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# The effect of visual therapy on the ocular motor control of seven- to eight-year-old children with Developmental Coordination Disorder (DCD)

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ABSTRACT

The aims of this study were to determine the extent of ocular, motor control problems and the effect of visual therapy on such problems, among seven- to eight-year-old children diagnosed with DCD. Thirty-two, children with a mean age of 95.66 months (SD $\pm$ 3.54) participated in the study. The MABC was used to classify children into DCD categories (<15th, percentile) while the Sensory Input Systems Screening Test and QNST-II, were used to evaluate ocular motor control. A two-group pre-test–post-test, cross-over design was followed with a retention test two years, thereafter to determine the lasting effect of the visual therapy, intervention. The 18-week visual therapy programme was executed once a week, for 40 min during school hours, after which the two groups were, crossed over. Percentages of ocular motor control problems ranging, between 6.25% and 93.75% were found in both the groups before participating, in the visual therapy programme, with the highest percentage problems found, in visual pursuit with the left eye. Visual therapy contributed to a, significant improvement of 75–100% in visual pursuit, fixation, ocular, alignment and convergence, with significant lasting effects ($p < 0.001$). Visual therapy is recommended for children with DCD experiencing poor, ocular motor control.


## 1. Introduction

Motor deficiencies and ocular motor control problems can appear to cause severe problems in the development of children (Wilson, 2005; Zoia, Castiello, Blason, & Scabar, 2005). Vision is the primary source with which 80–90% of all information from the environment is perceived, moves through the brain, and to which the body must pay attention (Saladin, 2007). The development and improvement of perceptual and motor skills such as spatial orientation, coordination (hand–eye, foot–eye, hand–foot–eye coordination), balance, and body awareness are dependent on an effective visual system as well as good eye muscle control (Cheatum & Hammond, 2000; Pienaar, 2008; Willoughby & Polatajko, 1995). If there is any faulty input of information by way of the visual system, the reaction of the motor output to such information will also be faulty, could lead to motor deficiencies, poor concentration and, indirectly, to a low self-image (Lefebvre & Reid, 1998; Peens & Pienaar, 2007; Pienaar, 2008).

Approximately 20–30% of all children attending school do, in fact, display ocular motor control problems (Auxter, Pyfer, & Huetting, 1997; Ciuffreda, 2002; Orfield, Basa, & Yun, 2001). Ocular motor control describes the ability of the three pairs of

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skeletal eye muscles (rectus lateralis and medialis, rectus superior and inferior, and the superior and inferior oblique) to work together in a synchronised and coordinated way to ensure correct movement of the eyes (Lane, 2005). If problems with ocular motor control do occur, this will lead to accommodation, fixation, convergence, visual pursuit, and ocular alignment problems, which again, in turn, may have an influence on the child's academic and sport performance (Bouchard & Tetreault, 2000; Lane, 2005; Lefebvre & Reid, 1998). It thus, appears that well-functioning eye muscles are important for effective functioning of the visual system.

Poor motor coordination is described as ''Developmental Coordination Disorder'' (DCD). The Diagnostic and Statistical Manual (DSM-IV) of the American Psychiatric Association (APA, 2000), defines the term DCD to identify children with motor clumsiness, or any problems or limitations with the development of motor coordination, which is considerably lower than the child's chronological age. The motor coordination problems must also interfere with academic performance as well as daily activities. Furthermore, these children must have normal intelligence, with no signs of neurological conditions (such as, for example, cerebral palsy or muscular dystrophy) or physical disturbances (APA, 2000). The occurrence of DCD in children between the ages of five and 11 years is estimated at between 3% and 22% worldwide (Alloway & Archibald, 2008; APA, 2000; Cardoso & Magalhães, 2009; Hoare & Larkin, 1991; Wilson, 2005), while Pienaar (2004) reported an occurrence of 36.4% in children living in the North West Province of South Africa.

Children who are diagnosed with DCD are described as a heterogeneous group regarding underlying problems because they do not only display coordination and perceptual-motor dysfunctions, but display developmental limitations such as ocular motor control, attention deficit, as well as learning-related problems (Hoare & Larkin, 1991; Peens & Pienaar, 2007; Piek & Dyck, 2004). Various researchers link certain neuromotor problems as well as sensory-neurological processing problems such as visual problems, sensory problems, kinaesthetic problems, and reflex problems to DCD (Alloway & Archibald, 2008; Piek & Dyck, 2004; Willoughby & Polatajko, 1995).

Vision therapy can be described as individualised intervention for the improvement of the binocular system, ocular motor control, visual processing, visual-motor skills, and/or perceptual-cognitive deficiencies (AAO, 2011; Adler, 2002; Ciuffreda, 2002; Helveston, 2005; Orfield et al., 2001; Scheiman et al., 2005). The aim of vision therapy, according to Ciuffreda (2002) and Shainberg (2010), is to improve visual deficiencies by establishing a stable binocular system, which then further integrates the ocular motor system with the head (hand–eye coordination), neck (proprioceptive information), and the rest of the body (body awareness, spatial orientation, and muscle tone). During vision therapy, use is made of lenses, prisms, and specialised visual devices (Adler, 2002; Hurst, van de Weyer, & Smith, 2006; Orfield et al., 2001; Scheiman et al., 2005).

Various researchers (AAO, 2011; Adler, 2002; Auxter et al., 1997; Helveston, 2005; Scheiman et al., 2005) are of the opinion that vision therapy does improve visual deficiencies such as binocular skills, ocular motor control, visual attention, visual perception, and visual processing skills. This improvement of ocular motor control can contribute to the improvement of the child's motor skills as well as academic skills such as reading, writing, spelling, and mathematical abilities (Helveston, 2005; Orfield et al., 2001). Cheatum and Hammond (2000) are, furthermore, of the opinion that remediation of ocular motor control contributes to the improvement of fine motor skills (reading, cutting, and writing), gross motor and perceptual skills (balance, hand–eye and foot–eye coordination, spatial orientation), and visual skills. The case study of Hurst et al. (2006) on an eight-year-old child with motor planning problems (dyspraxia) indicated that vision therapy of eight months improved the ocular motor control, gross motor skills, and academic skills of the child, while another case study on a 10-year-old boy with motor development deficiencies showed a positive influence on ocular motor control and motor skills (Dudley & Vasché, 2010).

Literature indicates that the success percentage of vision therapy on ocular motor control skills such as accommodation, fixation, convergence, and pursuit appears to be between 70% and 100% (Adler, 2002; Ciuffreda et al., 2008; Ciuffreda, 2002; Grisham, 1988; Scheiman et al., 2005). It would, however, appear that there is no research on the effect of vision therapy on the ocular motor control of children with DCD. The aims of this study were therefore to determine the extent of ocular motor control problems and the effect of vision therapy on ocular motor control problems among seven- to eight-year-old children diagnosed with DCD.

## 2. Materials and methods

### 2.1. Research design

A two-group pre-test–post-test cross-over design was followed with a retention test two years thereafter to determine the lasting effect of the visual therapy intervention.

### 2.2. Participants

This study is a follow-up on a research project undertaken in 2006. During the project in 2006, two Grade 1 classes from each of three mainstream primary schools, in the Potchefstroom area, North-West Province, South Africa were randomly selected to take part in the project. The total number of learners identified for the research project was 101 (48 boys and 53 girls between the ages of six and seven years). The distribution of the learners identified was representative within the different population groups (37 white, 50 black, and 12 children of colour). Of this group who took part in the first part of the project in 2006, 49 learners (20 boys and 29 girls) without DCD and 52 learners (28 boys

**Table 1**
Characteristics of the two groups according to gender, race, age, and DCD classification.

| Variables | Group 1 ($n = 16$) | | | Group 2 ($n = 16$) | | |
|---|---|---|---|---|---|---|
| | Boys | Girls | Total | Boys | Girls | Total |
| White | 5 | 2 | 7 | 5 | 1 | 6 |
| Black | 4 | 4 | 8 | 5 | 4 | 9 |
| Children of colour | 1 | 0 | 1 | 0 | 1 | 1 |
| Total | 10 | 6 | 16 | 10 | 6 | 16 |
| Mean age in months (M) | 95.90 | 95.83 | 95.87 | 95.10 | 96.00 | 95.55 |
| Standard deviation (SD) | 3.07 | 4.07 | 3.34 | 2.51 | 5.66 | 3.83 |
| Moderate DCD | 0 | 1 | 1 | 1 | 0 | 1 |
| Severe DCD | 10 | 5 | 15 | 9 | 6 | 15 |
| Total | 10 | 6 | 16 | 10 | 6 | 16 |

and 24 girls) with DCD were identified, of whom 29.3% ($n = 29$) were classified in the moderate DCD categories and 23.2% ($n = 23$) in the severe DCD categories (Wessels, 2007). The 52 learners who were identified with DCD were then approached in 2007 for participation in this follow-up study. Of this group, 12 had relocated, and the parents of eight did not return the informed consent forms; consequently, only 32 learners were available for this follow-up study. The composition of this group is displayed in Table 1. The children were eligible to participate in this study if they met the following criteria from the DSM-IV (APA, 2000): if their performance in daily activities, that require motor coordination, were substantially below that expected given the child's chronological age and measured intelligence (criterion A), and the presence of these motor clumsiness or motor coordination problems significantly interfere with the child's academic achievement or daily living as identified by the teacher or the parent (criterion B). If any of the children was diagnosed with any neurological condition such as cerebral palsy or any other medical disorder (criterion C) or if there were a possibility of mental retardation, reported by the teacher (criterion D) the learner were excluded from the project.

### *2.3. Measuring instruments*

#### *2.3.1. Movement assessment battery for children (MABC)*

The MABC (1992) was used to determine the motor coordination status of the children. Henderson and Sugden (1992) developed the MABC that is used for the evaluation of the motor coordination of four- to 12-year-old children. The MABC exhibits good reliability and validity of 0.75 (Henderson & Sugden, 1992; Leemrijse, Meijer, Vermeer, Lambregts, & Ader, 1999). The MABC consists of three sub-sections that measure: manual dexterity skills (three test items), ball skills (two test items), and static and dynamic balance skills (three test items). Each sub-section can be calculated separately and jointly as a total DCD score. The test is a norm-based measuring instrument that classifies children with DCD. Children who are classified on and/or below the fifth percentile need remediation, and between the fifth and 15th percentile, the child is indicated as at risk of DCD, and remediation is recommended. When the MABC total and the scores of the three subsections are low, this indicates a better performance; thus, the lower the score, the better the person preformed in the MABC test. The respective test items of the MABC were administered by trained postgraduate students in Human Movement Science, specialising in Kinderkinetics.

#### *2.3.2. Sensory Input Screening Measuring Instrument and quick neurological screening test II (QNST-II)*

Pyfer (1988) compiled the *Sensory Input Screening Measuring Instrument* that consists of the following test sections: equilibrium reaction, vestibular functioning, reflexes, bilateral integration, kinaesthetic and visual items. This criteria-based measuring instrument is suitable for use in age groups above 6 years (Auxter et al., 1997). Only the visual test items of the aforementioned test battery were used for this study. Vision was analysed by testing the following ocular muscle control functions: ocular alignment left and right (where the child must focus on an object for 10 s while one eye is closed), convergence–divergence (the child must focus on an object while the object is moved closer to and away from the nose from a distance of 45 cm), fixating on an object for 10 s with both eyes open as well as with the left and right eye separately from a distance of 45 cm away from the nose, and visual pursuit with both eyes open as well as with the left and right eye separately, using a 30 cm × 30 cm square from a distance of 30 cm away from the nose. The visual pursuit of a horizontal as well as a vertical line with both eyes, which is part of the QNST II, was also tested (Mutti, Martin, Sterling & Spalding, 1998). This test battery shows a validity of $r = 0.81$ (Mutti et al., 1998).

After the assessment of each of the ocular muscle control functions, the signs were then sub-divided into three classes, namely Class 1 – no ocular muscle control deviations; Class 2 – one to three ocular muscle control deviations; Class 3 – more than three ocular muscle control deviations. The following visual deviations were considered less severe, or overlapping deviations, and as a result only one point was obtained regardless if more than one of the following signs were present: eyes that are rubbed, eyes that burn, eyes that are blinked often, eyes that are red as well as tear/watery. The visual deviations that were considered more severe, and which indicated compensating movements, obtained one point if any of the following signs were present: turning the head to the left or right, moving the head side to side, or up and down during visual pursuit, eyes jumping over the midline, eye jerkiness, eyes not following the object/lose the object.

### 2.4. Visual therapy

The visual therapy was conducted on an individual basis for 18 sessions, once a week for 40 min during school hours, at the three different schools which form part of this study. During the visual therapy, certain perceptual and motor activities (balance, hand–eye coordination, bilateral integration, and vestibular integration) were combined with visual exercises, which focused on the improvement of ocular motor control. During the sessions, attention was paid to ''near vision'' and ''far vision'' activities during alternating sessions, while attention was paid to both ''near'' and ''far'' visual activities in some of the sessions. ''Near vision'' sessions consisted of eight to 10 visual activities, which were performed at a desk, while the ''far vision'' sessions consisted of six to eight visual and gross motor activities. Use was further made of various visual as well as motor devices during the visual therapy (see Appendix A).

During the visual therapy programme, work was done progressively in three different, but consecutive phases, namely: *monocular* (left eye and right eye were exercised separately): Lessons 1–6; *bi-ocular* (both eyes are open, but the left eye does not see the same as the right eye): Lessons 7–12; and, lastly, *binocular* (both eyes are open and see exactly the same): Lessons 13–18. Appendix B provides an example of progression that occurred during the visual therapy. The visual therapy was conducted by a postgraduate student in Human Movement Science, specialising in Kinderkinetics, who was trained by on optometrist to give this therapy.

### 2.5. Procedure

Ethical approval for the study was granted by the ethics committee (nr. 06M04) of the North-West University, Potchefstroom Campus as well as the North-West Department of Education. An appointment was arranged with the respective school principals, during which the aim and protocol of the study were explained to them. Written informed consent was obtained from the parents and each learner, before he/she was allowed to take part in the research. A discussion was held with the learners to explain the aim and protocol of the study. These learners were evaluated with regard to their DCD status and visual deviations.

The data collection occurred at the beginning of 2007, after which the intervention programme (visual therapy) started. The 32 learners, who participated in the study, were then randomly divided into two groups. Group 1 ($n = 16$) first received the visual therapy for 18 individual sessions. After that, the two groups were re-tested (PoT 1) with the MABC and the *Sensory Input Screening Measuring Instrument* to analyse the effect of the visual therapy on the learners' ocular motor control. After the first re-test opportunity (PoT 1), and a period of four weeks during the school holidays, Group 1 and Group 2 swopped around, so that Group 2 also received the visual therapy, consisting of 18 individual sessions. Both groups were re-tested (second post-test opportunity: PoT 2) with the MABC and the *Sensory Input Screening Measuring Instrument* after Group 2 also received the visual therapy to analyse the effect of the visual therapy on the ocular motor control of Group 2. Both groups underwent a retention test (RT) two years after the completion of the visual therapy to determine the lasting effect of this programme. During PoT 1, PoT 2 and the RT the researchers did not know which children were assigned to which group. The parents of the learners were asked not to let their children participate in any other form of visual- or motor therapy while they were part of this study.

### 2.6. Data analysis

For the data processing, the ''Statistica for Windows 2010'' computer programme package was used (StatSoft, 2010). Use was made of a statistical calculation [$n = (1.96)^2(6.52)^2/(3.75)^2$] (Steyn, Smit, Du Toit, & Strashorm, 1998), based on relevant results (Ernst, 2007), which determined that there had to be at least 11.6 learners ($n = 12$) per group in order for the results to still show statistical value. For descriptive purposes, data was, firstly, analysed using means (M), standard deviations (SD), and minimum and maximum values. Secondly, independent *T*-testing was used to determine the differences during each test opportunity between the two groups. A *p*-value smaller than, or equal to, 0.05 was accepted as significant. A repeated-measures-over-time analysis of variance (ANOVA) as well as a Bonferroni adaptation was used to determine the time effect of the intervention within the groups. Lastly, a two-way variance table was used to determine what percentage of children was experiencing visual problems. Effect sizes (ES) were calculated by subtracting the means (M) divided by the largest standard deviation (SD), to determine the practical significance of the results. For the interpretation of practical significance, the following guidelines were used, namely, $d \sim 0.2$indicates a small effect, $d \sim 0.5$ indicates a medium effect, and $d \sim 0.8$ indicates a large effect (Cohen, 1988).

## 3. Results

Independent *t*-testing was firstly conducted to determine any significant differences between the two groups in the MABC total and the sub-sections and the ocular motor control before starting with the visual therapy (see Table 2).

In the MABC test, a higher value is indicative of poorer performance, Table 2 indicates no statistical significant differences between the two groups with regard to the MABC total ($p < 0.334$), ball total ($p < 0.623$), and balance skills total ($p < 0.742$).

**Table 2**
Differences between the intervention- and control group during PrT, PoT 1 and 2 and the RT with regard to the MABC total and the sub-sections.

| Variables | Group 1 ($n = 16$) | | Group 2 ($n = 16$) | | Significance of differences | | | |
|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | *t* | *df* | *p* | *d* |
| Pre test (PrT) | | | | | | | | |
| MABC total | 22.09 | 5.54 | 20.31 | 4.69 | 30 | 0.981 | 0.334 | |
| Manual dexterity total | 9.53 | 2.57 | 7.66 | 2.51 | 30 | 2.088 | **0.05*** | **0.73**** |
| Ball skills total | 5.25 | 2.68 | 5.72 | 2.75 | 30 | -0.489 | 0.628 | |
| Balance skills total | 7.28 | 3.27 | 6.94 | 2.51 | 30 | 0.333 | 0.741 | |
| Post-test 1 (PoT 1) | | | | | | | | |
| MABC total | 3.78 | 1.71 | 19.53 | 4.45 | 13.22 | 30 | <**0.001*** | **3.54***** |
| Manual dexterity total | 1.94 | 1.09 | 6.41 | 3.31 | 5.13 | 30 | <**0.001*** | **1.35***** |
| Ball skills total | 0.69 | 1.08 | 5.41 | 1.45 | 10.44 | 30 | <**0.001*** | **3.26***** |
| Balance skills total | 1.09 | 0.99 | 7.47 | 2.32 | 10.11 | 30 | <**0.001*** | **2.75***** |
| Post-test 2 (PoT 2) | | | | | | | | |
| MABC total | 3.56 | 1.96 | 5.09 | 1.94 | 2.22 | 30 | **0.034*** | **0.78**** |
| Manual dexterity total | 1.75 | 1.11 | 2.81 | 1.29 | 2.50 | 30 | **0.018*** | **0.82***** |
| Ball total | 0.72 | 0.86 | 1.03 | 0.85 | 1.04 | 30 | 0.307 | |
| Balance skills total | 1.03 | 0.90 | 1.31 | 1.21 | 0.75 | 30 | 0.462 | |
| Retention test (RT) | | | | | | | | |
| MABC total | 3.00 | 1.71 | 5.00 | 2.18 | 2.71 | 30 | **0.011*** | **0.92***** |
| Manual dexterity total | 1.72 | 0.95 | 2.38 | 1.16 | 1.75 | 30 | 0.090 | |
| Ball total | 0.44 | 0.73 | 1.34 | 0.87 | 3.20 | 30 | **0.003*** | **1.03***** |
| Balance skills total | 0.75 | 1.22 | 1.06 | 0.81 | 0.85 | 30 | 0.402 | |

M – Mean; SD – standard deviation; *df* – degrees of freedom; *n* – number of learners.
* Statistical significance at $p$-Value $\leq 0.05$.
** Practical significance at $d$-Value $\geq 0.5$.
*** Practical significance at $d$-Value $\geq 0.8$.

Statistical and practical significance did however occur between both groups with regard to the manual dexterity skill total ($p < 0.045$ & $d > 0.73$), with Group 2 showing a lower mean value (20.31 vs. 22.09). Table 2 respectively indicates the differences between both groups in the different MABC sub-sections and total during PoT 1 (after Group 1 received visual therapy), PoT 2 (after Group 2 also received visual therapy) and the retention test. With regards to the MABC total and the sub-sections, Group 1 performed statistically ($p \leq 0.05$) and practically ($d \geq 0.8$) significantly better than Group 2 during PoT 1, after receiving visual therapy. During PoT 2 that followed after Group 2 underwent visual therapy, the MABC total and manual dexterity total were significantly ($p \leq 0.05$ and $d \geq 0.8$) better for Group 1. During the RT the MABC total ($p = 0.011$ and $d = 0.92$) and ball total ($p = 0.003$ and $d = 1.03$) showed significant differences between the two groups, where Group 1 scores were better. Even though the values of both groups increased over time, a greater increase was observed within Group 1 that first received the visual therapy.

Table 3 indicates no statistically significant differences ($p > 0.05$) during the PrT between the two groups in their ocular motor control functions. Practically significant differences were found between the two groups in visual pursuit with both

**Table 3**
Significance of differences in the different ocular motor control functions between the two groups during the pre-test (PrT).

| Variable | Group 1 | | | Group 2 | | | Significance of differences | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *n* | M | SD | *n* | M | SD | *df* | *t*-Value | *p*-Value | *d*-Value |
| Visual pursuit | | | | | | | | | | |
| Both eyes | 16 | 3.75 | 1.65 | 16 | 4.88 | 1.63 | 30 | −1.940 | 0.061 | **0.68*** |
| Left eye | 16 | 5.38 | 1.02 | 16 | 4.63 | 1.41 | 30 | 1.722 | 0.095 | **0.53*** |
| Right eye | 16 | 4.13 | 1.82 | 16 | 4.00 | 1.86 | 30 | 0.192 | 0.849 | |
| Horizontally | 16 | 4.31 | 1.25 | 16 | 4.31 | 1.62 | 30 | 0.000 | 1.000 | |
| Fixation | | | | | | | | | | |
| Both eyes | 16 | 2.81 | 1.97 | 16 | 2.69 | 1.62 | 30 | 0.195 | 0.846 | |
| Left eye | 16 | 4.44 | 1.21 | 16 | 3.75 | 1.84 | 30 | 1.247 | 0.222 | |
| Right eye | 16 | 2.63 | 1.86 | 16 | 3.50 | 1.03 | 30 | −1.65 | 0.110 | |
| Ocular alignment | | | | | | | | | | |
| Left eye | 16 | 3.63 | 2.39 | 16 | 4.00 | 1.63 | 30 | −0.52 | 0.608 | |
| Right eye | 16 | 2.94 | 1.81 | 16 | 2.94 | 1.57 | 30 | 0.00 | 1.000 | |
| Convergence–divergence | | | | | | | | | | |
| | 16 | 3.06 | 2.54 | 16 | 3.38 | 1.99 | 30 | −0.387 | 0.701 | |

M – means; SD – standard deviation; *df* – degrees of freedom; *n* – number of learners.
* $p$-Value $\leq 0.05$; $d$-value $\geq 0.5$.

**Table 4**
Significance of differences in the different ocular motor control functions between the two groups during post-tests 1 and 2 and the retention test.

| Variables | Group 1 (n = 16) | | Group 2 (n = 16) | | Significance of differences | | | |
|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | *df* | *t*-Value | *p*-Value | *d*-Value |
| Post-test 1 (PoT 1) | | | | | | | | |
| Visual pursuit both eyes | 0.13 | 0.34 | 5.44 | 1.71 | 30 | −12.176 | <0.001* | −3.11** |
| Visual pursuit left eye | 0.13 | 0.50 | 5.13 | 1.41 | 30 | −13.383 | <0.001* | −3.55** |
| Visual pursuit right eye | 0.00 | 0.00 | 4.44 | 1.97 | 30 | −9.032 | <0.001* | 2.25** |
| Visual pursuit horizontal line | 0.00 | 0.00 | 4.81 | 1.60 | 30 | −12.025 | <0.001* | 3.01** |
| Fixation both eyes | 0.00 | 0.00 | 3.25 | 1.69 | 30 | −7.678 | <0.001* | 1.92** |
| Fixation left eye | 0.00 | 0.00 | 3.94 | 1.95 | 30 | −8.084 | <0.001* | 2.02** |
| Fixation right eye | 0.00 | 0.00 | 3.94 | 1.18 | 30 | −13.331 | <0.001* | 3.34** |
| Ocular alignment left eye | 0.00 | 0.00 | 4.25 | 1.65 | 30 | −10.283 | <0.001* | 2.58** |
| Ocular alignment right eye | 0.00 | 0.00 | 3.50 | 1.79 | 30 | −7.826 | <0.001* | 1.96** |
| Convergence–divergence | 0.19 | 0.75 | 4.13 | 2.22 | 30 | −6.729 | <0.001* | −1.77** |
| Post-test 2 (PoT 2) | | | | | | | | |
| Visual pursuit both eyes | 0.13 | 0.50 | 0.19 | 0.54 | 30 | −0.889 | 0.381 | |
| Visual pursuit left eye | 0.06 | 0.25 | 0.06 | 0.25 | 30 | 0.000 | 1.000 | |
| Visual pursuit right eye | 0.00 | 0.00 | 0.06 | 0.25 | 30 | −1.000 | 0.325 | |
| Visual pursuit horizontal line | 0.13 | 0.50 | 0.13 | 0.50 | 30 | 0.000 | 1.000 | |
| Fixation both eyes | 0.00 | 0.00 | 0.19 | 0.54 | 30 | −1.380 | 0.178 | |
| Fixation left eye | 0.00 | 0.00 | 0.13 | 0.34 | 30 | −1.464 | 0.154 | |
| Fixation right eye | 0.00 | 0.00 | 0.06 | 0.25 | 30 | −1.000 | 0.325 | |
| Ocular alignment left eye | 0.00 | 0.00 | 0.13 | 0.50 | 30 | −1.000 | 0.325 | |
| Ocular alignment right eye | 0.00 | 0.00 | 0.06 | 0.25 | 30 | −1.000 | 0.325 | |
| Convergence–divergence | 0.19 | 0.75 | 0.13 | 0.34 | 30 | 0.303 | 0.764 | |
| Retention test (RT) | | | | | | | | |
| Visual pursuit both eyes | 0.06 | 0.25 | 0.19 | 0.40 | 30 | −1.054 | 0.300 | |
| Visual pursuit left eye | 0.06 | 0.25 | 0.06 | 0.25 | 30 | 0.000 | 1.000 | |
| Visual pursuit right eye | 0.00 | 0.00 | 0.06 | 0.25 | 30 | −1.000 | 0.325 | |
| Visual pursuit horizontal line | 0.13 | 0.50 | 0.13 | 0.50 | 30 | 0.303 | 0.764 | |
| Fixation both eyes | 0.00 | 0.00 | 0.19 | 0.54 | 30 | −1.379 | 0.178 | |
| Fixation left eye | 0.00 | 0.00 | 0.13 | 0.34 | 30 | −1.464 | 0.154 | |
| Fixation right eye | 0.00 | 0.00 | 0.06 | 0.25 | 30 | −1.000 | 0.325 | |
| Ocular alignment left eye | 0.00 | 0.00 | 0.13 | 0.50 | 30 | −1.000 | 0.325 | |
| Ocular alignment right eye | 0.06 | 0.00 | 0.06 | 0.25 | 30 | −0.591 | 0.559 | |
| Convergence–divergence | 0.19 | 0.75 | 0.13 | 0.34 | 30 | 0.303 | 0.764 | |

M – means; SD – standard deviation; *df* – degrees of freedom; *n* – number of learners.
* *p*-Value ≤ 0.05.
** *d*-Value ≥ 0.8.

eyes ($d = 0.68$), where Group 2 performed worse than Group 1 (4.88 vs. 3.75), and the left eye ($d = 0.53$), where Group 1 performed worse than Group 2 (5.38 vs. 4.63).

Table 4 indicates that, during PoT 1, statistically ($p < 0.001$) and practically ($d \geq 0.8$) significant differences occurred between the two groups in all the ocular motor control functions that were measured. Group 1 performed better in all the measurements. No statistically significant differences occurred between the two groups during PoT 2 or the RT two years later. When change over time within each group were analysed separately, statistically significant differences are evident in all the ocular motor control functions in Group 1 from the PrT to PoT 1 after vision therapy had been received ($p < 0.001$), between the PrT and PoT 2 ($p < 0.001$), and between the PrT and RT ($p < 0.001$). No statistically significant differences were found from PoT 1 to PoT 2. The same trend was also found in all the ocular motor control functions in Group 2 during PrT and PoT 2 after vision therapy had been received ($p < 0.001$) and PrT and RT ($p < 0.001$).

A repeated-measures-over-time analysis (ANOVA) was performed and confirmed the results in Table 4, with a significant group effect with regard to the interaction of the two groups over time in all the ocular motor control components, which indicates that the two groups reacted differently over time as seen in Figs. 1–4.

From this, it appears that Group 1 reacted significantly differently over time from Group 2 in all four measurements of visual pursuit. The results are graphically presented in Figs. 1–4. The intervention effect is clearly visible in Fig. 1 with regard to differences between the groups in all aspects of visual pursuit during PoT 1 where Group 1 had already undergone visual therapy [PrT–PoT 1 (Fig. 1(a and b))] [visual pursuit with both eyes $F(3, 90) = 64.535$, $p < 0.001$; visual pursuit with left eye $F(3, 90) = 118.77$, $p < 0.001$; visual pursuit with right eye $F(3, 90) = 38.557$, $p < 0.001$; visual pursuit on a horizontal line $F(3, 90) = 71.121$, $p < 0.001$].

Fig. 2(a–c) also shows a significant interaction of the two groups over time in all the aspects of fixation during PoT 1 where only Group 1 had already undergone visual therapy [fixation with both eyes $F(3, 90) = 21.618$, $p < 0.001$; fixation with left eye $F(3, 90) = 38.768$, $p < 0.001$; fixation with right eye $F(3, 90) = 40.976$, $p < 0.001$]. A significant interaction of the two groups over time was also found with regard to ocular alignment with the left and right eye and convergence–divergence and is shown in Figs. 3(a and b) and 4.

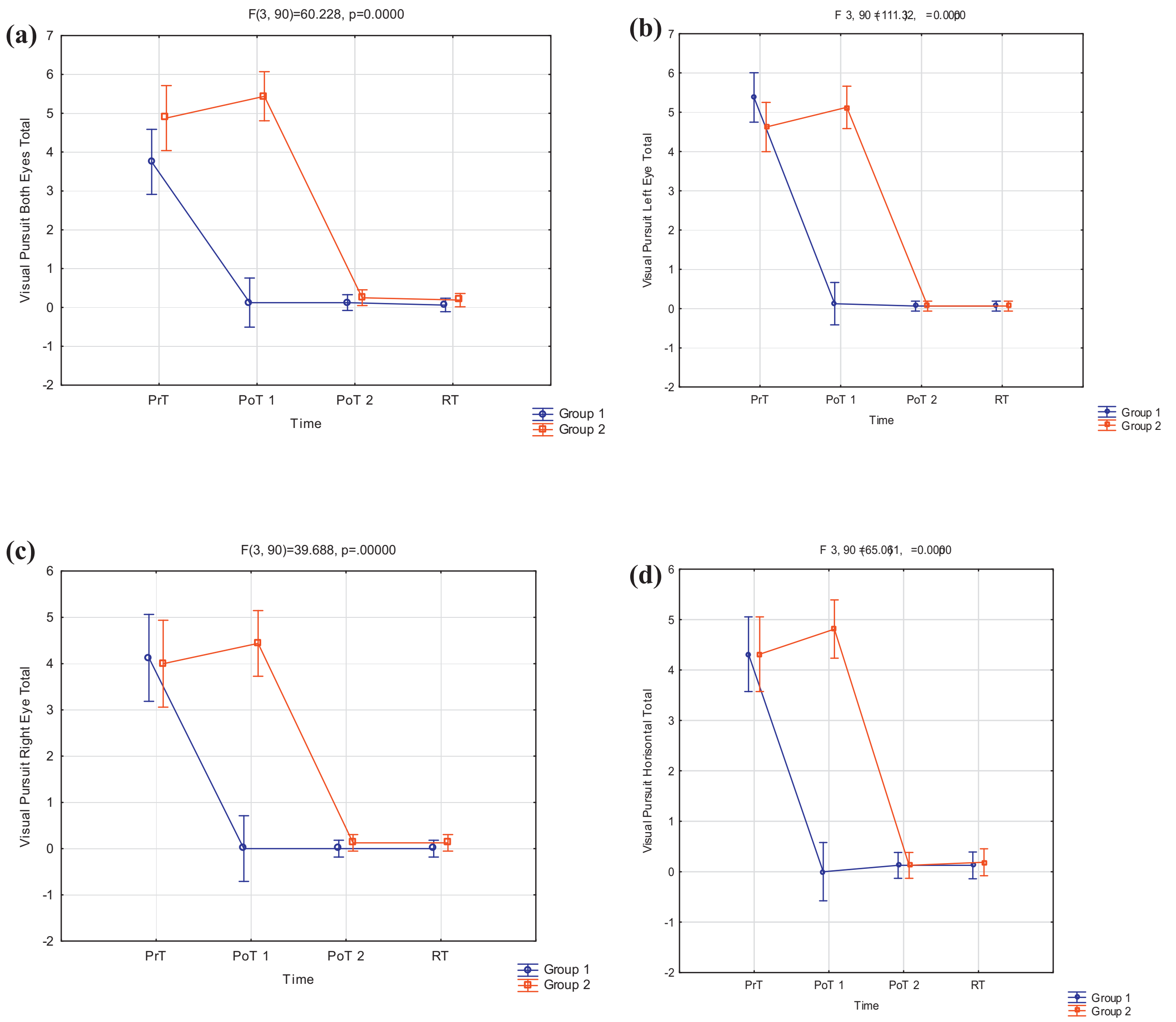


**Fig. 1.** (a–d) The effect of visual therapy on visual pursuit (both eyes, left eye, right eye, and horizontally) of the subjects in the Group 1 and Group 22 (a).

Table 5 indicates the percentage of ocular motor control function deviations (Class 1 – no visual deviations; Class 2 – one to three visual deviations; and Class 3 – more than three visual deviations) during the PrT, PoT 1, PoT 2 and RT in both groups.

From Table 5, it emerges that the highest percentage of learners during the PrT (in both groups) was classified in Class 3 (severe visual deviations) with visual pursuit (both eyes – 62.5% and 87.5%; left eye – 93.8% and 75%; right eye – 81.3%; horizontal line – 68.8% and 81.3%). After both groups had received visual therapy (PoT 1 and PoT 2), no learners displayed deviations any longer, and the highest percentage of learners moved to Class 1 (no visual deviations). Relapse effects did, however, occur in Group 1 during the RT, where one learner relapsed from Class 1 to Class 2 in visual pursuit on a horizontal line, and one learner moved from Class 2 to Class 1 in visual pursuit with both eyes. No relapse effects occurred in Group 2.

Table 5 indicated that a large percentage of learners, in both groups, were in Class 3 during the PrT in fixation with both eyes (43.8% and 18.8%), fixation with the left eye (75% and 56.3%), and fixation with the right eye (31.3% and 50%). After Group 1 had received visual therapy (PoT 1), all the learners moved from Class 2 and Class 3 to Class 1, and this remained unchanged during PoT 2 and the RT. The results of PoT 2 (after Group 2 had also received visual therapy) show that a large percentage of learners (87.5%; $n = 14$) moved from Class 2 and 3 to Class 1, during fixation with both eyes and the left eye, while only 12.5% ($n = 2$) still occurred in Class 2. Fixation with the right eye showed the highest percentage improvement with 93.8% ($n = 15$) that occurred in Class 1. During the RT, no relapse effects occurred.

It further appears from Table 5 that both the groups had a large percentage of learners in Class 3 during ocular alignment with the left-(62.5% and 56.3%) and right eye (50%) during the PrT. After Group 1 had received visual therapy, all the learners moved from Class 2 and Class 3 to Class 1, while only 93.8% of the learners in Group 2 moved from Class 2 and Class 3, after the group had also received visual therapy. Relapse effects were observed in both of the groups during the RT where, during

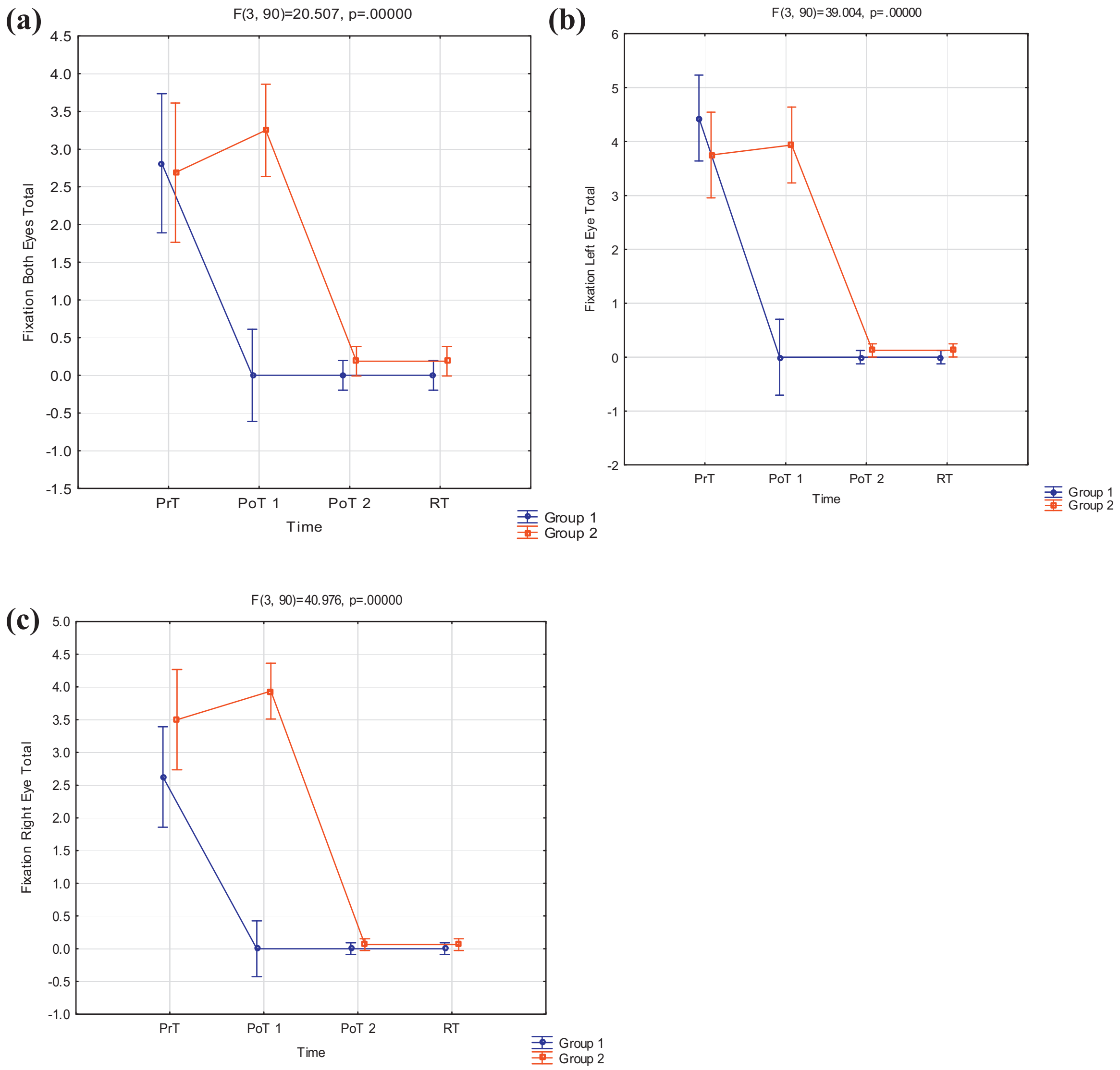


**Fig. 2.** (a–c) The effect of visual therapy on visual fixation of the subjects in Group 1 and Group 2.

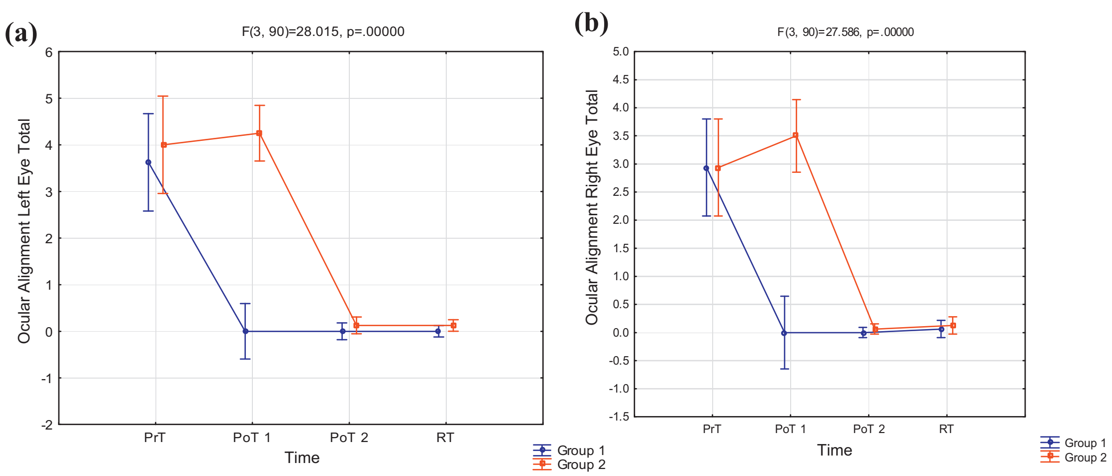


**Fig. 3.** (a and b) The effect of visual therapy on ocular alignment of the subjects in Group 1 and Group 2.

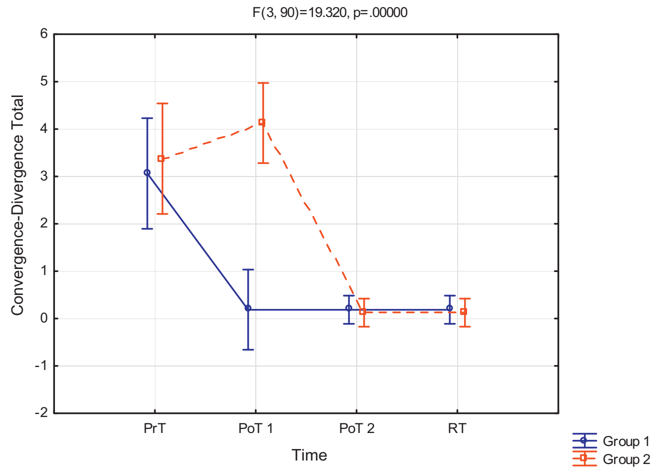


**Fig. 4.** The effect of visual therapy on convergence–divergence of the subjects in Group 1 and Group 2.

**Table 5**
The effect of the intervention as seen in the percentage of ocular motor control deviations in the two groups.

| Variables | Pre-test (PrT) | | | | | | Post-test 1 (PoT 1) | | | | | | Post-test 2 (PoT 2) | | | | | | Retention test (RT) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class 1 | | Class 2 | | Class 3 | | Class 1 | | Class 2 | | Class 3 | | Class 1 | | Class 2 | | Class 3 | | Class 1 | | Class 2 | | Class 3 | |
| | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| Visual pursuit BE | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 1 | 6.3 | 1 | 6.3 | 14 | 87.5 | 1 | 6.3 | 1 | 6.3 | 14 | 87.5 | 13 | 81.3 | 3 | 18.8 | 0 | 0.0 | 13 | 81.3 | 3 | 18.8 | 0 | 0.0 |
| Group 2 | 1 | 6.3 | 5 | 31.3 | 10 | 62.5 | 14 | 87.5 | 2 | 12.5 | 0 | 0.0 | 14 | 87.5 | 2 | 12.5 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 |
| Visual pursuit LE | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 0 | 0.0 | 4 | 25.0 | 12 | 75.0 | 0 | 0.0 | 4 | 25.0 | 12 | 75.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 |
| Group 2 | 0 | 0.0 | 1 | 6.3 | 15 | 93.8 | 15 | 93.8 | 2 | 12.5 | 0 | 0.0 | 15 | 93.8 | 2 | 12.5 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 |
| Visual pursuit RE | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 2 | 12.5 | 1 | 6.3 | 13 | 81.3 | 2 | 12.5 | 1 | 6.3 | 13 | 81.3 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 |
| Group 2 | 1 | 6.3 | 2 | 12.5 | 13 | 81.3 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 |
| Visual pursuit H | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 1 | 6.3 | 2 | 12.5 | 13 | 81.3 | 1 | 6.3 | 2 | 12.5 | 13 | 81.3 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 14 | 87.5 | 2 | 12.5 | 0 | 0.0 |
| Group 2 | 0 | 0.0 | 5 | 31.3 | 11 | 68.8 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 |
| Fixation BE | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 2 | 12.5 | 11 | 68.3 | 3 | 18.8 | 2 | 12.5 | 11 | 68.8 | 3 | 18.8 | 14 | 87.5 | 2 | 12.5 | 0 | 0.0 | 14 | 87.5 | 2 | 12.5 | 0 | 0.0 |
| Group 2 | 4 | 25.0 | 5 | 31.3 | 7 | 43.8 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 |
| Fixation LE | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 2 | 12.5 | 5 | 31.3 | 9 | 56.3 | 2 | 12.5 | 5 | 31.3 | 9 | 56.3 | 14 | 87.5 | 2 | 12.5 | 0 | 0.0 | 14 | 87.5 | 2 | 12.5 | 0 | 0.0 |
| Group 2 | 0 | 0.0 | 4 | 25.0 | 12 | 75.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 |
| Fixation RE | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 0 | 0.0 | 8 | 50.0 | 8 | 50.0 | 0 | 0.0 | 8 | 50.0 | 8 | 50.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 |
| Group 2 | 4 | 25.0 | 7 | 43.8 | 5 | 31.3 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 |
| Ocular alignment LE | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 1 | 6.3 | 6 | 37.5 | 9 | 56.3 | 1 | 6.3 | 6 | 37.5 | 9 | 56.3 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 14 | 87.5 | 2 | 12.5 | 0 | 0.0 |
| Group 2 | 4 | 25.0 | 2 | 12.5 | 10 | 62.5 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 |
| Ocular alignment RE | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 2 | 12.5 | 6 | 37.5 | 8 | 50.0 | 2 | 12.5 | 6 | 37.5 | 8 | 50.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 14 | 87.5 | 2 | 12.5 | 0 | 0.0 |
| Group 2 | 3 | 18.8 | 5 | 31.3 | 8 | 50.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 16 | 100 | 0 | 0.0 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 |
| Convergence–divergence | | | | | | | | | | | | | | | | | | | | | | | | |
| Group 1 | 3 | 18.8 | 2 | 12.5 | 11 | 68.8 | 3 | 18.8 | 2 | 12.5 | 11 | 68.8 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 |
| Group 2 | 6 | 37.5 | 0 | 0.0 | 10 | 62.5 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 | 15 | 93.8 | 1 | 6.3 | 0 | 0.0 |

Class 1 – no visual deviations; Class 2 – one to three visual deviations; Class 3 – more than three visual deviations; BE – both eyes; LE – left eye; RE – right eye; H – horizontally.

ocular alignment with the left eye, one learner in Group 2 relapsed from Class 1 to Class 2, while with ocular alignment with the right eye, one learner in both groups relapsed from Class 1 to Class 2.

During the PrT in convergence–divergence, 62.5% ($n = 10$) of the learners in Group 1 and 68.8% ($n = 11$) of the learners in Group 2 were in Class 3, however, 37.5% of the learners in Group 1 and 18.8% of the learners of Group 2 were in Class 1. After the Group 1 had received visual therapy and were again tested (PoT 1), 93.8% of the learners shifted from Class 2 and 3 to Class 1, and the results remained exactly the same during PoT 2 and the RT. The same trend was also found in Group 2 after they had also received visual therapy, and no relapse effects occurred.

## 4. Discussion

The aims of this study were to determine the extent of ocular motor control problems and the effect of vision therapy on ocular motor control problems identified among seven- to eight-year-old children diagnosed with DCD. The results of this study showed that the mean scores of the both groups' MABC total (22.09–3.78; 20.31–5.09), manual dexterity total (9.53–1.94; 7.66–2.81), ball total (5.25–0.69; 5.72–1.03) and balance skills total (7.28–1.09; 6.94–1.31) were significantly reduced after completion of the vision therapy. The results further indicated ocular motor control deviations that varied from 62.5% to 100% in the groups before the start of the intervention. Problems with visual pursuit in the Group 1 and Group 2 were the highest with 96.9% and 93.8%, respectively, followed by problems with fixation (83.3% and 91.7%) and ocular alignment (78.1% and 90.6%). Although a high percentage of the learners also showed convergence–divergence deviations, such deviations were the lowest with 81.2% (Group 1) and 62.5% (Group 2), respectively. This study's results indicated a slightly higher percentage of ocular motor control deviations than reported in other studies; it still corresponded to the findings of studies performed on children with motor deficiencies, where the ocular motor control deviations varied between 53% and 92% (Dudley & Vasché, 2010; Hurst et al., 2006; Orfield et al., 2001; Pienaar, 1993).

The results, furthermore, showed that the ocular motor control of both the groups improved significantly ($p < 0.001$) after both groups received visual therapy. The biggest shift between the visual classes (from Class 2 and 3 to Class 1) occurred in Group 2, in visual pursuit with the left eye, right eye, and on a horizontal line, fixation with the right eye, ocular alignment, and convergence–divergence (93.8%), with the smallest shift in visual pursuit with both eyes of 75%. In Group 1 the biggest shift occurred from Class 2 and 3 to Class 1 in visual pursuit with the right eye, fixation, and ocular alignment (100%), while the smallest percentage shift occurred in visual pursuit with both eyes (87.5%). These results agree with the findings of other studies, which reported a total improvement of ocular motor control between 53% and 100% after visual therapy was completed (Adler, 2002; Ciuffreda et al., 2008; Ciuffreda, 2002; Dudley & Vasché, 2010; Grisham, 1988; Hurst et al., 2006; Scheiman et al., 2005). None of these studies, however, focused on children diagnosed with DCD.

During the retention test, one learner in Group 1 and Group 2 shifted from Class 2 (moderate visual deviations) to Class 1 (no visual deviations) in their visual pursuit with both eyes. A possible explanation for this improvement could be that visual pursuit is not yet fully developed by the age of seven years and that a systematic improvement is still reported by researchers up to the age of nine years, after which a levelling off occurs between nine and 11 years (Cheatum & Hammond, 2000; Gilligan, Mayberry, Stewart, Kenyon, & Gaebler, 1981; Lane, 2005). Another possible explanation could be an improved functioning of the sensory systems, of which the visual system is one, and that the learners had possibly learnt how to use the visual system more efficiently (Kokot, 2003; Krog & Krüger, 2011). These results also correspond to the findings of Gilligan et al. (1981), which indicated that learning experience played an important role in the development of the ocular motor control functions. Although visual pursuit with both eyes improved, it appeared that, visual pursuit on a horizontal line and ocular alignment (left and right eye), of the same learner in Group 2 shifted back from Class 1 to Class 2. The same trend also occurred in Group 1, where one learner shifted back from Class 1 to Class 2 during ocular alignment with the right eye. Although these relapse effects occurred, and only in two learners, no learner relapsed to Class 3. The two learners who did display relapse effects could perhaps have had more severe underlying neurological problems that could not be addressed by visual therapy in the short term or as a whole. The results, furthermore, showed a sustainable effect, two years after the visual therapy, on the ocular motor control of most of the learners. This retention effect is in accordance with Grisham's (1988) finding, which showed that visual therapy still had a positive effect on the learners two years after the programme was completed.

The study did have some limitations; however, valuable results regarding the use of visual therapy on a group of children with DCD, who also presents ocular motor control problems, were still obtained. It is, consequently, recommended that further similar studies should be conducted to prove the valuable use of visual therapy as an intervention method for children that are diagnosed with DCD who also experience ocular motor control problems.

In summary, no other studies could be found that focussed on the effect of visual therapy on the ocular motor control functions of children with DCD. This study did however found that visual therapy did improve the ocular motor control functions (visual pursuit, fixation, ocular alignment and convergence–divergence) of all the learners who took part in the programme with a good retention effect. Visual therapy can, consequently, be recommended for children with DCD experiencing poor ocular motor control.

## Acknowledgements

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## Appendix A

Apparatus used during the vision therapy.

| Accommodation flippers (±1.00; ±1.50; ±2.00) | Convergence cards (Cats, Humpty-Dumpty) |
|---|---|
| • Bernell-O-Scope | • Aperture ruler |
| • Red–green Tranaglyph Orthoptics Kit | • Life-saver free-space fusion cards |
| • Various Hart Charts (big and small) | • Free-space fusion cards |
| • Brock string | • Diopter glasses (nos. 4 and 8) |
| • A mini-trampoline | • Equilibrium board |
| • Fixation objects (for example, Marsden ball) | • Balls of different sizes |
| • Balancing apparatus | • Vectograms |
| • Flashlights | • Eyepatch |
| • Fine motor games such as, for example, Tangram Duet, StackiQ, Pegboard Combo | |

## Appendix B. Appendix B

Example of two vision therapy lessons (progression).

| Lesson 2: "Near reading" All exercises are first performed with the left eye, then the right eye separately (monocular) | Lesson 12: "Near and far reading" All the exercises are performed with both eyes open (bi-ocular) |
|---|---|
| Visual pursuit: | Accommodation, fixation, convergence–divergence, visual pursuit skills, |
| Marsden ball: | hand–eye coordination, vestibular function, bilateral integration, spatial orientation: |
| | Far reading (3 m): |
| • Horizontally | • ±1.00 accommodation flipper |
| • Vertically | • Heel–toe walk on line, while reading letters and numbers on the Hart Chart |
| • Up and down | • Stand still on balance board, read first colour on nearby Hart Chart, then a number on the Hart Chart further away, while child is wearing griffon mask |
| • Diagonally | • Jump on trampoline (star-soldier and alternating jumps) with the 8-diopter glasses on, while reading different letters on the Hart Chart that is pasted to the wall. A ball is also thrown at the child every now and then, to catch |
| Convergence–divergence: | "Near vision" |
| • Move object closer to, and further from, the eyes | Binocular skills, fixation, and convergence-divergence: |
| Visual pursuit and fixation: | Bernell-O-Scope |
| Pencil push-ups: | Central fusion, depth perception, fixation, convergence-divergence, peripheral vision: |
| • Read near–far | Red-green Tranaglyph Orthoptics Kit |
| • Read left–right | Binocular skills: |
| • Read first the colour, then the shape | Free-space fusion cards: help the child to get a single picture/image |
| Accommodation and visual pursuit: | Depth perception and fine motor activity: |
| Near reading (30 cm): | Play snap with the "red/green" cards |
| • ±2.00 accommodation flipper | |
| • Read Hart Chart with letters and shapes on | |
| Visual perception and fine motor activity: | |
| • Tangram Duet: build the same picture on the card with a certain number of different shapes | |

## References


American Academy of Ophthalmology (AAO). Complementary therapy assessment: vision therapy for learning disabilities. [web] (http://www.aao.org/). Date of access: 10.01.11.

Adler, A. (2002). Efficacy of treatment for convergence insufficiency using vision therapy. *Ophthalmic & Physiological Optics: The Journal of the British College of Ophthalmic Opticians (Optometrists), 22*(6), 565–571.

Alloway, T. P., & Archibald, L. (2008). Working memory and learning in children with developmental coordination disorder and specific language impairment. *Journal of Learning Disabilities, 41*(May/June (3)), 251–262.

American Psychiatric Association (APA). (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., pp. 943–). Washington, DC: Author.

Auxter, D., Pyfer, J., & Huetting, C. (1997). *Principles and methods of adapted physical education and recreation* (8th ed., pp. 605–). Chicago, IL: Brown Y Benchmark.

Bouchard, D., & Tetreault, S. (2000). The motor development of sighted children and children with moderate low vision aged 8–13. *Journal of Visual Impairment & Blindness, 94*(September (9)), 564–573.

Cardoso, A. A., & Magalhães, L. (2009). Bilateral coordination and motor sequencing in Brazilian children: Preliminary construct validity and reliability analysis. *Occupational Therapy International, 16*(2), 107–121.

Cheatum, B. A., & Hammond, A. A. (2000). *Physical activities for improving children's learning and behavior: A guide to sensory motor development*. Champaign, IL: Human Kinetics.

Ciuffreda, K. J. (2002). The scientific basis for and efficacy of optometric vision therapy in nonstrabismic accommodative and vergence disorders. *Optometry, 27*(12), 735–762.

Ciuffreda, K. J., Rutner, D., Kapoor, N., Suchoff, I. B., Craig, S., & Han, M. E. (2008). Vision therapy for oculomtor dysfunctions in acquired brain injury: A retrospective analysis. *Optometry, 79*(1), 18–22.
Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
Dudley, L. M., & Vasché, T. (2010). Vision therapy for a patient with developmental delay. Literature review & case report. *Journal of behavioral optometry, 21*(2), 39–45.
Ernst, J. (2007). *Motor development and growth status of 2–6-year old children infected with human immunodeficiency virus (HIV).* [PhD Thesis] Potchefstroom: North West University.
Gilligan, M. B., Mayberry, W., Stewart, L., Kenyon, P., & Gaebler, C. (1981). Measurement of ocular pursuits in normal children. *The American Journal of Occupational Therapy, 35*(4), 249–255.
Grisham, J. D. (1988). Visual therapy results for convergence insufficiency: A literature review. *American Journal of Optometry and Physiological Optics, 65*, 448–454.
Helveston, E. M. (2005). Visual training: Current status in ophthalmology. *American Journal of Ophthalmology, 140*, 903–910.
Henderson, S. E., & Sugden, D. A. (1992). *Movement assessment battery for children*. London: The Psychological Corporation.
Hoare, D., & Larkin, D. (1991). Coordination problems in children. *National Sports Research Center, 18*, 1–15.
Hurst, C. M. F., van de Weyer, S., & Smith, C. (2006). Improvements in performance following optometric vision therapy in a child with dyspraxia. *Ophthalmic & Physiological Optics, 26*, 199–210.
Kokot, S. J. (2003). A neurodevelopmental approach to learning disabilities. In D. Montomery (Ed.), *Gifted and talented children with special educational needs: Double exceptionality* (pp. 11–24). London: David Fulton.
Krog, S., & Krüger, D. (2011). Movement programmes as a means to learning readiness. *South African Journal for Research in Sport, Physical Education and Recreation, 33*(3), 73–87.
Lane, K. A. (2005). *Developing ocular motor and visual perceptual skills: An activity workbook*. Thorofare, NJ: Slack incorporated.
Leemrijse, C., Meijer, O. G., Vermeer, A., Lambregts, B., & Ader, H. J. (1999). Detecting individual change in children with mild to moderate motor impairment: The standard error of measurement of the Movement ABC. *Clinical Rehabilitation, 13*, 420–429.
Lefebvre, C., & Reid, G. (1998). Prediction in ball catching by children with and without a developmental coordination disorder. *Adapted Physical Activity Quarterly, 15*, 299–315.
Mutti, M. C., Martin, N. A., Sterling, H. M., & Spalding, N. V. (1998). *Quick Neurological Screening Test* (2nd ed., pp. 1–93). Novato, CA: Academic Therapy Publications.
Orfield, A., Basa, F., & Yun, J. (2001). Vision problems of children in poverty in an urban school clinic: their epidemic numbers, impact on learning and approaches to remediation. *Journal of Optometric Vision Development, 32*(3), 114–141.
Peens, A., & Pienaar, A. E. (2007). The effect of gender and ethnic differences on the success of intervention programmes for the motor proficiency and self-concept of 7–9-year old DCD children. *South African Journal for Research in Sport, Physical Education and Recreation, 29*(1), 113–128.
Piek, J. P., & Dyck, M. J. (2004). Sensory-motor deficits in children with developmental coordination disorder, attention deficit hyperactivity disorder and autistic disorder. *Human Movement Science, 23*, 475–488.
Pienaar, A. E. (1993). *Die voorkoms en remediëring van grootmotoriese agterstande by kinders in die junior primêre fase[nl]The incidence and remediation of gross motor deficiencies in children in the junior primary phase.* [Ongepubliseerde PhD Tesis]nl[PhD–Thesis] PU vir CHO[nl]PU for CHE: Potchefstroom[nl]Potchefstroom.
Pienaar, A. E. (2004). Developmental coordination disorder in an ethno-racially diverse African nation: Should norms of the MABC be adjusted? *Journal of Human Movement Studies, 47*, 75–92.
Pienaar, A. E. (2008). *Motoriese ontwikkeling, groei, motoriese agterstande, die assessering en die intervensie daarvan: 'n Handleiding vir nagraadse studente in Kinderkinetika[nl]Motor development, growth, motor deficiencies, the assessment and intervention thereof: Manual for postgraduate students in Kinderkinetics*. Noordwes-Universiteit[nl]North-West University: Potchefstroom[nl]Potchefstroom.
Pyfer, J. T. (1988). *Implications of the neurological system in motor development*. Houston, TX: Texas Woman's University.
Saladin, K. S. (2007). *Anatomy and physiology: The unity of form and function* (4th ed., pp. 1140–). New York, NY: McGraw-Hill.
Scheiman, M., Mitchell, G. L., Cotter, S., Cooper, J., Kulp, M., Rouse, M., et al. (2005). A randomized clinical trail of treatments for convergence insufficiency in children. *Archives of Ophthalmology, 123*, 14–24.
Shainberg, M. J. (2010). Vision therapy and orthoptics. *American Orthoptic Journal, 60*, 28–32.
StatSoft. (2010). *Statistica for windows: General conventions & statistics*. Tilsa, OK: Statsoft.
Steyn, S., Smit, C., Du Toit, J., & Strashorm, C. (1998). *Moderne statistiek in praktyk*. Strasharm.
Wessels, Y. (2007). *Motoriese ontwikkelingstatus, aandagafleibaarheid-hiperaktiwiteitsindroom (ADHD) en leerverwante probleme by 6- en 7-jarige kinders[nl]Motor development, attention deficit hyperactivity disorder (ADHD) and learning related problems in 6- and 7-year old children.* [Verhandeling – MA][nl](M.A. Dissertation) Potchefstroom[nl]Potchefstroom: Noordwes-Universiteit[nl]North-West University.
Willoughby, C., & Polatajko, H. (1995). Motor problems in children with developmental coordination disorder: Review of the literature. *The American Journal of Occupational Therapy, 49*(8), 787–794.
Wilson, P. H. (2005). Practitioner review: Approaches to assessment and treatment of children with DCD: An evaluative review. *Journal of Child Psychology and Psychiatry, 46*(8), 806–823.
Zoia, S., Castiello, U., Blason, L., & Scabar, A. (2005). Reaching in children with and without developmental coordination disorder under normal and perturbed vision. *Developmental Neuropsychology, 27*(2), 257–273.