was adjusted for age. The results were analyzed as a graph of their skill development, their comprehension was given in points, and a percentage relationship was determined to compare results with the group. All tests were created as simply as possible taking into consideration the developmental, communication and behavioral challenges and individual features of the children with ASD. Comparative statistical analysis of pre- and post- intervention results was done based on the ANOVA test (IBM SPSS Statistics Grad Pack 22.00 and the Mann-Whitney U-test) using Statistica (version 6.0;

Stat So Inc., Tulsa, OK, USA) with each testing procedure; results were considered statistically significant with p values (M ± SD) less than 0.05 interpreted as significant, and not significant at p>0.05. Correlative analysis was used to show the effect of MNRI VRNT intervention on visual skills and the academic skills of reading and writing.

Neurophysiology basics of visual reflex patterns for support of academic skills

Specialists measured the performance of visual reflex patterns and voluntary visual skills in 240 children diagnosed with ASD (7-10 years old) and in 260 children (7-10 y.o.) with typical development. The basis was to keep tests as simple as possible because of the behavioral and communication challenges in working with children with ASD. Testing visual reflex patterns allows us to obtain information about whether the corresponding visual nerve pathways (extrapyramidal, responsible for automatic functions) are mature and can support higher level functions (pyramidal, consciously programmed and controlled abilities and skills). Correlative analysis of the level of their development in academic skills can provide substantial evidence about this maturity and its basis for corresponding work of nerve pathways, brain connectivity, and neuroplasticity.

Visual activity supports reading, writing and other school skills requiring neurophysiological maturity of such visual responses and reflexive eye movements as: saccades, smooth pursuits, and convergence, with their main task of directing the gaze toward selected objects which is the basis for reading and writing. Central-peripheral visual system integration is paramount to being able to read in a smooth efficient pattern as well as to properly space their writing within a specific area. Otherwise, the kid is at the end of the paper in the middle of a word before they realize that they ran out of room- so they start curling the words down the page, or write the opposite direction. The paradox of educational systems is that there are no well-established testing services for the visual reflexes, thus our schools do not target their functions directly. The system does not work with these children at their level but instead tries to push their under developed visual system to perform at an unrealistically higher level – to recognize letters, shape, decoding, and thus comprehension. In other words, the educational system targets pyramidal system development, missing the function with extrapyramidal. So the actual state of the child's brain development and demands in school are often incoherent. The MNRI concept of reflex integration encourages a problem solving approach by targeting and addressing the visual reflexes first and then building a bridge between the reflex level and visual skills, and then next, to academic functions.

Brain stem (extrapyramidal system) and cortex centers (pyramidal) control reflexive responses particularly the horizontal and vertical involuntary eye movements caused by specific stimulus. These eye movements are the basis for reading and writing. An area in the pons, the paramedian pontine reticular formation, controls voluntary horizontal saccades. The abducens nucleus, as the source for abducens nerve activity, connects with the oculomotor nucleus and controls horizontal pursuits and reflexive saccades [31-35,46]. The midbrain reticular formation controls vertical eye movements. These saccades movements used in later academic skills formation are needed to move eyes to follow the shapes of letters to recognize and decode them. The mature brain stem is capable of supporting cortical level brain functioning and when maturity is lacking, connectivity in the lower and higher brain levels occur causing confusion in visual tasks; to move eyes from left to right (for texts), to recognize and decode each symbol and coordinate it with the memory and link letters with syllables and words (formation of the concept of words), to coordinate the technical aspects of reading with abstract meaning of words and visual and visual-auditory stimuli (objects) that all together allows correct comprehension of the text or event. In writing, all these skills function at more the advanced levels needed to combine the expression of their thoughts.

Saccade is the quick switch of vision from one object to another. If a person is reading and someone comes into the room, a saccadic eye movement shifts the reader's gaze from the text to the person. For voluntary saccades, the posterior parietal cortex directs visual attention to the stimulus. The posterior parietal cortex signals the superior colliculus (the brain stem center) for orientation. The superior colliculus also receives information from the frontal eye fields. The superior colliculus then signals the paramedian pontine reticular formation and/or the midbrain reticular formation. The paramedian pontine reticular formation controls voluntary horizontal saccades by activating the abducens nucleus, which then activates the oculomotor nucleus. The midbrain reticular formation controls vertical saccades. The optic nerve projects from the retina to the midbrain and to the lateral geniculate. Reflex connections in the midbrain control the constriction of the pupil and reflexive eye movements. Visual information relayed by the lateral geniculate to the visual cortex provides conscious vision [31,33-35].

The gaze reflex, which directs the eyes to certain directions when a sudden or unexpected stimulus emerges and keeps the eyes focused on specific visual objects, is another visual response that creates the basis for visual focusing and attention as a potential future ability. There are six cardinal positions of gaze that allow comparisons of the horizontal, vertical, and diagonal ocular movements produced by the six extraocular muscles. The positions are: up/right, up/left, right, left, down/right, and down/left. In each position of gaze, one muscle of each eye is the primary mover of that eye and is yoked to the primary mover of the other eye. (In addition, there are upward gaze, downward gaze, and convergence). The gaze is based on the optic nerve projected from the retina to the midbrain and to the lateral geniculate. Reflex

Normal Function		Dysfunction/Pathology	
Points	Level of reflex integration	Points	Level of reflex integration
20	Full/Complete integration	10-11.99	Marginal pathology and dysfunction
18 – 9.99	Mature and integrated	8 – 9.99	Incorrect, light dysfunction
16 – 17.99	Correctly developed – normal	6 – 7.99	Dysfunction
14 – 15.99	Functional, but low level of development	4 – 5.99	Severe dysfunction
12-13.99	Functional, but very low level of development	2 – 3.99	Pathology
10-11.99	Marginal pathology and dysfunction	0 – 1.99	Severe pathology

Table 2: Clinical evaluation: Criteria for reflex assessment scores (in points 0-20).

connections in the midbrain control the constriction of the pupil and reflexive eye movements. Visual information relayed by the lateral geniculate to the visual cortex provides conscious vision. The ability to move the eye to all these positions is essential for reading and writing. The gaze is also influenced by auditory information (via the superior colliculus) and behavior-ocular reflex 'training' constancy control (activation of sensory axon of optic- II nerve synapsed to motor axons – via cranial nerves – oculomotor-II, trochlear-IV, abducens-VI) [31-33].

Cortical centers determining eye movements include the frontal, occipital, and temporal eye fields. The frontal eye fields provide voluntary control of eye movements when a decision is made to look at a particular object. The occipital and temporal eye fields contribute to the ability to visually pursue moving objects (eye pursuit movements). The dorsolateral prefrontal cortex inhibits reflexive eye movements as appropriate. Another area in the posterior parietal cortex provides cortical input for smooth eye pursuit movements [32]. The processing of visual input at the level of cortical functions allow the skills of reading and writing to be free of reflexive eye movement. This is possible only when the maturation of reflex circuits (myelination of sensory and motor axons) happens. In our traditional educational and therapy system, professionals use the concept of inhibition of immature or hyperactive reflex patterns which is not just non-productive, it is not conducive to nervous system development (blocks the process of myelination), stress- resilience, and particularly brain connectivity.

Thus, development of voluntary visual and school skills depend on maturity of the reflex circuits (extrapyramidal nervous system) and work with visual reflex maturity must be the choice of a helping specialist.

Standardized testing of the visual functions in a child diagnosed with ASD is a big challenge for therapists and teachers [2,33,46] and often ends in misinterpretation. This particularly relates to intelligence and reading skills [47] as deficits in social interaction and associated disruptive behavior (such as self-stimulation, task avoidance, and escapism behaviors) may interfere with testing. In our study we utilized testing procedures that do not require the involvement of cortical control which is so complicated for them and leads to a blockage in behavior and lowers their motivation to participate. Visual reflex assessments test involuntary patterns with no expectations and demands, and so it is easy, safe, and non-threatening for a child. The testing of visual skills was organized in the same way. The testing of academic skills was done in a very natural situation by teachers working with these children.

Brief description of visual reflexes, their specific functions in children with ASD

Binocular vision or physiological binocular single vision is the simultaneous vision achieved through coordinated work of both eyes blending the visual images from the two eyes into a single percept based on the fusion reflex. Binocular vision as the blending of sight requires clear visual axis in both eyes, the ability of the retinal-cortical cells to promote the fusion of two slightly dissimilar images (sensory fusion), and precise coordination of the two eyes in all gaze directions (motor fusion) [5,31,47]. Binocular vision is based on functions of several reflexes [32,33]:

- Visual fixation (also known as controlling visual attention) keeps the eyes in a fixed position adjusted to movement of the head, body, and limbs).
- Orientation fixation or pursuits (horizontal eye axis reflex where eye movements follow a slow-moving object or panorama with no rapid jerks and continued fixation).
- Disjunctive reflexes (convergence/divergence reflexes).
- Accommodation convergence reflex (aligns the eyes and keeps them focused on the object; includes vergence fixation reflex, accommodation reflex and fusional vergence reflex).
- Fixation reflex (the eye keeps the orientation point and can come back to original point).
- Pupillary reflex (pupil constricts when light is shined into eye).
- Conjugate (parallelism of the two eyes in all positions of gaze).

The binocular vision is prepared in utero time development [32,33]. The embryo demonstrates ability for fixation at 28-29 weeks of gestation. After birthing this ability seems to be 'lost' – it goes to a latent state as a newborn has to deal with effects of the birth and stress of gravity (change of environment from fluid to air, terrestrial attraction). At birth the binocular vision is functioning poorly and will develop further through 'the training' of the fixation reflex, with the child having only random, non- conjugate, and aimless ocular movements. During the first few weeks of life an infant shows an inability for fusion and pursuit movements. The development of mono- or uniocular takes place in the first 2-3 weeks. After adapting time to terrestrial life, the fusional responses start functioning as unconditioned reflexes depending on the connectivity of the eyes, visual nerve providing the input to thalamus, pretectum (midbrain of brain stem), and reticular-activating system (RAS; diencephalon, brain stem).

At the end of 1-1.5 months the binocular vision starts functioning as a conditioned reflex acquired and maintained by cerebral activity and is developed based on individual experience. Once formed, with continued reinforcement and coordinated with other reflexes, it becomes an ability for binocular single vision, also known as psycho-optical reflex. Binocular vision consists of all the activities mediated from the retina through the brain to maintain the images received on the two foveas with the ultimate aim of attaining single, united perception. [33,34,47]. The development of binocularity takes place from 6 weeks to 6 months. The formation of the convergence, which is not well demonstrated at birth, is seen at the end of first month of life and is well established by 6 months.

The development of the accommodation mechanism depends on the ability of ciliary muscles for convergence with the eyeballs parallel with convergence and is seen at 6 months. Children diagnosed with ASD demonstrate an immature of binocular single vision mechanism and its reflexes. They show significant delays in binocular vision, preferring monocular vision and a lot of convergence causing fatigue. Because autistic children often have trouble with the ambient vision system, they do not have an accurate assessment of space or "where is it". The inaccuracies observed in the aiming of their eyes is often because that is where they erroneously believe the object to be. Aiming the eyes at where they believe they are looking often causes over-convergence and fatigue, therefore you will often observe them closing one eye or turning their head to an extreme angle as a coping mechanism in order to reduce the visual conflict that occurs from inaccurate aiming of the eyes [41]. Their fixation reflex is impaired with chaotic eye movements and is fragmented, as seen in their impulsive visual behavior [11]. Thus, the binocular vision in children with ASD needs special corrective therapy to facilitate further maturation of reflex patterns or, in other words, to create automaticity as the basis for higher visual functions and correct connections with the brain.

Children diagnosed with ASD (n=360) in Study Group (n=240) and Control Group 1 (n=120) demonstrated a poorly developed visual field seen in a narrower range of parallel eye positioning at a distance of 3-4 meters; significant asymmetry of two visual monocular visual fields with a dominance of the range of visual field for the left eye in 78.9%/284 of children; refusal of binocular vision and preference to use monocular vision in 67.8%/244); inability for distant vision in 63.9%/230; a tendency for exaggerated convergence in 93.9%/33; fragmented and chaotic eye tracking in 76.9%/227; compensation by pathological nystagmus or saccades in 88.9%/320; looking more upward or downward in 77.8%/280, and looking sideways, upward, and pathologically freezing in a specific position in 23.9%/86.

Visual fixation: The results of this test in children in the Study and Control Group 1 demonstrated immaturity, delay, and abnormal visual fixation. The children were particularly poorly oriented toward visual targets: unstable in focusing in 78.9%/284, easily distracted, fragmented and chaotic in 76.9%/227, and some compensated with pathological nystagmus or saccades in 88.9%/320.

Vergence is a simultaneous rotational movement of both eyes in medial or lateral direction while looking at an object with binocular single vision. Under normal conditions vergence causes changes in accommodation that changes eye focus. Vergence movements are far slower, around 25°/s slower in comparison with saccades (500°/s) [35,41]. The extraocular muscles have two types of fibre each with its own nerve supply, sensory, and motor axons, hence they have a dual mechanism – bringing sensory input and regulating motor output [33-35].

Convergence: It is a rotational movement of both eyes in a medial direction when looking at an object at a closer distance. The eyes rotate around a vertical axis towards each other to project the image in the center of the retina in both eyes [33-35,41]. Eighty-seven percent of children diagnosed with ASD in both groups, Study and Control 1, demonstrated exaggerated and insufficient convergence with the tendency for look at objects too closely while holding the objects 10-15 cm. from the eyes/nose (the main culprit behind eyestrain causing blurred vision and headaches). This can be explained as the tendency of these children to hold the objects too close in order to induce some magnification, and if maintaining binocularity, they would be expected to over converge due to poor spatial representation, but if they give up binocularly due to the stress, then a lack of convergence and probably intermittent exotropia would be noticed. They also often refused to cooperate with the convergence test, if the object was not of interest to them.

Divergence: It is a simultaneous rotational movement of both eyes in outward direction when looking at an object at a far distance until parallel, effectively fixating at the point of infinity (or very far away). The eyes rotate around a vertical axis away from each other to project the image in the center of the retina in both eyes to maintain single binocular vision [31,41]. Eighty-nine percent of children with ASD in both groups, Study and Control 1, demonstrated a poor ability for divergence with the tendency for dissociation (absence of presence) when asked to look far or they ignored the object moving away from their eyes in the divergence test. Children diagnosed with ASD in Study Group and Control Group 1 demonstrated poorly developed convergence (93.9%/338), divergence (87%).

Eye tracking: The results of this test in children in the Study and Control Group 1 demonstrated immaturity, delay, and limited eye movements for horizontal and vertical pursuit eye tracking after the moving the visual object. The children were unstable for control of the head righting and constantly moved their head showing very narrow range of eye movement. Their eyes movements were not free from the movements of their head. Particularly 88.6%/319 of children were having problems with horizontal eye-tracking, and 76.7%/276 were showing poor ability and limited span for vertical eye- tracking. Their eye-tracking was also fragmented, stopping and coming back to find the visual object; they became distracted from accomplishing their task in a short time. A large number of children compensated with saccades movements - 88.9%/320.

Spontaneous physiological nystagmus: This is often called 'dancing eyes' and is an involuntary, jerky eye movement determined by the direction of the eye movement in relation to response of the stimulated semicircular canals. When the head rotates around any axis, distant visual images are sustained by the eyes rotating in the opposite direction on the respective axis. The semicircular canals in the vestibular system take in the input as a result of the angular acceleration and send signals further on to the nuclei in the brain to regulate the eye movements. From there, a signal relayed to the extraocular muscles allow one's gaze to fixate on the object as the head moves. Nystagmus occurs when the semicircular canals are being stimulated while the head is not in motion [34,35,41].

Children diagnosed with ASD in both the Study and Control Group 1 demonstrated pathological nystagmus, particularly: hyperactive responses in 64% individuals, delayed responses in 36%, with 4% of them closer to norm. This data indicates that nystagmus is a major problem for these children and can explain the reason associated with abnormal functioning of the vestibular system. This inability to do pursuit eye movements as well as poor focusing gives evidence of why children with ASD often lack skills needed for reading, visual recognition, and decoding.

Vestibular-Ocular and Ocular-Vestibular Reflex: There are two main Vestibular-ocular and Ocular-vestibular Reflexes (VORs) with Horizontal head movements and Vertical head movements. These reflexes serve to stabilize visual images while our body and head moves. All Vestibular- ocular reflexes move the eyes in the opposite direction of head movement to maintain stability of the visual field and visual fixation on objects. This stabilizing prevents the 'seen' world from jumping around when we move (i.e., during walking – note the lack of visual image stability in videotapes when a filmmaker walks with the camera). In daily life, lack of image stability can cause visual and proprioceptive disorientation. The specifics of the Ocular-vestibular Reflex are concerned with the change of eye movement related to head movement [34,35,48].

Horizontal Vestibular-ocular reflexes are active when the head turns to the right or left. When the head turns, for example, to the right side, signals from the right horizontal semicircular canal increase, and signals from the left horizontal semicircular canal decrease. This information triggers the vestibular nuclei for coordination of visual stabilization. Information is sent from the vestibular nuclei to the nuclei of cranial nerves III (Oculomotor, which moves eyes up, down, and medially) and VI (Trochlear, which moves eyes medially and down), activating the rectus muscles that move the eyes to the left and inhibiting the rectus muscles that move the eyes to the right [32,34,35,49]. Horizontal Vestibular-ocular Reflexes activate the Gaze Reflexes and direct the following movements of gaze:

- **Saccades:** Fast eye movements to switch gaze from one object to another. The high-speed eye movements bring new objects into central vision where details of images are seen.

- **Smooth pursuits:** Eye movements that follow a moving object.
- **Vergence movements:** The direction of the eyes to adjust for different distances between the eyes and the visual target. In cases where the Horizontal Vestibular-ocular reflex is not matured and integrated in children or adults, it negatively affects the formation of reading skills, especially horizontal tracking. The lack of co-links in the Horizontal Vestibular-ocular Reflex with gazing inhibits the abilities of vision stability and mobility. This can result in the inability to move the eyes for visual decoding (i.e., recognition of letters and syllables or combining them into words and sentences to gain the meaning). Gaze stabilization (visual fixation) during head movements is achieved by:

a) Vestibular-ocular reflex: The action of vestibular information on eye position during fast movements of the head.

b) Optokinetic reflex: The use of visual information to stabilize images during slow movements of the head

c) The vertical vestibular-ocular reflex: It is activated by head flexion (forward movement) and extension (backward movement). This reflex, like the Horizontal Vestibular-ocular Reflex, moves the eyes in the direction opposite of head movement to maintain the stability of the visual field and visual fixation on an object. Stimulating a pair of semicircular canals induces eye movements in almost the same plane as the canals.58 Difficulty in holding the head up will negatively affect the maturation of this reflex and visual stability. Neurological control of the optokinetic reflex involves the following structures in sequence: retina, optic tract, pretectal area of the midbrain, medial vestibular nucleus, and oculomotor nuclei [34,35,39,49].

Optokinetic reflex: It presents a version of a saccade and pursuit eye movement. It is elicited by moving visual stimuli and adjusts the eye's position during slow head movements [47-49]. The head of a person who is walking moves relative to objects in the environment. The optokinetic system allows the eyes to follow large objects in the visual field. Neurological control of the optokinetic reflex involves the following structures in sequence: retina, optic tract, pretectal area of the midbrain, medial vestibular nucleus, and oculomotor nuclei [34,35,39-49]. The influence of optokinetic stimuli on the perception of movement is illustrated by responses to unexpected movement of nearby large objects. For example, a driver stopped at a stoplight may misinterpret the sudden movement of a bus in the adjacent lane as their own car rolling backward. The person hits the brakes, only to realize the car was not moving. This illusion of motion called vection happens as result of triggering of the optokinetic reflex.

Results and Discussion

Visual Reflex Assessment (VRA)

Specialists working with children diagnosed with ASD in this research focused on visual reflex pattern assessment, particularly, with binocular single vision (X1), convergence (X2), divergence (X3), eye tracking (X4), physiological nystagmus (X5), ocular- vestibular and vestibule-ocular (X6) and optokinetic (X7) reflex patterns. The measured patterns were compared and correlated with abilities of children with ASD with visual skills, such as: spatial orientation (center-periphery; left to right and vice versa; up and down and vice versa; diagonal up to down and vice versa; following a circle shape to both sides), and then with the academic skills of reading and writing.

The comparative analysis of visual reflex patterns of children diagnosed with ASD (n=360) with those with typical development (n=260) has demonstrated that children with ASD have 85.71% of their visual reflex patterns (6 patterns out of 7) as immature and dysfunctional, with 14.29% (1 out of 7) as marginal between dysfunction and functional. There are no reflex patterns at the functional level of development (Table 3). This finding of immaturity of visual reflex patterns (extrapyramidal and subcortical activity) can mean that their automaticity level for abilities is not matured, and "does not give freedom" for higher functions [46]. An example can be as follows: in testing for eye tracking, a child cannot follow a moving object just by using their eye movements, so they turn their head every time to help the eyes with their lack of mobility. This can be explained in that reflex patterns are immature (lack or poor myelination of the sensory-motor pathways) and the nervous system cannot support learned visual skills (cortical activity). Thus, we see the fact that children with no special visual reflex training will be challenged to maintain the formation of skills at the next cortical level of development. This is what professionals and parents witness when children are in stress or in a state of anxiety: they stop being capable of using their learned abilities and fail to retain academic skills that they have learned, need to remember, and are expected to use. The MNRI VRNT program suggests tools and exercises to manage this separation between automatic responses or reflexes that must be neurologically matured and skills that are learned on consciousness level.

The in-depth analysis of level of development of visual reflexes in groups of children diagnosed with ASD shows some typical challenges for this group of disorder. For example, their eye tracking is poorly developed, their eye movement is limited (type of 'tunnel vision' is present), and they are unable to maintain simultaneous awareness of both central and peripheral vision; and, their vision is fragmented, with no smooth movements performed. The ocular-vestibular and optokinetic patterns are extremely dysfunctional, with saccades being the most challenging causing delay in comprehension of what they read or write; losing their place on a page and then pause or stop reading or writing. Attempted instructions and activation of these reflexes mainly causes a refusal to track the moving object with eye saccades (fast-short or fast-long) being triggered.

Physiological nystagmus in children in the Study Group is hyperactive in 84%, hypoactive in 24%, and functional saccades was noted in only 2%. This result can mean that these last three dysfunctional reflex patterns are the cause of many other delays and dysfunctions in the operation of the visual system of children with ASD.

All visual reflex patterns of children with typical development described above are functional. On the next stage of research, a comparative analysis of the visual reflex patterns was done for children in Study Group (n=240) before and after the MNRI VRNT, and in Control Group 1 (n=120) in pre- and post-tests (no MNRI intervention), which produced important data (Table 3). Children in Study Group after the MNRI VRNT therapy demonstrated significant changes in 71.43%/5 reflex patterns out of seven: eye tracking, binocular vision, convergence and ocular- vestibular and optokinetic. Some positive changes occurred with divergence reflex patterns though not at the same high level of statistical significance. Physiological nystagmus responses did not show significant improvement and was found to be very challenging to change within the short time of eight days which means that this reflex is severely problematic and needs more prolonged time for correction. More detailed analysis showed that the improvement in visual reflex patterns happened at a statistically significant level of $p<0.05$ as follows:

- **Binocular vision:** 76.3% (n=183) of children's reflexes moved to the next level of development (from 7.3 ± 0.6 points initially to 9.7 ± 0.8*).

- **Convergence:** 74.2% (n=178) of children's reflexes moved to the next level of development (from 9.57 ± 0.9 points initially to 11.34 ± 0.7*).
- **Eye tracking:** 68.3% (n=164) of reflexes moved to the next level of development (from 6.6 ± 0.7 points initially to 9.82 ± 0.8*).
- **Optokinetic:** 52.1% (n=125) of children's reflexes moved to the next level of development (from 6.9 ± 1.2 points initially to 9.36 ± 1.3*).
- **Ocular-vestibular:** 42.1% (n=101) of children's reflexes moved to the next level of development (from 5.74 ± 0.6 points initially to 8.54 ± 0.8*).

Two reflex patterns improved to a certain extent, but on a statistically significant level, as p>0.05 in post-assessment:

- **Divergence:** 38.3% (n=92) of children's reflexes moved to the next level of development (from 6.8 ± 0.6 points initially to 8.68 ± 1.4) but with no statistical significance for whole group.
- **Physiological nystagmus:** It improved in 24.6% (n=59) of children and moved to the next level of development (from 6.2 ± 0.9 points initially to 7.2 ± 1.2), but with no statistical significance for whole group.

For further analysis of the main challenges in the ASD concerned with visual skills and control we asked professionals and parents to give descriptions of visual behaviors of their children on spectrum and the description by parents and teachers of visual behavior. The following descriptions of visual behavior were given as major causes to learning to read and write:

- 94% – Keeping iPad, iPhone, computer devices too close triggering excessive convergence causing eyestrain or near vision fatigue,
- 89% – Poor visual attention and ignoring the perception of demonstrated objects, poor response to instructions and lack of organized selective perception,
- 89% – Improper head righting and control with a preference for their head position leaned too much to the side (or for too long of time) for activation of monocular vision and blocking the horizontal/vertical,
- 87% – Constantly shaking the object/s in front of their eyes/face, 78% – jumping and playing with hands movements (like stimming), 68% – tension and closing eye/s to change the accommodation, 63% – freezing response when bigger object/s move closer and fast, 48% – oversensitivity to light,
- 43% – Pushing on their eyeballs causing double vision,
- 38% – Banging their head and chin, ears, under nose, clue/dimensions for visual perception (?),
- 28% – pulling on their eyelids and eyelashes.
- Description of visual spatial orientation and visual-manual control was another group of noted challenges in children with ASD by professionals and parents:
- 83% – Fragmented work on paper/text with many distractions, 78% – holding pen/pencil and paper incorrectly while working,
- 76% – Poor/improper orientation in space for a paper including center and periphery, up and down, also left and right, front and back and ability to (turn easily and continue to write/draw on other side),
- 38% – Easily irritated while doing school work (writing/drawing or reading) and start banging their head and hit their chin, ears, stimulate under their nose,

	Visual Reflexes	**Level of development of visual reflex patterns in Children with ASD** in Study Group (n=240) vs. in Typical; (Scoring 0-20 points)		
		ASD (n=240)	**Typical (n=260)**	**Significance**
X1	Binocular single vision (fixation and visual field	7.5 ± 0.7	16.8 ± 0.6	P<0.05
X2	Convergence	10.3 ± 0.9	17.5 ± 0.5	p<0.05
X3	Divergence	6.8 ± 1.8	17.5 ± 0.5	p<0.05
X4	Eye Tracking	6.4 ± 0.8	17.5 ± 0.7	p<0.05
X5	Physiological nystagmus	6.2 ± 1.2	15.8 ± 0.6	p<0.05
X6	Ocular-vestibular	6.3 ± 1.4	15.9 ± 0.8	p<0.05
X7	Optokinetic	6.9 ± 1.6	16.5 ± 0.9	p<0.05
	Dysfunctional reflexes (6-9.99 points)	85.71%/6	0	
	Marginal between dysfunctional and functional state (10-11.99)	14.29%/1	0	
	Functional but very low level of development (12-13.99)	0	0	
	Functional but low level of development (14-15.99)	0	28.57%/2	
	In norm (16-17.99)	0	71.43%/5	

Table 3: Summary results of assessment of level of development of visual reflex patterns in children with ASD (n=240) vs. in typical (n=260); Scoring 0-20 points.

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- 28% – Poor ability to imitate lines and figures (horizontal, vertical, diagonal, circle, triangle, square etc.).

This description gives a larger picture on how poorly developed visual reflex patterns negatively affect visual behavior and school skills of children diagnosed with ASD, which inhibits their academic success (Table 4).

The results of visual reflex patterns pre- and post-tests in children of Control Group 1 (ASD) and Control Group 2 (typical development), (both groups did not have MNRI VNT) showed no significant changes on pre-post data. This data in Control Group 1 (ASD) gives evidence that only specially oriented therapy can affect the reflex patterns. In Control Group 2 the results stayed the same – showing the norm. The measured patterns were further compared and correlated with visual skills development of children with ASD.

Visual Skills Assessment (VSA)

The tests for visual skills provided for children diagnosed with ASD in Study (n=240) and Control Group 1 (n=120) was processed according to scoring of '0' to '20' – with the same criteria presented in Table 1. Results of their visual skills are presented below (Table 5).

The data in Table 5 shows that 80%/12 visual skills tested in children diagnosed with ASD in the Study Group and 86.7%/13 in Control Group 1 were on the dysfunctional level, and 20%/3 were on the border of dysfunctional and functional. The data from testing the visual skills showed that imitation (7.240.34 points in Study Group and 8.9 ± 0.6 – in Control Group 1), dynamic hand-eye coordination (9.95 ± 0.35 and 9.4 ± 0.57), form perception and processing (7.4 ± 0.42 and 6.9 ± 0.6), visual orientation within 'center-periphery' (7.5 ± 0.5 and 8.2 ± 0.4), visual orientation in 'left and right' (8.3 ± 0.53 and 8.4 ± 0.36), and eye tracking while reading (8.9 ± 0.45 and 8.6 ± 0.52) were dysfunctional. Also the visual skills performing on a level of conscious control – accommodation (eye-focusing; 7.6 ± 0.54 and 8.4 ± 0.38), convergence stability (7.8 ± 0.6 and 8.2 ± 0.36), directionality in perception (8.1 ± 0.55 and 8.4 ± 0.42), eye tracking (pursuits and saccades; 8.3 ± 0.61 and 8.4 ± 0.6), and visual fixation at close and far/distant (8.7 ± 0.55 and 8.9.1 ± 0.7) were very challenging suggesting that these skills were are dependent on visual reflexes ('automatic' programs) and cause significant deficits as the development of their reflexes were immature. This is a reason why children diagnosed with ASD read, they follow the text line by line and have a tendency to move their head along with their eyes. This suggests that their eyes do not have the freedom to work independently from the movements of their head (the extrapyramidal system was dominating over the pyramidal system). The intervention of the MNRI The VNT used in this study, targets a solution for these deficits giving a potential for further development of the delayed reflex patterns and supports neurological maturation for higher functions to be free from automatic brain stem responses (extrapyramidal system).

The analysis of the results of changes in visual skills of children with ASD after the MNRI VNT intervention in a Study Group (Table 5) show that every tested skill improved at a statistically significant level.

Further details are presented here:

I. The therapy changes that resulted in moving to a higher level of functioning were observed in such visual skills as: directionality in perception (in pre-test: 8.10.55 and post-test: 13.1 ± 0.53*), eye tracking (pursuits and saccades; 8.3 ± 0.61 13.4 ± 0.4*), imitation (7.24 ± 0.34 and 13.8 ± 0.4*), visual fixation at close and far/distant (8.7 ± 0.55 and 13.9 ± 0.51*), dynamic hand-eye coordination (9.95 ± 0.35 and 13.85 ± 0.48*), visual analysis of simple components of pictures/picture model (9.87 ± 0.44 and 13.1 ± 0.55*). All moved from a dysfunctional level to functional level (very low level of development) at P<0.05. This data shows the positive achievement in the children after MNRI VNT in the Study Group; their skills were corrected and working properly, although further work was still recommended.

	Visual Reflexes	Children with ASD (n=360)				Children with Typical Development (n=260)	
		Study Group (n=240)		Control Group 1		Control Group 2	
		Pre-Test	Post-test	Pre-Test	Post-test	Pre-Test	Post-test
1	Binocular single vision (fixation and visual field	7.3 ± 0.6	9.7 ± 0.8*	7.6 ± 0.5	7.5 ± 0.7	16.8 ± 0.6	16.4 ± 0.5
2	Convergence	9.57 ± 0.9	11.34 ± 0.7*	9.78 ± 0.9	9.67 ± 0.8	17.5 ± 0.5	17.3 ± 0.6
3	Divergence	6.8 ± 1.2	8.68 ± 1.4	6.56 ± 1.9	6.68 ± 1.7	17.5 ± 0.5	16.8 ± 0.7
4	Eye Tracking	6.6 ± 0.7	9.82 ± 0.8*	6.56 ± 0.6	6.64 ± 0.6	17.5 ± 0.7	17.4 ± 0.5
5	Physiological nystagmus	6.2 ± 0.9	7.2 ± 1.2	5.87 ± 1.3	6.11 ± 1.3	15.8 ± 0.6	15.6 ± 0.4
6	Ocular-vestibular	5.74 ± 0.6	8.54 ± 0.8*	5.9 ± 0.8	6.11 ± 1.4	15.9 ± 0.8	16.2 ± 0.9
7	Optokinetic	6.9 ± 0.5	9.36 ± 0.3*	6.7 ± 0.9	6.9 ± 0.9	16.5 ± 0.9	16.7 ± 0.9
	Average	7.0 ± 0.87	10.2 ± 1.0	7.0 ± 0.99	7.1 ± 1.1	16.8 ± 0.7	16.6 ± 0.64
	Dysfunctional reflexes (6-9.99 points)	100%/7	71.43%/5	100%/7	100%/7	0	0
	Marginal between dysfunctional and functional state (10-11.99)	0	28.57%/2	0	0	0	0
	Functional but very low level of development (12-13.99)	0	0	0	0	0	0
	Functional but low level of development (14-15.99)	0	0	0	0	28.57%/2	0
	In norm (16-17.99 points)	0	0	0	0	71.43%/5	0
	Total improved patterns		57.14%/4 p<0.05		0% p>0.05		0% p>0.05

*- Statistically significant at p<0.05

Table 4: Comparative results of visual reflex patters of children with ASD in pre- and post-tests in Study Group (run the MNRI Visual Training), Control Group 1 and of children with typical development in Control Group 2 (didn't have the MNRI Visual Training).

Visual Skills		Study Group (n=240)		Control Group 1 (n=120)	
		Pre-test	Post-test	Pre-test	Post-test
1	Convergence stability	7.8 ± 0.6	11.9 ± 0.62*	8.2 ± 0.36	8.3 ± 0.42
2	Directionality in perception	8.1 ± 0.55	13.1 ± 0.53*	8.4 ± 0.42	8.3 ± 0.38
3	Form perception/processing	7.4 ± 0.42	11.1 ± 0.48*	6.9 ± 0.6	7.1 ± 0.72
4	Eye tracking (pursuits and saccades)	8.3 ± 0.61	13.4 ± 0.4*	8.4 ± 0.6	8.2 ± 1.3
5	Accommodation (eye-focusing)	7.6 ± 0.54	11.8 ± 0.7*	8.4 ± 0.38	8.3 ± 0.62
6	Visual orientation within 'center- periphery'	7.5 ± 0.5	11.9 ± 0.6*	8.2 ± 0.4	8.3 ± 0.45
7	Visual orientation in 'left and right'	8.3 ± 0.53	12.9 ± 0.42*	8.4 ± 0.36	8.2 ± 0.4
8	Eye tracking while reading	8.9 ± 0.45	12.5 ± 0.6*	8.6 ± 0.52	8.4 ± 0.49
9	Imitation: drawing a line from left to right, right to left, diagonal lines	8.62 ± 0.34	13.8 ± 0.4*	8.9 ± 0.6	8.5 ± 0.57
10	Imitation: drawing a circle in both direction – from left to write and vice versa	7.24 ± 0.34	11.6 ± 0.47*	7.4 ± 0.48	7.5 ± 0.58
11	'Hand-eye' = look at hands (f. ex., left and right) while moving them in different directions	7.4 ± 0.38	11.1 ± 0.5*	6.9 ± 0.52	7.1 ± 0.6
12	Looking (visual fixation) at close and far/distant objects (ability to follow instructions – with demo)	8.7 ± 0.55	13.9 ± 0.51*	8.9.1 ± 0.7	8.9 ± 0.62
13	Ability to follow verbal instructions and for gaze in different directions: up, down, to sides, to center	9.84 ± 0.44	12.7 ± 0.5*	9.63 ± 0.56	9.7 ± 0.48
14	Holding a pen/pencil and control hand-eye movements (dynamic hand-eye coordination)	9.95 ± 0.35	13.85 ± 0.48*	9.4 ± 0.57	10.1 ± 0.6
15	Ability for visual analysis of simple components of pictures/picture model	9.87 ± 0.44	13.1 ± 0.55*	8.94.8 ± 0.5	9.1 ± 0.6
	Average points	8.37 ± 0.47	12.74 ± 0.5*	8.63 ± 0.45	8.66 ± 0.54
	p-value	p<0.05		p>0.05	
*- Statistically significant at p<0.05					

Table 5: Comparative results of visual skills of children with ASD in pre- and post-tests in Study Group (run the MNRI Visual Training) and Control Group 1 (didn't have the MNRI Visual Training).

II. Analysis of the other data demonstrated changes in visual skills of these children on a lower level but still of statistical significance: visual orientation in 'left and right' (8.3 ± 0.53 and 12.9 ± 0.42*), eye tracking while reading (8.9 ± 0.45 and 12.5 ± 0.6*), follow verbal instructions and gaze in different directions (9.84 ± 0.44 and 12.7 ± 0.5*); improvement of visual skill from a level of 'dysfunctional' to 'marginal between dysfunctional and functional': convergence stability (7.8 ± 0.6 and 11.9 ± 0.62*), form perception/processing (7.4 ± 0.42 and 11.1 ± 0.48*), accommodation (eye- focusing; 7.6 ± 0.54 and 11.8 ± 0.7*), visual orientation within 'center-periphery' (7.5 ± 0.5 and 11.9 ± 0.6*), imitation: drawing a circle in both directions – from left to right and vice versa (7.24 ± 0.34 and 11.6 ± 0.47*), and hand-eye, the need to look at their hands while moving them in different directions (7.4 ± 0.38 and 11.1 ± 0.5*). These changes meant that, after the therapy intervention, the children started using their improved reflexes to build their visual skills, which became possible only when the nervous system regulation mechanism was enhanced (release of inhibition neurotransmitters in basal ganglia increased enough to balance excitation) and when linking of the extrapyramidal functions and pyramidal parts of the nervous system was available.

III. Results of the analysis of visual skills in children diagnosed with ASD in Control Group 1 showed no significant changes in pre- and post-test after eight days which supports the positive developmental effects of the MNRI tools. The comparative analysis of reflex pattern changes and visual skills shows a correlation between them (Tables 2, 3 and 4), and can be interpreted as a sign that therapy on reflex patterns (neurological maturation of extrapyramidal pathways) is essential before remedial therapy on visual skills or tutoring academic skills (pyramidal nervous system) should be done. The experience gained in using the MNRI Visual Reflex Integration training also shows that therapeutic tools must be directed at non-conditioned visual reflexes improvement (developing from 1 to 4 months of life). This indicates that the work of the brain and motor axons were strengthened, especially the functions of the pretectum area of the brain stem that is responsible for adjusting eye movements and the vestibular control.

Results of school skills assessment

Participants were asked to read and write with five-minute hands-on tasks which were checked by a teacher. All tests were very simple and took into consideration the developmental challenges and individual features of the children diagnosed with ASD.

- **Reading:** Age-specific criteria for reading were used. Children aged 7-8 were expected to read the text of 27-32 phrases (=55-60 words), 8-9 – 45-50 phrases (=90-100 words), and 9-10 – 57-60 phrases (=114-116 words) (see in Methods chapter).
- **Writing:** Their abilities were evaluated by first checking their writing content, a graph evaluation of the writing was analysed, and age-specific criteria for writing was used. All children were asked to rewrite letters and sentences with and without example text; age-specific criteria was used to define their abilities.

The children demonstrated following abilities (Table 6).

Reading:

- 2.2% (n=8) – Read with comprehension on a very good/excellent level (high norm – 5 points),
- 24.2% (n=87) – Read with comprehension on good level (average norm – 4 points),
- 46.4% (n=162) – Recognized letters and could connect them into syllables and phrases and comprehend them to some extent (fair level – 3 points),
- 27.2% (n=93) – Recognized letters with poor ability to connect them into syllables and phrases and with very poor understanding or no comprehension (poor level – 2 points).

Writing:

- 1.7% (n=6) – Wrote proficiently with very good/excellent comprehension (high norm – 5 points),
- 18.6% (n=67) – Recognized letters and could write them by memory and could connect them into syllables and phrases and comprehend them at a good level (average norm – 4 points),
- 46.7% (n=168) – Wrote the letters based on examples but showed poor ability to connect them into syllables and phrases and with poor understanding (fair level – 3 points),
- 33.0% (n=119) – Wrote the letters based on examples but could not connect them into syllables, showed very poor understanding, or no comprehension (poor level – 2 points).

Next, the results on these skills were analyzed in comparison to those in Study Group and Control Group 1 before and after the MNRI Visual Reflexes Neuro Training (Tables 6 and 7), and then compared with visual reflex patterns and visual skills results (Figure 1).

Analysis of reading skills of children with ASD (n=360) shows that the majority of them – 33.0% (n=119) scored poorly ('2 points') and 46.7% (n=168) scored at the fair level ('3 points') in the pre- test. The data in Table 6 also shows the improvement in reading abilities of children in Study Group after eight days after the MNRI Visual Reflex Neuro Training *vs.* no significant result in post- test in the Control Group of children with ASD that had no visual reflex integration. Particularly, the number of children scoring at the poor level ('2 points') – 39.1% (n=94) decreased accordingly to 17.5% (n=42) resulting in an increase of the number of children with skills at the fair level, which in the pre-test was characteristic of 40% (n=96) and in post-test increased to 57.9% (n=139). The number of children with 'good' result ('4 points') in 19.2% (n=46) and with 'very good/excellent' result ('5 points') in 1.7% (n=4) increased accordingly to 21.7 (n=52) and 2.9 (n=7). These results show significant changes in reading ability in 43.33% (n=104 out of 240) of children diagnosed with ASD after improvement of their visual reflexes patterns and skills. The coefficient (index) of the change also validated the tendency for improvement of skills for all ranges of scores (Table 6). These changes are also significant in comparison with traditional methods used in school systems, as the results after the MNRI VNT

Dynamic of changes in reading skills in children with ASD (n=360) in *Study Group* (n=240) and *Control Group 1* (n=120) before and after the MNRI VRNT

Skill cluster	Groups	Pre- post-test and result index	Poor (2) n	Poor (2) %	Fair (3) n	Fair (3) %	Good (4) n	Good (4) %	Very Good/ Excellent (5) n	Very Good/ Excellent (5) %
Reading	Both (n=360)	Pre-test	119	33.0	168	46.7	67	18.6	6	1.7
	Study (n=240)	Pre-test	94	39.1	96	40.0	46	19.2	4	1.7
		Post-test	42	17.5	139	57.9	52	21.7	7	2.9
		Improve: Index of improve:	52↓	0.44	43↑	1.44	6↑	1.13	3↑	1.7
		Overall improve: 43.33% (n=104)								
	Control 1 (120)	Pre-test	25	20.8	72	60.0	21	17.5	2	1.7
		Post-test	23	19.2	70	58.3	23	19.2	3	2.5
		Improve Index of improve	2↑	1.1	2↑	1.0	2 ↓*	1.1	1	1.5
		Overall improve: 5% (n=6)								

↑- increase towards good result (positive effect)
↓- decrease in poor result (positive effect)
↓* - decrease in good result (negative effect).

Table 6: Comparative results of reading skills of children with ASD in pre- and post-tests in *Study Group* run the MNRI Visual Reflex NeuroTraining) vs. *Control Group 1* (did not have the MNRI Visual Reflex NeuroTraining).

Dynamic of changes in writing skills in children with ASD (n=360) in *Study Group* (n=240) before and after the MNRI VRNT and in *Control Group 1* (n=120)

Level of skills development (points)

Skill cluster	*Groups*	Pre- post-test and result index	Poor (2) n	Poor (2) %	Fair (3) n	Fair (3) %	Good (4) n	Good (4) %	Very Good/ Excellent (5) n	Very Good/ Excellent (5) %
Writing	Both (n=360)	Pre-test	98	27.2	167	46.4	87	24.2	8	2.2
	Study (n=240)	Pre-test	73	30.4	126	52.5	36	15.0	5	2.1
		Post-test	42	17.5	139	57.9	52	21.7	7	2.9
		Improve: Index of improve:	31↓	12.9 0.58	13↑	5.4 1.1	16↑	6.7 1.45	2↑	0.8 1.38
		Overall improve: 33.75% (n=62)								
	Control 1 (120)	Pre-test	25	20.8	41	34.2	51	42.5	3	2.5
		Post-test	27	22.5	42	35.0	48	40.0	3	2.5
		Improve Index of improve	2↑	1.7 0.92	1↑	0.83 0.98	3 ↓	2.5 0.95	0	0 1
		Overall improve: 3/5%								

↑- increase towards good result (positive effect)
↓- decrease in poor result (positive effect)
↓* - decrease in good result (negative effect).

Table 7: Comparative results of writing skills of children with ASD in pre- and post-tests in study group (received MNRI Visual Reflex neuro training) and Control Group 1 (did not receive the MNRI intervention).

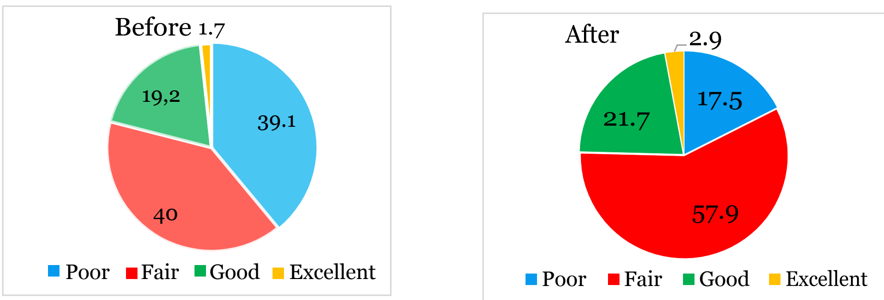

Figure 1: Changes in reading skills (scores in percentage) in children with ASD in Study Group (n=240) before and after the MNRI VRNT.

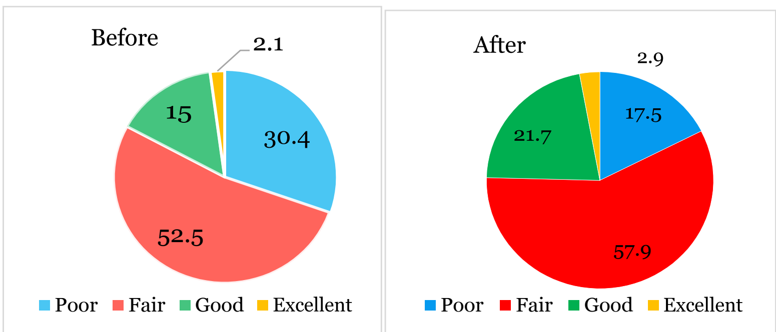

Figure 2: Changes in writing skills (scores in percentage) in children with ASD in Study Group (n=240) before and after the MNRI VRNT.

program took place in a shorter time and with less teaching effort. This result indicates that additional neurophysiological potentials of reflex circuits and visual skills could be used for even more success in the academic skills of these children (Figure 1).

These positive changes however, were lower than the average MNRI VRNT results for reading improvement which means that children with a diagnosis of ASD needed a longer therapy time for reading skills enhancement based on repatterning of their visual reflexes and skills.

These results should also remind educators and helping specialists about the importance and need to work with visual reflexes prior to reading instruction for children and especially those with neurodevelopmental deficits.

Analysis of the scores or writing skills of children with ASD (n=360) shows that the majority, 27.2% (n=98) had poor and 46.4% (n=167) fair skills in the pre-test (Table 7). The scores for the academic skills in the Study Group (n=240) demonstrate that the writing abilities of children positively changed within eight days of MNRI VRNT *vs.* results in the Control Group (n=120) that did not have this training program (Figure 2).

Particularly, the poor result ('2') that was characteristic of 30.4% (n=73) of children, and fair ('3') of 52.5% (n=126) prior to the training in the Study Group decreased after the visual training accordingly to 17.5% (n=42) and 57.9% (n=139); whereas the number of children with good results ('4 points') in 15.0% (n=36) of children increased to 21.7% (n=52), and with very good and excellent result ('5 points') - from in 2.1% (5) to 2.9% (n=7). These results show significant changes in writing ability in 25.8% children with ASD (n=62 out of 240) after improvement of their visual reflex patterns and visual skills within eight days of the intervention with the MNRI program. The coefficient of the change also showed the tendency for enhancement of skills for all ranges of scores (Table 7).

Correlating analysis of results on visual skills and educational tests of reading and writing abilities showed that poor academic abilities of these children are rooted in dysfunctions in their visual reflex patterns. The range of improvement of academics of children with ASD in Study Group before and after the MNRI VRNT was significant at $p<0.05$ *vs.* results of testing these skills in children with ASD in Control Group that did not go through MNRI VRNT; their scores did not increase and were at $p>0.05$ with no statistical significance, which further proves our hypothesis that specially oriented exercises targeting the visual reflexes are able to improve school skills.

Conclusion

A comparative analysis of visual reflex patterns of children with ASD (n=360) with those with typical development (n=260) demonstrated that children with ASD have 85.71% of visual reflex patterns (6 patterns out of 7) immature and dysfunctional, 14.29% (1 out of 7) on marginal level between dysfunction and functional. The in-depth analysis of visual reflexes of children in study.

Group and Control Group 1 (n=360) indicated that the disorders in many are caused because of the ineffective work of physiological nystagmus, which was hyperactive in 84% of these groups, resulting in challenges in eye tracking, ocular-vestibular and optokinetic patterns, and subsequently negatively affecting their reading and writing skills. In other words, the challenges with academic skills in these children are caused not only by lack of communication and comprehension but also by poorly developed visual skills blocking normal physiological functions of their eyes. All visual reflex patterns of children with typical development described above are functional. The visual skills of 80% these children (12 out of 15 tested) were of dysfunctional level. The analysis of their school scores for academic skills showed that 73.6% of them had an inability to read or demonstrated poorly developed reading skills and 79.7% had low quality writing abilities. A substantive improvement in all outcome measures for the Study Group (children with ASD; n=240) that underwent the MNRI VRNT intervention was noted. Particularly, positive changes for all visual abilities and skills and their links with academic abilities of writing and reading occurred in only eight days? of receiving this intensive intervention.

Visual reflex patterns: 71.43% (5 out of 7) of visual reflex patterns of these children improved significantly ($p<0.05$) which was characteristic for every child. The MNRI VRNT increased the level of visual reflex functionality for a variety of patterns of children with ASD but the positive dynamic was noted particularly for the following: visual convergence, visual divergence, horizontal eye tracking, ocular-vestibular and optokinetic which affects positively their academic skills of reading and writing, and overall neurodevelopment.

Visual skills: The improvement of visual reflex patterns allowed the children to improve their visual skills: 75% of them (9 out of 12) moved from dysfunctional to a level of functional, though at a very low level, and 25% (3 out of 12) grew to a marginal level between functional and dysfunctional. These children showed that they started using their reflex responses properly and began building visual skills which were possible only when the nervous system's ability for regulation (adequate amounts of inhibitory neurotransmitters are released) or the linking of the extrapyramidal functions and pyramidal parts of the nervous system for conscious control of the eyes functions.

Reading and writing skills: The academic scores of children in the Study Group (n=104) for reading improved by 43.33% and in writing by 33.75% (n=62). The coefficient of the improvement showed the same tendency for significant changes. It also was noted that their oral-motor skills including clarity of sound in pronunciation, speech, and comprehension was seen in the use of more complicated language construction and their typing improved.

However, the significance of positive changes in all these areas was on a lower level than those in children with typical development which shows the necessity for further corrective therapy of reflex patterns in children with ASD. There was no statistical significance in improvement in levels of development of visual reflex patterns and academic skills in Control Group 1 and Control Group 2 that did not go through MNRI VRNT. Results of analysis of visual reflexes and skills in children with ASD in Control Group 1 showed no significant changes in pre- and post-test after eight days which proves our hypothesis that specially oriented exercises targeting the visual reflexes are needed to improve their visual skills for children with ASD and who received MNRI interventions.

The comparative analysis of reflex pattern changes and visual skills showed a correlation between the improved reflex patterns and visual skills proving that work on reflex patterns (neurological maturation of extrapyramidal pathways) is needed before work on visual skills and school skills (pyramidal nervous system) are undertaken. Our experience using the MNRI VRNT training also shows that therapeutic tools must be oriented to non-conditioned visual reflexes improvement (which should fully develop between the 1st and 4th months of life). These results show significant changes in the abilities for reading and writing in children with ASD after improvement of their visual reflexes patterns and skills on a statistical level of $p<0.05$. This also is a reminder to educators and helping specialists about the necessity to work with visual reflexes prior to initiating reading instruction in children, especially those with neurodevelopmental deficits. Results of the reading and writing skills in children with ASD that did not go through MNRI VRNT did not show statistical significance proving the efficacy of MNRI VRNT in impacting academic skills.

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