# Article • Inhibition of Primitive Reflexes and Its Relationship with Visual Projection in Children and Adolescents

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## ABSTRACT

**Background:** Primitive reflexes (PRs) are of great importance to visual function due to their ability to interfere with visual projection (VP). VP is defined as the binocular behavior pattern, which, when measured, determines whether there is an orthophoria or identifies the point closest to it. The purpose of this study was to assess the relationship of four primitive reflexes and to determine how their inhibition modified VP.

**Methods:** We investigated the use of two different therapies for the inhibition of four PRs, including the Moro reflex (MR), the tonic labyrinthine reflex (TLR), the asymmetric tonic neck reflex (ATNR), and the symmetric tonic neck reflex (STNR), in a group of 78 children (aged 4 to 15) with modified VP. The Van Orden star (VOS), which aids in understanding how progressive inhibition of PRs modifies VP, was the outcome measure.

**Results:** The results showed a significant correlation between inhibition of PRs and improvement in VP ($p=0.000$; $<0.05$). The values obtained suggest that the changes obtained as a consequence of inhibiting PRs are similar regardless of the therapy used. For the total sample of 78 children, the majority experienced an increase in VOS scores of 1 to 4 points.

**Conclusion:** The results suggest that inhibition of PRs enhances motor control and is significantly associated with the improvement of binocular coordination.

**Keywords:** primitive reflexes, Van Orden star, visual projection

## Introduction

There is a paucity of information on how primitive reflexes (PRs) relate to vision. Studies on how the Van Orden star (VOS) test is used for both training in visual therapeutic practice and at the diagnostic level are also scarce. There are also no studies that correlate the effects of inhibition of PRs and improvement in visual projection (VP) as seen with the VOS.

PRs are complex, automatic brain stem-mediated movement patterns that begin as early as 9 to 12 weeks post-conception and are fully present at birth in healthy, full-term infants. During the process of central nervous system (CNS) maturation, they become increasingly difficult to obtain after the first six months of life, when voluntary motor activity combined with cortical inhibition arises and takes control.[1,2] The movement patterns that arise during the life of the fetus and that are fundamental to the survival of the newborn,[3] as well as the body posture and attitude of the full-term newborn, are influenced by PRs.[4] Initially, they became of interest to clinicians working with children with cerebral palsy and later to those working with children with learning difficulties.[5] They are among the earliest, simplest, and most useful tools for assessing the integrity of the CNS in infants and young children.[1] Thus, posture, as a reflection of muscle tone, is used for the evaluation of CNS maturation in the neonate.[4] Posture is an active process, regulated by a wide variety of sensory and central inputs, which adjust to prevent any unintentional change in position. Posture is the result of cooperation between many reflexes that directly influence tonicity.[6]

Kovesova and Kolar[7] point out that PRs organized at the spinal column and brain stem level do not disappear after the neonatal stage; these motor patterns are simply inhibited by higher levels of control as the CNS matures. Some studies prove how PRs, also referred to as disinhibition or release signs, may reappear in senescence and due to the progression of neurological diseases. Several PRs are strongly correlated with conditions associated with dementia, such as Alzheimer's disease, vascular dementia, or dementia in Parkinson's disease.[8]

It is generally accepted at the medical level that primitive and postural reflexes at certain key stages of development provide reliable diagnostic signs of maturity in CNS functioning,[9,10] helping the newborn to adjust to their new environment and to build a base of motor and cognitive skills. PRs involve changes in the level and distribution of tone that can affect posture and movement.[10] In addition, some reflexes are present in childhood and last until adulthood without being a cause of pathology.[11] The palmomental reflex, for example, may be present in healthy people of all ages.[12] There is a growing accumulation of evidence that supports the theory that abnormal PRs and postural activity may exist to a lesser degree in the general population.[9]

Abnormal persistence of PRs make children more likely to have visual skill deficits,[13] as they provide a primary mechanism through which the newborn can learn to understand what is seen during the first few months of life and also teach them to coordinate the fine ocular musculature in such a way as to acquire appropriate accommodation, fusion, fixation, and convergence.[14] Inadequate integration and non-inhibition of primitive and postural reflexes can affect an individual's visual development, balance system, and academic performance,[5] while lack of integration can lead to poor eye movements and poor fixation from far to near distance. In addition, individuals with immature primitive and postural reflexes may have difficulty with visual coordination, hand/eye coordination, and visual memory.[10] The perceptual dysfunction resulting from retained reflexes contributes to the difficulties that a child experiences in acquiring automated perceptual skills, such as those required to read and write. This is thought to be due to compromised visual tracking, pursuit, and sequencing, all functions of oculomotor control, which in turn are influenced by the vestibular system. The vestibular system mainly detects movement and stabilizes the visual axis, thus controlling the movement of the eyes, as well as helping to maintain alignment and posture of the head and body.[15]

Vision is much more than the ability to see small details at great distances. It is the total capacity to organize the entrance of light, recognize the spatial relationships between things, and build an internal representation of reality, in addition to being a very complex and highly parallel processing activity involving almost all parts of the human body. The psychophysical studies of human vision during the last century have shown that we perceive objects in depth, encoding the instantaneous geometric disparities of the retina produced by the stimulation of each eye for a single object in depth.[16] In a dynamic, three-dimensional environment, the quality of the retinal image and the registration of the neural image depend on the performance of the motor visual system.[17]

In recent years, professionals from multiple disciplines have tried to stress the importance of considering the influence of visual skills, apart from the high-level visual information processing capacity, on the functioning of their clients. It has been emphasized that in order to establish best practices, clinicians should also consider the state of their patients' basic visual skills, such as oculomotor function and binocular visual function.[18] Binocular vision is clearly of importance in the precise use of the hand for fine motion and also in an association between binocular vision and eye and hand control.[19]

As an example, unintentional movement of the extremities, such as tremor, impairs the control of fine motor and involuntary movements of the eyes, such as nystagmus, which can impair vision.[20] The evaluation of PRs has become part of the assessment of visual development in many professional settings.[5] If the visual system is to remain stable, the structure where it is housed must be stable. The development of the visual thematic system depends first on active participation and then on the inhibition of at least four of these PRs at the right time. These reflexes are the Moro reflex (MR), the tonic labyrinthine reflex (TLR), the asymmetric tonic neck reflex (ATNR), and the symmetric tonic neck reflex (STNR).[14,21]

The MR is the earliest of the primitive reflexes to emerge. Initially, it may be more active in Caesarean versus vaginal births,[22] and it is closely linked to the TLR in the first months of life. Both reflexes are of vestibular origin, and both can be activated by either stimulation of the labyrinth or alteration of the position of the body in space.[14] Retention of the TLR can influence binocular vision, leading to disturbances in visuomotor coordination and frequent careless mistakes.[23] While the MR is an involuntary protective motor response against abrupt interruption of body balance or extremely abrupt stimulation,[2] a retained MR can lead to poor visual control of eye movements, which can result in perceptual problems. Being an involuntary reflex in response to threat, one of the mechanisms to cope with this stress is over-stimulation of the sympathetic nervous system. If stress is chronic, a pupillary alpha omega response and constriction in functional visual fields can be observed.[10]

The ATNR is seen in infants, and it is usually integrated at 6 months, although it may be present in children up to eight years of age,[24] while other authors point out that it is commonly found in healthy preschool children.[25] The ATNR is involved in the orientation of the neonate, and because it is present when near-point fixation is developed, it plays an important role in visuomotor development.[3] Liederman and Coryell[26] point out that this reflex promotes hand/eye coordination, particularly during the second month of life: "hands were placed more frequently within the child's focal visual field when the arms were in the asymmetric pattern position than when they were not." A retained ATNR is related to issues involving visual midline crossing and poor eye tracking (if active in combination with under-developed head righting reflexes) and may interfere with hand/eye coordination and control when writing.[15] As a result of this retained reflex, it is believed that there is, among school children and neuropsychiatric adults, a bias of selective attention toward the right side of the visual field that may appear when under a cognitive load. When under significant performance pressure, a similar behavior to neglect appears in paper and pencil tasks.[11] The most studied symptoms related to the activity of the ATNR refer to learning difficulties as visual alterations among others,[25] and visual asymmetry may not be caused by the visual system itself. It could be the result of an immature neural network involving motor and visual cognition.[11] Previous studies indicated that, even in healthy infants and adults, the persistence of the ATNR influences movements in specific states, including movement stress and relaxation.[27]

If the STNR is active for too long, upper and lower coordination of the body is impeded, cross-pattern movements may be hindered, and the expansion of visual space and poor hand/eye coordination may be evident.[14] This could be characterized by poor posture and difficulties of approach.[23] It seems logical that focus changes are affected, because one of the roles of this reflex involves balancing, at the motor level, the flexor and extensor tone of the extremities according to the position of the head when the body remains in the quadruped position. Depending on the body response to flexion or extension of the head, the head will take the appropriate position to see in close vision by activating accommodation or by raising the head for focus in far vision. As to how this reflex affects learning, persistent responses from the STNR and ATNR are associated with significant manifestations of ADHD symptoms,[28] while a study shows how the traits of inattention as described by parents are phenotypically linked to subtle alterations in eye movements.[29] The concept of orthophoria is the aligned position of the two eyes, both in the presence or absence of fusion. Orthophoria indicates a well-integrated binocular pattern.[30]

The objective of this retrospective observational study was to obtain measurable data that corroborate the relationship between PRs and VP. The questions we want to answer in this paper focus on the determination of whether inhibition of PRs results in an improvement in VP, whether patients organized by chronological age and stimulated by two different therapies obtain similar results, and whether various variables raised, such as sex, binocular difficulties, learning difficulties, motor difficulties, situation of the parents, repetition of a school course, and the use of prescription glasses, are significant factors in the results obtained.

## Methods

### Participants

For the observational retrospective study, we obtained from our database a list of patients who participated in a binocular visual review from 2017 to August 2020. One test that was carried out in that initial visual review was the VOS. Patients who showed the presence of retained PRs started PR inhibition treatment. Once the treatment was completed, the VOS test was repeated.

Inclusion criteria were: completion of PR inhibition therapy; inhibition of the four referenced reflexes; age 4 to 15; and having binocular difficulties, learning difficulties, and/or motor type difficulties. Exclusion criteria were: patients with known visual pathologies, patients whose PR inhibition treatment did not require more than eight months, patients who had previously performed any vision therapy (VT) at another center, patients who had previously received PR inhibition therapy at another center, and patients who worked at home less than six days a week.

Using these eligibility criteria, we obtained 78 patients (44 male and 34 female) distributed as shown in Table 1.

**Table 1. Distribution of Patients**

| Age | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|
| # of Patients | 2 | 6 | 21 | 21 | 9 | 9 | 3 | 3 | 3 | 1 |

***Figure 1. Advance Cheiroscope***

Depending on age, 26 patients received DM primary reflex therapy, a therapy designed for inhibition of PRs specifically in children aged 4 to 6 years, and the remaining 52 underwent Institute of Neuro Physiological Psychology (INPP) therapy, a therapy designed for PR inhibition specifically in patients aged 7 years and older. Three of the 6-year-old patients received INPP therapy based on the fact that they had almost reached 7 years of age.

The study was approved by the Ethics Committee of Research with Medicines of the Hospital Universitario y Politécnico La Fe of Valencia, Spain. (Registration Number: COM1-04/11/2020).

**Instruments**

The test used in the initial evaluation and bimonthly PR reviews for all patients was a battery of exercises called Diagnostic Evaluation of Neurodevelopmental Delay. The chapters *Primitive Reflex Tests* and *Postural Reflex Tests* were used.[31]

The device for performing the VOS was an Advance Cheiroscope (CH) with a transilluminated background (Figure 1) from the North American manufacturer Keystone. CH consists only of two lenses or prismatic spheres suspended on a drawing surface. There are four ways to use it, one of which is the "absent mirror," which was used in this study.[32] It is a device by which the target or fixation object of one eye can be controlled and kept separate from the field of view of the other eye, and in which free and easy access to the field is available by the hand and arm.[33] The VOS is added to the drawing surface.

**Assessment of Reflex Activity**

PRs were evaluated, and each patient was assigned a specific therapy according to age. Those between 4 and 6 years old received DM therapy, while those 7 years and older received INPP therapy.

*Moro reflex*

In order to evaluate the MR, the children stood upright with their eyes closed, heads slightly extended, feet together, and arms in a semicircle at chest level with their hands a few centimeters apart. Holding the children with our hands from the upper part of their backs, we carefully reclined them backwards and accompanied them until they reached an angle of approximately 30º. As we leaned them back, the children remained rigid, as if they were a statue. When they reached this position, they were told that we were going to release them quickly and briefly and then re-catch them. To release them, we simply withdrew our hands backwards from their back so that their body would quickly reach acceleration and immediately re-catch them from the back. When they were released, no alteration to the original position of the arms or leg movements should be observed. This sequence was only performed once, and possible arm abduction or leg compensation shift was scored.

*Tonic labyrinthine reflex*

The child stood upright with feet together, arms close to the body, and looking straight ahead with their eyes open. The first test was performed when the child gently flexed their head until their chin touched their chest, and they remained in that position for 10 seconds. They then extended their head slowly until positioned as though looking at the ceiling, holding it in this position for 10 seconds. This maneuver was repeated four times, in which there should have been no alterations to the original position of the trunk and extremities or oscillations of the body. In this process, the possible oscillation of the body that could cause the movement of flexion and extension of the head or complete loss of balance was especially graded. Alterations in the tonicity of the arms and legs were also identified. The sequence was then repeated with the eyes closed, and a blindfold was placed over them to ensure zero vision.

*Asymmetric tonic neck reflex*

In order to evaluate this reflex, a child was placed in a quadrupedal position with the knees and arms apart. Their head was gently rotated until their chin reached their shoulder, and they remained in that position for 10 seconds. The head was then rotated in the opposite direction until the chin met the opposite shoulder and was held in this position for the same amount of time. This operation was repeated four times, and no change from the original position was noticed. In the process of these movements, elbow flexion was especially graded, although the change in the position of the trunk and legs was also considered.

The ATNR was additionally assessed in a second way in children assigned to INPP therapy. This test is called the Schilder test. The child was positioned upright, with their feet together and their arms parallel stretched forward and at 90° to the body, looking straight ahead with their eyes closed (a blindfold was placed over the eyes to ensure that they had zero vision). Brief instructions were given, explaining that the head was to be turned laterally to one side until the chin almost reached one shoulder. The same operation was then performed in the opposite direction. The maneuver was repeated four times in a slow and gentle manner. The children had to try to keep their arms always facing forward, without changing the original position. The degree of oscillation of the arms to the sides, and additionally the degree of downward fall of the arms, were graded.

*Symmetric tonic neck reflex*

The child was placed in a quadrupedal position with the knees and arms apart, this reflex information being provided via two positions. Firstly, the child gently extended their head backwards until reaching its maximum position as though looking at the ceiling. The child had to remain in this position for about 10 seconds. Then, they would gently bend their head downward as though they were going to look at their knees, and when they reached the lowest position, with the chin touching the sternum, they would stop for another 10 seconds. This maneuver was repeated four times, and no movement of arms or legs appeared. In this reflex, the possible flexion of the elbows during head flexion and the flexion of the knees during head extension were especially graded.

The score was made based on five variables.

"0" No presence of the reflex. Complete inhibition of the reflex without alteration to the original position.

"1" Residual presence of the reflex. Very subtle alterations or movements from the original position.

"2" Average presence of the reflex. Clear presence with abnormal motor movement or alteration.

"3" Obvious presence of the reflex. There are quite obvious changes associated with it and low motor control.

"4" Retained presence of the reflex. The reflex is observed in its totality and complexity and with all possible alterations present.

In the initial evaluation and according to the results, instructions on exercises were given to inhibit the observed PRs. These exercises were then replicated daily at home under parental supervision. Bi-monthly reviews were subsequently carried out, and depending on progress, the exercises were modified. All assessments and reviews were conducted at our center in the presence of parents.

Therapy was understood to be over when the MR, TLR, ATNR, and STNR obtained a score of "0" or when a maximum of two of these reflexes obtained a maximum value of "1" and the remaining two scores of "0." In the cases in which doubts appeared, a second auxiliary therapist re-evaluated the children in a parallel and independent way, informing the main therapist and concluding whether the treatment could be completed or whether some more work on the reflexes was required in order to achieve complete inhibition.

The battery of exercises used on the 78 children was selected from a total of 14 exercises used in INPP therapy and 13 exercises in DM therapy. The choice of exercises was determined based on the presence and intensity of each of the observed PRs.

The battery of exercises used in INPP therapy consisted of 2 passive exercises and 12 active exercises. From the previous exercises, an average of 7 exercises was selected for each child during the time of their treatment. The battery of exercises used in DM therapy consisted of 5 passive, 4 active, and 4 active exercises with parental guidance. From the previous exercises, an average of 9 exercises was selected for each child during the time of their treatment.

**Assessment of VOS Test**

Once the PR inhibition therapy was completed, the children were encouraged to perform the final VOS test using the same instructions as when performing the initial test. In the early 1940s, Van Orden developed the Binocular Visual Behavior Pattern, commonly known as the VOS. The star indicates how a patient focuses with each eye individually while performing binocularly.[34] The standard design, as designed by Van Orden, is a translucent white paper with two columns of figures, with the columns

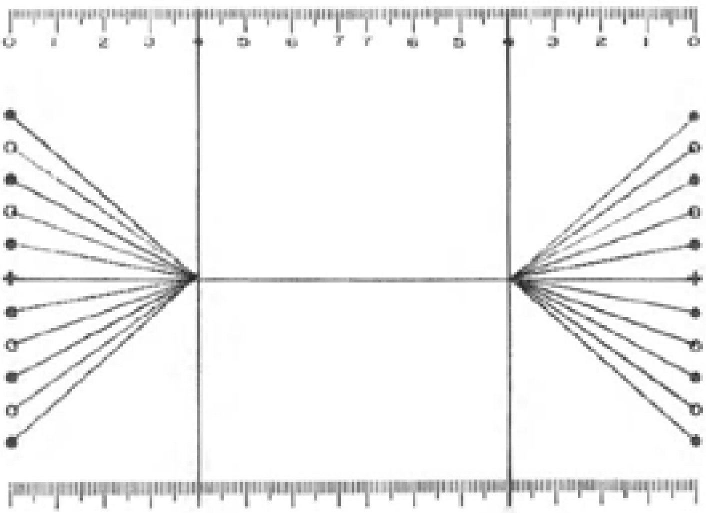

***Figure 2. Orthophoric VOS***

composed of eleven figures placed 140 mm apart (Figure 2).[35] The objective is to plot a visual behavior pattern in order to record how the eyes coordinate binocularly. The resulting graph gives a binocular visual behavior pattern or shows the projection in space of the corresponding visual areas. Features include phorias, asymmetries, scotomas, suppression areas, signs of discomfort, reading difficulties, and skill deficiencies.[30]

Most five- and six-year-old children are physically able to perform the procedure. There are suggested techniques available for young children that may also be useful for patients who have difficulty processing instructions. The interpretation of the VOS is both qualitative and quantitative. Qualitatively, all lines on each side must end at a single point or apex, forming a different center. Quantitative assessment focuses on the location of the centers in relation to each other, lateral phoria, and vertical phoria. Phoria in this context refers to the relationship between the centering and the actual location of objects in space.[34]

The term organizational is used here to mean a more static structuring of space that would be indicated by the lines reaching the same apex. A grouping of lines that intersect closer to an apex would be classified as more organized. A grouping of lines that intersect only in one region or area is less organized, and there is an expected amount of separation between the two apices of the star. Apices that are too close to each other show an esophoric character or too-close posture in eye space. When the apex is too far away, it shows an exophoric character or too-far-away posture in the space of the eyes.[36]

The VOS examines how we perceive and represent the world around us,[35] and this interpretation of the VOS has important implications for the prevention and early detection of functional visual problems. Its use can be extended to patients of all ages who experience changes that require new and higher visual system demands. The VOS has at least six applications, some of them being guiding VT, tracking VT progress, and evaluating the visual development of preschool children and the impact of primary grades on visual performance.[33,34]

It is very important to note that the perception of an individual's space influences their sensory system and, therefore, will influence the drawing of that individual's star. A model is never correct or incorrect; it is based on the facts available at that time, and, in fact, it reflects the state of equilibrium that has been reached, whether ideal or distorted. Thus, its clinical interpretation is a tool to recognize spatial behavior, as it must be borne in mind that vision is not in the eye but in the brain. The VOS is a representation of the projected visual behavior.[35]

As a test of visual ability, it provides a permanent record of the presence of suppression, the magnitude and variability of lateral and vertical phoria, and the adequacy of hand/eye coordination.[37] The type and degree of suppressions, namely complete, alternating, peripheral, perimacular, and macular, are graphically demonstrated when using CH. The demonstration is important to both the patient and the professional, as it shows the concessions that the individual has made to respond satisfactorily to their visual environment. It is clear how the degree or skill in hand/eye coordination can be shown. Spasmodic, unsafe, and uncertain movements are the predominant symptoms of lack of coordination.[33]

Figure 2 shows how each center is located at the intersection of the vertical and horizontal lines; the patient is orthophoric, laterally and vertically. The input (actual location) and output (perceived location) match. There is no distortion in the visual space of this patient, and the objects are and appear to be in the same place.[34]

*Instructions to undergo the VOS test*

The patient had their face centered on the CH with the indication that they were not allowed to raise their heads; they had to grasp two pencils of equal size, one in each hand, and proceeded to place each pencil on the first icon of their respective sides. Then, the patient drew a line simultaneously from the icon on the left towards the center and from the icon on

***Figure 3. VOS test***

the right towards the center. They had to look at the center of the paper, and when they observed that the pencil tips had come together but without the tips touching, they stopped drawing the line (Figure 3). Then, they moved on to the second icon and traced another line. The patient used the same technique with the remaining icons until they reached the 11th icon. At that moment, the test concluded.

*VOS score*

The score used for the study contained 5 values, with V1 being the lowest score as a highly undesirable result and V5 being the highest score as a highly desirable result (Figure 4).

V1. Neither of the sides have a shape
V2. One side has a malformed apex or does not form the apex
V3. Intermediate value, both sides are relatively organized, but they can show a fan shape on both sides or similar
V4. Both sides have the apex formed quite clearly, although they do not project exactly on the frontal and/or sagittal axis
V5. Both sides are formed, organized; both apices practically located at the point of orthophoria

### Statistics

The sample consisted of 44 boys (56.4%) and 34 girls (43.6%) of the total sample size n = 78 schoolchildren, aged between 4 and 15, with an average age of 7.4 years and a standard deviation of 2 years. The coefficient of variation is 27%, which indicates a large dispersion of age data.

The allocation of children to both therapies was carried out as follows: 26 children (33.3% of the

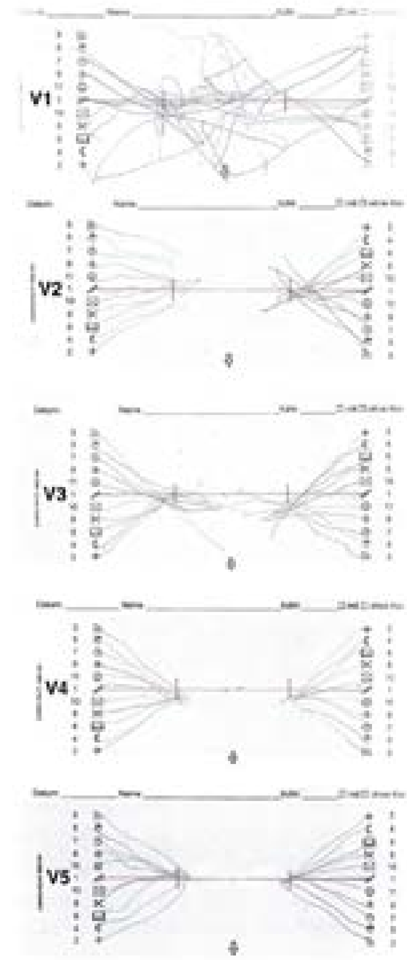


***Figure 3. VOS score***

sample) followed DM Primary Reflexes therapy, and 52 (66.7%) the therapy developed by the INPP.

The statistical analysis was developed with the help of the statistical package SPSS (Statistical Package for the Social Sciences, Inc., Chicago, IL, USA) in its version 21.0 for Windows.

## Results

### Variation in VOS Results

The values obtained in both therapies, shown in Table 2, suggest that the changes obtained as a consequence of inhibiting primitive reflexes are very similar regardless of the therapy used.

**Table 2. The Type of Variation on the VOS Scale**

| | The Entire Sample | | DM Therapy | | INPP Therapy | |
|---|---|---|---|---|---|---|
| | Fre-quency | % | Fre-quency | % | Fre-quency | % |
| Decrease | 5 | 6.4 | 2 | 7.7 | 3 | 5.8 |
| Maintenance | 11 | 14.1 | 4 | 15.4 | 7 | 13.5 |
| Increase | 62 | 79.5 | 20 | 76.9 | 42 | 80.8 |
| Total | 78 | 100 | 26 | 100 | 52 | 100 |

**Table 3. Frequencies and Percentages Relative to the Different Variations of the VOS Score**

| Variation | −2 | −1 | 0 | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|---|---|---|
| Frequency | 3 | 2 | 11 | 17 | 22 | 18 | 5 | 78 |
| Percentage | 3.8 | 2.6 | 14.1 | 21.8 | 28.2 | 23.1 | 6.4 | 100 |

The variable VOS score variation was defined as the difference between the final and initial VOS scores—the variable response is of the greatest interest in our analysis.

For the total sample of 78 children, the majority (about 80%) experienced an increase in VOS scores of 1 to 4 points. Only five children, two of them from DM therapy and three from INPP therapy, had a slight decrease of one or two points. Eleven children, four DM and seven INPP, maintained the score from the start to the end of therapy.

For five children, there was a decline in VOS score of one or two points; for 14.1% of the children, the score was unchanged. An increase in score was achieved in almost 80% of children, with 79.5% gaining between one and four points. The most frequent gain of two points was achieved in 28.2% of the sample. Frequency and percentage results related to variation difference are shown in Table 3.

## Difference between Initial and Final Values of VOS

The linear correlation between quantitative variables was analyzed using Pearson's r correlation coefficient and the independence test, the most relevant result being that there was a highly significant correlation between inhibition of PR and improvement in VP. The two Pearson r coefficients indicated a highly significant correlation (p=0.000; <0.01) with a 99% confidence level. The lower the initial VOS score, the higher the variation produced by the therapies; the lower the final VOS score, the lower the variation. The linear correlation is presented in Table 4.

The association or dependence between the applied therapy and the variation in the VOS scale led to the conclusion that the type of variation produced by both therapies was practically identical, being contingency coefficient C (value=0.048 (very close to zero); p=0.915 (very close to 1)).

**Table 4. Correlation Produced by Reflex Inhibition Therapies in the Final Value of VOS**

| | | Initial VOS Score 1–5 Scale | Final VOS Score 1–5 Scale |
|---|---|---|---|
| Variation produced by therapy in VOS | r by Pearson | −0.605 | 0.737 |
| | p-value | 0.000 | 0.000 |
| | n | 78 | 78 |

**Table 5. Correlations and Test Results of Different Quantitative Variables**

| | | Age | Months of Therapy |
|---|---|---|---|
| Variation produced by therapy in VOS | r by Pearson | 0.114 | 0.135 |
| | p-value | 0.320 | 0.240 |
| | n | 78 | 78 |
| DM therapy | r by Pearson | 0.118 | 0.034 |
| INPP therapy | r by Pearson | 0.116 | 0.179 |

## Variations Produced by Two Quantitative Variables

Given that the two p-values exceeded the significance of 0.05, with a confidence level of 95%, we concluded that the variation produced by the therapies as a whole, as well as separately for each of the two analyzed therapies, was not significantly correlated with any of these two variables. The results are shown in Table 5.

## Changes Produced by Qualitative Variables

None of the seven qualitative variables shown in Table 6 determined any significant association of the rate of change in VOS score variation. No observed value of the seven variables differed from that

**Table 6. Contingency Type of Variation VOS vs. Different Qualitative Variables**

| | Coeff. C p-Value | Conclusion |
|---|---|---|
| Sex | 0.124 0.546 | The rate of change produced is independent of the sex of the 78 children (p=0.546; >0.05). |
| Repeat school year | 0.152 0.398 | The rate of change produced does not depend on whether or not the child has repeated the course (p=0.398; >0.05). |
| Binocular difficulties | 0.166 0.332 | The rate of change produced is independent of whether or not the child had binocular difficulties at the start of therapy (p=0.332; >0.05). |
| Learning difficulties | 0.122 0.552 | The rate of change produced is independent of whether or not the child had learning difficulties at the start of therapy (p=0.552; >0.05). |
| Motor difficulties | 0.183 0.260 | The rate of change produced is independent of whether or not the child had motor difficulties at the start of therapy (p=0.260; >0.05). |
| Parents' situation | 0.158 0.369 | The exchange rate produced is independent of the parents' situation (separated or married) (p=0.369; >0.05). |
| Wear prescription glasses | 0.197 0.207 | The exchange rate is independent of whether or not the child wears prescription glasses (p=0.207; >0.05). |

expected under the assumption of independence, which confirmed the previous conclusion. Repeating these associations separately, between the two therapies, no significant association was found in any test.

**Student's t Test**

To determine whether the average increase in variation was positive, Student's t test (Table 7) was applied after verifying that the data were adjusted to normal using the Kolmogorov–Smirnov test.

**Table 7. Student's t Test Result**

| | | | Variation Produced by Therapy in VOS |
|---|---|---|---|
| Test value = 0 | t | | 10.161 |
| | gl | | 77 |
| | p-value | | 0.000 |
| | Mean difference | | 1.63 |
| | 95% confidence interval for difference | Bottom | 1.31 |
| | | Top | 1.95 |

Given that the p-value = 0.000 is less than 0.05, with a 95% confidence level, it was concluded that the therapies applied achieved a highly significant increase in the average of the changes in the VOS score for the sample of 78 children.

**Results Regarding Sex**

By comparing the total averages, regardless of the therapy applied (Table 8), females outperformed males, with a mean increase in the VOS score of 35.5% and an average of 1.91 compared to an average of 1.41 for males. The p-value of 0.121 (>0.05) of the Student's t test indicated that the averages of males and females were not significantly different.

The application of DM therapy produced nearly equal averages; females outperformed males by 1.3% (1.55 compared to 1.53). The p-value of 0.981, well above 0.05 and very close to the unit, confirmed this conclusion.

INPP therapy, on the other hand, gave very different average results: 2.09 in females and 1.34 in males, a 56% out-performance in favor of females. The test showed a p-value of 0.074 (<0.10; double of 0.05 if we consider a unilateral test), which allows us to conclude, with a confidence level of 95%, that the average results of the females significantly exceeded those of the males.

**Age of Onset and Duration of Therapy**

The average age of initiation of therapy (Table 9) was significantly different, as children aged between 4 and 6 years were systematically included in DM therapy, while children aged 7 years and older were systematically included in INPP therapy.

**Table 9. Age of Onset and Duration of Therapy**

| Variable | DM Therapy | INPP Therapy | p-Value |
|---|---|---|---|
| Age of onset | 5.62 ± 0.637 (4, 6) | 8.31 ± 1.842 (6, 15) | 0.000 |
| Duration of therapy | 12.7 ± 1.225 (10, 14) | 12.0 ± 1.836 (8, 17) | 0.045 |

Finally, being a single child vs. having more siblings, permanently taking methylphenidate, or being adopted or not did not provide significant data in the study.

The duration of therapy with p-value of 0.045 (<0.05), led us to conclude, with a 95% confidence level, that among the mean durations of both therapies, the mean length of DM therapy (12.7 months), significantly exceeded the mean length of INPP therapy, which was 12 months.

## Discussion

The presence of PRs after the age of three can affect motor and cognitive development in children,

**Table 8. Basic Parameters of Therapies According to Sex**

| | Therapy | Sex | n | Average | SD | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| Variation produced by therapy in VOS | DM therapy | Male | 15 | 1.53 | 1.407 | −1 | 3 |
| | | Female | 11 | 1.55 | 1.128 | 0 | 3 |
| | INPP therapy | Male | 29 | 1.34 | 1.446 | −2 | 4 |
| | | Female | 23 | 2.09 | 1.474 | −2 | 4 |
| | Total | Male | 44 | 1.41 | 1.419 | −2 | 4 |
| | | Female | 34 | 1.91 | 1.379 | −2 | 4 |
| | | Total | 78 | 1.63 | 1.415 | −2 | 4 |

although it can also do so at the level of visual organization. The visual system is not exempt from external, environmental influences or from internal, bodily influences. This presence of the PRs hinders a motor organization that translates into a possible anomalous visual projection.

The abnormal VP can translate into motor clumsiness as well as academic delay. At the motor level, an inadequate projection can imply that calculations regarding distances suppose a whole challenge and that a simple action such as going up or down the stairs is carried out slowly or prudently since they show insecurity. It must be borne in mind that an inadequate projection implies that an individual is focusing on a point where things are not really there, highlighting the difference between visual entry and exit. At the academic level, this can have the same consequences: the reading process, already complex for many children, can be even more difficult due to the difference between where the words are and where they focus, so additional effort is added.

Most published studies show the effects of uninhibited primitive reflexes with learning disorders, attention deficit, language problems, dyspraxia, and postural problems. However, there are no conclusive studies that confirm the relationship between sensory disturbances, and more specifically visual disturbances, and the activity of PRs.[38] We hope that this study provides conclusive data that such a relationship does exist.

The results show that the inhibition of PRs significantly increases the final values of the VOS. The results suggest a relationship between the body and the visual system, as well as between inhibition of PRs and improvement in VP. We establish that PR inhibition balances visual asymmetries and improves visual fixation.

Around 80% of the children improved, 14% maintained the same projection index, and the VP of 6% worsened. The data coincide and are very similar regardless of which therapy, which suggests that it is the selection of the appropriate therapy, its quality in the execution, and periodicity that lead to an improvement in visual projection.

In the VOS test, we found five cases where the result was worse than the initial result, but we did not manage to obtain any clear pattern as to the reasons why this occurred. The only relevant data are that of the five cases, four of them were males and one was a female. For the 11 patients who maintained the same end-of-treatment score, 6 were males and 5 were females.

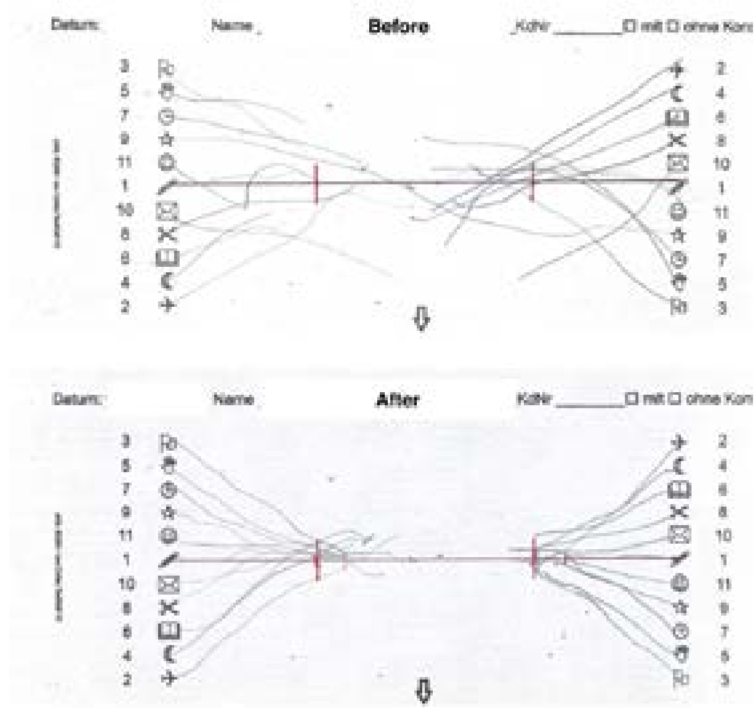

***Figure 3. Example of a VOS before and after treatment***

No individual characteristic analyzed represented significant data, as all of the characteristics were homogeneous. Thus, it is not possible to determine or to suggest any objective cause that could help to clarify these facts.

Within the type with the greatest variation, we noted that the highest percentage (28.2%) improved by two points, followed by 23.1% that improved by three points. This means that more than half of the children and adolescents improved by between two and three points, which represents a considerable improvement in visual projection. A total of 21.8% showed improved projection by one point, and, finally, 6.5% improved by four points. This last case that occurred in five children in the sample is not common, as such a change is usually only possible through therapies aimed particularly at vision; however, we consider it to be very positive.

Inhibition of PRs consists of replicating standardized exercises that must be performed on a daily basis and movements that are not visual exercises, leading to normalization and balance of the visual system, with the result of an improvement in VP. An example is shown in Figure 5.

The data shows that age is not a variable that can be correlated as significant in the final result. We believe that the key to success is in applying the appropriate therapy to the characteristics of the children. Most of the INPP exercises cannot be performed by children under 7 years of age because the required control and the necessary tone is not fully developed, which can lead to failure. In fact, there are certain exercises within INPP practice that are still very complex for children who have just turned 7, so certain methods must be established to facilitate their execution. DM therapy could be used for children over 7 years of age. However, we would not recommend it, as these exercises provide a lower level of control and intensity. Other DM exercises are performed passively or are supervised by parents. Considering the characteristics of older children, not all exercises would be recommended for therapeutic use at older ages. Each age group needs a therapy planned and designed for its characteristics.

If the chosen therapy is adequately adapted to the motor qualities of the children and the inhibition of the PRs is achieved, then there is a high probability of obtaining a quantitative and qualitative improvement in the final VOS value. In this case, the results of this study show that the variation produced by both therapies is practically the same in terms of the impact produced by DM and INPP on the final VOS value. However, one observed data point is the qualitative difference in working with the group of young children aged between 4 and 6 years of age. Both evaluations and daily work by parents at home with this group are more complex than those of older children because more effort and dedication are required.

Within the qualitative variables, neither the sex of the children (44 male and 34 female ($p=0.546$; $>0.05$)) nor the fact that they had repeated a school year (8 children ($p=0.398$; $>0.05$)) constituted significant variables in the final variation of the VOS score. Moreover, the other three qualitative variables failed to determine any significant association with the rate of change in the VOS score variation.

Binocular difficulties ($p=0.332$; $>0.05$) are understood as those dysfunctions that, without being pathological, cause difficulties in the normal functioning of visual coordination, such as accommodative and vergence dysfunctions.

Learning difficulties ($p=0.552$; $>0.05$) are those that could cause inadequate academic development, such as processing difficulties; slow reading; and confusion of letters, words, or line breaks when reading.

Motor difficulties ($p=0.260$; $>0.05$), such as motor type dysfunctions in general, may have associated problems in body coordination, clumsiness when doing sports, or non-pathological walking disorders.

The treated children came to our center as a consequence of one of these three causes. These are not exclusive, and, in many cases, the parents argued that their children showed one, two, or even all three dysfunctions on a day-to-day basis. It is logical to think that this is the case since the presence of PRs in childhood or adolescence is not always selective, and it may affect more than one area, becoming multifactorial. For instance, a binocular difficulty such as convergence insufficiency can lead to a child showing academic delays due to difficulties in reading. In the same way, a vestibular difficulty can lead not only to difficulties in the spatial location necessary in ball sports but also to difficulties in visual fixation. It is also true that, sometimes, compensations appear that mask some difficulties, although these are underlying and can be subtly observed. The parental situation, that is, the possibility that the family may be made up of a single parent or separated or married parents, did not represent a significant variable ($p=0.369$; $>0.05$). Wearing glasses ($p=0.207$; $>0.05$) also did not show a significant association.

The variation in the result of the VOS had a greater impact on females than on males. The results in DM therapy were on average similarly increased by males and females. With INPP therapy, the result was broader, with the average improvement in males being 1.34 points compared to 2.09 for females. The general average by sex was an increase of 1.41 points in males compared to 1.91 points on average in females, which shows a clear improvement in the final result of the visual projection. The overall count was an average increase of 1.63 regardless of sex. It also follows that among the two therapies, DM therapy is more conservative while INPP is more aggressive, with the latter decreasing the improvement more in males than in females and the former increasing it more in females than males. We did not note any clear reason for this difference in females; perhaps it is due to the qualitative improvement in the performance of exercises at home or to biological reasons. A more complete study should be conducted to obtain definitive data.

The only significant variable found corresponds to the difference between both therapies in the time required to achieve PR inhibition ($p=0.045$; $<0.05$). DM required $12.7 \pm 1.225$ months on average, with a range between 10 and 14 months for children with an average age of $5.62 \pm 0.637$ years. INPP, on the other hand, required an average of 12.0 ± 1.836 months, with a range between 8 and 17 months for children with an average age of 8.31 ± 1.842 years. We believe that the reason lies in the motor skills corresponding to each age. Under 7 years of age, exercises tend to be more passive and accompanied by parents. Above 7 years, the requirement may be as great as the motor characteristics of that age allow it to be. We can summarize by stating that above 7 years of age, the therapy used can be more intense and include more motor and muscular demands, while below this age, what cannot be achieved with demand and intensity is achieved periodically through a longer duration in time. Regardless of whether the therapies used are more or less passive, more or less active, or more or less accompanied, if the primitive reflexes are inhibited, the results are practically identical.

This is corroborated by the quantitative variable of months of therapy. The variation produced in the final VOS value is not correlated with the months of therapy ($p=0.240$; $>0.05$). This shows that the aim is not to demonstrate that the longer the better or the shorter the better, but rather, when the inhibition of the PRs is achieved, the objective will have been met, and it will be this inhibition that will have led to an improvement in VP.

In our clinical practice, VT is usually the goal in the correction of binocular difficulties as well as academic difficulties. Our approach is to start VT once the PRs are inhibited. A properly performed PR inhibition program can be a great resource as a pre-VT stage. With the results obtained, it would be reasonable to think that motor organization should initially prevail to the visual organization; otherwise, it could represent a permanent break throughout the VT, slow it down, or prevent success since the structural base may not be fully organized.

The combination of VT exercises with PR inhibition exercises is also a widespread practice, but our experience led us not to adopt these guidelines, because the workload of this combination greatly exceeds the capacity of children and adolescents. If they also have to combine this with academic activities, the experience may not be very pleasant for them. Moreover, the rhythms used in both therapies are not easy to associate. It is not logical to stimulate eye control exercises through VT when the lack of motor control provokes stimuli opposite to those needed in VT. On the other hand, we can also claim that inhibition of PRs is not substitute for VT. What this study shows is that the body is an indivisible part of the visual system and cannot be viewed as both segregated and disconnected.

As for the score of the last VOS test, it is natural to assume that reaching a V5 score, the most highly desirable score, is not simple and is difficult to attain solely in the application of an individualized PR inhibition program, as it is usually only possible to achieve this score from a complete and perfectly structured VT process administered by behavioral optometrists.

Improving projection does not mean that the visual system is completely corrected or that binocularity appears systematically or is guaranteed. It means that the VP levels improve, but then other therapies (in this case, VT) must be continued in order to continue structuring visual skills in a coherent way. We must be aware that the inhibition of PRs has limitations in terms of the organization of the visual system, although it is the base through which it can be later achieved.

The two VOS tests were executed in different time slots. The first test was carried out during the morning, without attending school, when the children were fresher, had a greater attention span, and were more predisposed to the test. In contrast, the final test was always carried out in the afternoon after the school day and with the tiredness that this could bring. We have not been able to confirm whether this can represent a significant variable.

With the improvement in VP comes another qualitative but not measurable characteristic: namely, the improvement in the quality of the strokes in the VOS test. The type of exercise that is developed during the approximately 12 months of therapy provides greater control of the whole body. The smooth, coordinated movements and the application of the right amount of muscle tone in the limbs, trunk, and head lead to a spatial understanding that improves proprioception and balance. Furthermore, this translates into projection. People see the world from their own perspective; if their projection is not adequate, they cannot be sure of the actions that they carry out. Moreover, insecurity leads to clumsiness or extreme caution. The improvement in motor skills that is achieved through inhibition of PRs is what leads to maturity of the central nervous system and, therefore, to better motor planning, including in the visual system. Children and adolescents often improve not only in the projection of the visual system but also in concepts such as self-regulation and, consequently, better executive function.

Regarding our hypothesis on how PRs improve VP, visual processing begins in the retina—here, the image of the world breaks down through visual filters. In mammals, the visual message moves to an intermediate station in the thalamus, the lateral dorsal geniculate nucleus (LDGN). It is a structure that receives the axons of the ganglionic cells in an organized manner according to the eye from which the image comes. This information is transmitted to the primary visual cortex (V1), from which connections are made with many other cortical and subcortical visual structures. LDGN plays a key role in the transmission of visual information to the brain body. Unlike the retina, this is a site where both the processing and transmission of information occurs; the thalamic transmission can be modulated by a series of inputs that arise from the brainstem and depend on the state of behavior of the organism.[39] In certain areas of the brainstem, nitric oxide (NO) is released when activity increases. The NO increase acts on the thalamus–cortical neurons of the lateral geniculate nucleus, which, in turn, increases their activity. In this sense, NO functions as a general system to gain enhancement by amplifying signals such as center–periphery antagonism.

NO has a modulating function in relation to the ubiquitous neuromodulator that is involved in multiple functions of the visual system, including the responsiveness of visual cortical and thalamic neurons.[40] The nitrinergic system is involved in the control of eye movements.[41] Various circuits of LGN could provide a substrate for binocular modulation; thus, it could be concluded that the outputs of both eyes are found and interact somewhere in the brain before binocular combination in the primary visual cortex.[42]

NO is an important neuromodulator that can be released in the thalamus in a large amount as ordered by the trunk and diencephalon activator systems. At the same time, most experimental results indicate that NO produces activation of the neurons on which it acts, and, therefore, its role within complex circadian control mechanisms would be to facilitate the functioning of the triggering systems. This is also the case with the transition from sleep to wake.[43]

In addition, a wake activator could have motor activity; in fact, the serotonin system may be related to the arousal that accompanies the standardized and automatic motor activity.[44] There is a sensory influence on the cortex that maintains the brain activity necessary for attentional modulation; the activity of the cortical neurons is maintained by a reflex mechanism to proprioceptive and exteroceptive stimuli.[45]

In summary, the thalamus and cortex, in combination with levels of arousal, are modulated by the reticular system to provide the appropriate and necessary substrate for perception and for the complex cognitive processes to take place.[46] Therefore, with the data obtained, we could speculate that standardized repetitive exercises used to inhibit PRs could have an effect similar to that observed during the transition from sleep to wake.

It may be risky to assume that stimulating the brainstem through specific motor exercises of PR inhibition could increase NO at the thalamic level. This could increase the gain and the signal reaching the cortex, therefore improving binocular vision, VP, and consequently fixation. The fact that binocularity improves or appears could explain why visual asymmetries are reduced to a greater or lesser extent with a result of better VP.

Evidence also indicates that NO is involved in cortical activation, and it also affects other subcortical structures, including, among others, the upper colliculus and higher-order thalamic regions, such as the pulvinar nuclei.[40] The rostral pole of the upper colliculus is also known as the fixation zone, which is important to drive the eyes.[47] The upper colliculus appears to be provided not only with a visual map but also with information on the point to which the eye is pointing,[48] and the fact that it plays a fundamental role in the control of saccadic eye movements should be considered.[49] On the other hand, the pulvinar nuclei are also involved in vision; one of the observed actions of the cells of the pulvinar nuclei is that of the reach of an arm to an object.[50]

PR inhibition exercises require continuous motor planning due to their high level of control. The CE is the brain's autopilot, specializing in preprogramed automatic synchronization of muscle contractions to optimize motor performance and playing an important role in calibrating visual movement signals to maintain eye fixation.[51] The CE has also been involved in adjusting biases in the control systems for stable fixation.[20] A differential role for later CE is indicated in adaptive control of convergence eye movements, while vergence eye movements shift our gaze in depth, allowing us to see in 3D.[52] There is evidence of CE motor control of the eye supporting its involvement in the mid-line,[53] and it is also involved in the control of eye movements, visuospatial care, and peripheral vision, all of which are important for visual aspects, such as reading.[54]

## Conclusions

The results of the study show a complete lack of dependence of any quantitative and qualitative exposed variables, with the conclusion that inhibition of PRs improves VP in a significant way. Such improvement is a result of the application of two therapies specifically designed for two age groups that must be systematically performed on a daily basis, following the therapist's guidelines for as long as the therapist deems appropriate. The specific inhibition of four PRs, namely the MR, TLR, ATNR, and STNR, may be the key to the process of improvement in VP. These are not the only PRs, but they are the main representatives of motor and postural control, and effort must be directed toward their total inhibition.

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