African Vision and Eye Health
ISSN: (Online) 2410-1516, (Print) 2413-3183

The prevalence of poor ocular motilities in a mainstream school compared to two learning-disabled schools in Johannesburg

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Dates:
Received: 09 Oct. 2015
Accepted: 29 Feb. 2016
Published: 10 June 2016

How to cite this article:
Metsing IT, Ferreira JT. The prevalence of poor ocular motilities in a mainstream school compared to two learning-disabled schools in Johannesburg. Afr Vision Eye Health. 2016;75(1), a328. http://dx.doi.org/10.4102/aveh.v75i1.328

Background: Ocular motilities play a major role when reading for the continuous acquisition and updating of visually presented information. Accurate oculomotor control is required to be able to learn how to read and to efficiently read to learn. This process requires accurate decoding accomplished by precise oculomotor control.

Aim: A comparison of the prevalence of poor ocular motilities between mainstream and learning-disabled schools were explored from three different schools; one mainstream and two disabled schools. One hundred and ninety-two children, age range 8–13 years (mean = 10.30, s.d.: ± 0.999) in grades 3 and 4, with 112 children from the two learning-disabled schools and 80 children from the mainstream school participated in the study.

Method: The standardised direct observation test, using the Northeastern State University College of Optometry scoring criteria, was used to evaluate saccadic and pursuit eye movements. Fixation maintenance was evaluated using the Southern California College of Optometry scoring criteria. The Gulden fixation stick with a 6/24 letter E was used as a fixation target.

Results: The results showed that children from the learning-disabled schools appeared to have a higher incidence of poor saccadic accuracy compared with children from the mainstream school. No significant associations in both the mainstream and the learning-disabled children were found for head movements, pursuits and fixation ability. However, the results suggest a statistically significant association between poor saccadic accuracy and children from the learning-disabled schools.

Conclusion: This study provides further evidence for a link between poor saccadic accuracy and children from the school of the learning disabled.

Introduction

There are two types of eye movements required in the process of reading, namely, pursuits and saccadics. The saccadic eye movements are described as rapid eye movements used when reading, requiring a fixation pause each time an object of interest is focused on the retina. The normal saccadic eye movements during the process of reading consist of the fixational pauses referred to as duration of fixation, the forward saccadic eye movements (left to right) and the larger leftward saccadic movements directed from left to right and vice versa.[1] Accurate eye movements and continuous integration of the information obtained from each fixation by the brain is required for efficient reading.[2] Acquisition of continuous clear vision of moving objects within a stable visual environment is achieved by accurate and normal pursuit eye movements, and these eye movements were found to improve during childhood.[3]

Eye movements of poor readers (or when text is difficult to decipher in normal cases) are characterised by increased fixation duration, increased forward saccade frequency reduced in length and increased regression frequency.[4] Efficient reading is therefore due to a complex interaction of oculomotor function, the accommodation-vergence mechanism and information-processing systems. Collective oculomotor dysfunctions (decreased forward saccades length, increased regressions, increased fixation duration, and lag of accommodation) were reported to be related to poor reading performance.[5] Various studies supported the existence of a cognitive link with oculomotor readiness and reading comprehension.[6,7,8,9] Omission of content words, word order transpositions, letter sequence switches and letter reversals can occur, contributing to the frequent occurrence of regressions of eye movements in order to re-establish lost comprehension.[4] In the literature, it has been repeatedly documented that poor readers have reading eye movements that differ from normal readers.[10,11,12,13]

Note: This article includes research from the author's Master's degree under supervision of Prof. J.T. Ferreira.

Smooth pursuit eye movements mirror attentional ability, and deficits of these eye movements suggest a general ocular motor deficit in the readers. These eye movements are executed voluntarily, requiring a conscious effort.[14] Visual attention and the smooth pursuit eye movements are controlled through the magnocellular pathway and are found to be deficient in the reading disabled.[15] However, reading is a learned skill involving comprehension of text, which is a complex process requiring more than just the understanding of the words in the individual sentences. Successful reading requires meaningful connections to be made between words and sentences. Therefore, to gather meaningful information through reading, eye movements play an important role even though these can be different between individuals.[16]

In response to the assumptions that abnormal eye movements play a major role in reading difficulties, clinical tests to study and assess these eye movements have been designed. Assessment of oculomotor functions involves the evaluation of the stability of fixation, saccadic and pursuit function. There are several tests that can be used to evaluate ocular motilities, for example, the Pierce saccade, developmental eye movement (DEM), and the King-Devick tests using similar principles.[17] A low correlation for the DEM ratio score was found, thus leading to the questioning of its reliability.[18]

There appears to be limited research data on the prevalence of poor ocular motilities in the general population of school children. Most studies have focused on evaluating characteristics of ocular motor disorders on clinical populations (e.g. children with dyslexia or learning problems) and others on comparing clinical characteristics of eye movements in normal populations. Numerous studies have therefore focused on linking eye movement deficiencies with reading.[19,20,21] The dearth of studies investigating the prevalence of poor eye movements is attributed to different methods used to evaluate eye movements, namely, the traditional methods (e.g. direct observation), instruments (e.g. Visagraph) and computer software, and the results of most investigations were found to be unequivocal and at times confusing.[21,22]. Eye-trackers with a high enough spatial and temporal resolution to monitor eye movements during passage reading are reported to be costly, not particularly durable, and rarely portable.[16]

The aim of this study was to investigate the prevalence of poor ocular motilities in children from mainstream and learning-disabled schools using the Northeastern State University College of Optometry (NSUCO) oculomotor test. The NSUCO test consists of a standardised instructional test, description of appropriate targets, instructions on target placement, a standardised scoring system and normative data. The NSUCO oculomotor test is recognised as the first standardised direct observation test to have been developed, and the test was found to be reliable, quick, inexpensive and repeatable.[17,23] Therefore, the NSUCO oculomotor test was considered for this study because of its reliability and repeatability especially with proper adherence to the protocol listed in the test manual. This test was also reported to demonstrate good predictive validity for children's reading skills.[23,24]

Methods

Study sample

The study sample was selected at two different locations: a mainstream school in Johannesburg and two schools specialising in the education of children with learning disabilities in Roodepoort. The mainstream school was selected purposively because of its proximity and due to the fact that it is an 'average' school in Johannesburg. All children in grades 3 and 4 from both schools were selected to participate in this study. According to Scheiman and Rouse,[4] children with learning disabilities are identified when their reading is well below grade level and is generally identified during the third or fourth grade, because this is the stage of learning when children acquire the reading ability and any delays may become identifiable.[4] This contributed to the researcher selecting children from grades 3 and 4 instead of considering the other grades. The children included in the study were therefore from the mainstream school (not identified as having learning problems) and learning-disabled (identified as having learning problems) schools. Written informed consents for children to participate in the study were obtained from all parents of the participants. Therefore, from the learning-disabled and mainstream schools, consent was given for 112 and 80 children with their age ranging between 8 and 13 years (mean = 10.3 years).

No information was obtained regarding specific learning disorders in the target populations especially for the children in the schools of the learning disabled. This information was regarded as confidential and therefore inaccessible to the researcher as well as the academic performance of the mainstream school learners included in the study. The two populations were diverse, with children from the mainstream schools coming from a different socio-economic background where they were all black (approximately 100%), from poor family backgrounds (orphans, parents domestic workers or unemployed) and those from the schools of the learning disabled were mainly white people (about 80% were white people and about 20% were Africans) coming from middle-class backgrounds. One hundred and nine respondents were boys and 82 were girls, with the gender information of one respondent missing due to incomplete information taken when filling in the demographic data on the record card.

Data collection

The research record card designed by the principal investigator for the recording of the functional visual skills evaluated was used to collect data (see Appendix 1). The class lists were furnished to the researcher with the names, age and gender of the respondents, and this information was filled in the record card by the researcher herself before the visual evaluations. The visual evaluations were done under the supervision of the principal investigator together with 18 fourth-year optometry students from the University of

Johannesburg. The field workers were orientated beforehand through a workshop conducted by the researcher on the techniques to evaluate the visual skills (emphasis was on the targets used, methods, time factor, postures and illumination).

The visual evaluations were done in the morning from 9:00 until 11:30, with each child evaluated for approximately 25 min. The respondents were evaluated in pairs with five different stations set up for measuring visual acuities, retinoscopy (static and dynamic), ocular motilities, accommodation (facility and amplitude), cover test with near point of convergence, smooth vergences, vergence facility and ocular health. Children who were evaluated were kept in a separate room that was made available by the targeted schools. For the purpose of this publication, the author will only discuss the findings of the ocular motility tests.

Procedures

Fixation maintenance ability, pursuits and saccadic eye movements were the three motility skills evaluated. The standardised direct observation test, using the NSUCO, was used to evaluate saccadic and pursuit eye movements, as it is regarded as reliable and repeatable.[17,24] For the scoring criteria for fixation maintenance the Southern California College of Optometry (SCCO) scoring criteria were used; the NSUCO is a quick and easy test for position maintenance.[25] The targets used for testing ocular motilities were approximately the size of a 6/24 letter E on the Gulden fixation stick.[17,23,24] The ocular motilities were performed with the respondent standing directly in front of the examiner, as posture is important in the execution of proper ocular motilities.[2]

Fixation maintenance

The ability of the respondent to maintain steady fixation on a fixated object was evaluated, as this is important in the process of reading. Position maintenance was assessed by asking the respondent to fixate monocularly on a target at a distance of 40 cm. The respondents were expected to maintain a steady fixation with no noticeable drifting of the eyes from the fixated target. Children experiencing problems with maintaining steady fixation were instructed to hold their thumbs at 40 cm to determine if the proprioceptive input from the hand support was of help in maintaining steady eye position.[17] The five-point scale of SCCO system criteria helped in evaluating the fixating ability performance (Table 1).[24]

Pursuit eye movements

The pursuit eye movements were tested monocularly and binocularly at a distance of 40 cm with the respondent maintaining a well-balanced posture while standing. Respondents were instructed to follow a target that was moved through the horizontal, vertical, and diagonal meridians, as well as through a circle. The target was held by the examiner at the midline of the respondent's body and moved in a circle of no more than approximately 20 cm in diameter. Two rotations were made clockwise and two counterclockwise. A sweep horizontally through the midline of the body was made when switching from clockwise to counterclockwise rotation.[17] The examiner observed the pursuit eye movements and rated the performance in four categories including head movement, body movement, ability and accuracy using the five-point scale (Appendix 1) for the scoring criteria.[17,23]

TABLE 1: System for ranking position maintenance.

Ranking	Position
1. Very weak	Unsteady fixation almost continuously
2. Weak	Steady fixation for less than 5 s or hand support
3. Adequate	Steady fixation for at 5 s
4. Strong	Steady fixation for at least 10 s
5. Very strong	Steady fixation for more than 10 s

Source: Adapted from Griffin JR and Grisham JD. Binocular anomalies. Diagnosis and vision therapy. 4th ed. 2002, pp. 45–46

The oculomotor skills were then ranked from 5 (best) to 1 (worst). Completion of two rotations in each direction (clockwise and counter clockwise) with no refixations and no head or body movements was rated as normal, and abnormal if the respondent could not complete ½ a rotation in either clockwise or counterclockwise direction, if they show refixations 5–10 times or more, or show large movements of the head or body at any time.[17,23]

Saccadic eye movements

The evaluation of saccadic eye movements involved the examiner holding two different targets. Using the Gulden fixation stick, green and red stickers were placed on each stick. The test was performed at approximately 40 cm from the respondent, and on verbal command the child was instructed to move the eyes to the appropriate target. This was repeated until the respondent made five round trips or ten fixation movements from one target to another. The saccadic eye movements were tested in the horizontal, vertical and diagonal meridians, as well as monocularly and binocularly.[17,23] Using the NSUCO, four categories of performance were rated, including head movement, body movement, ability and accuracy. The scoring criteria were based on the five-point scale of NSUCO with 5 (best) to 1 (worst), see Table 4. The children were regarded as normal if they completed five round trips, meaning that no overshooting was noted, and no head movements were observed, but abnormal if they completed less than two round trips, with large over- or undershooting noted one or more times, and with large movements of the head or body.

Results

Fixation ability

Of the 192 respondents included in the study, only one subject was not evaluated, and from the two groups 8.9% had poor fixation ability. Of those with poor fixation ability, 12.5% were from the mainstream group compared to 6.3% from the learning-disabled group. The relationship between poor fixation ability and the mainstream group calculated using Cramer's V measure was found to be 0.275, indicating a weak relationship between the two variables. There was therefore no significant relationship between poor fixation ability and children from the two schools of the learning disabled.

Pursuit eye movements

Head movements

In the mainstream school, 17.5% respondents had moderate-to-large head movements when pursuit eye movements were evaluated, with 8.1% respondents in the two schools of the learning disabled. There was no significant relationship between children in the mainstream school and moderate-to-large head movements when pursuit eye movements were evaluated since $p = 0.127$.

Pursuit accuracy

The prevalence of poor saccadic accuracy in the learning-disabled group was 21.6% with 8.8% reported in the mainstream group. A relationship between poor saccadic accuracy and children from the learning-disabled schools ($p = 0.00$) was found to exist. However, this relationship was found to be weak (Cramer's V measure of association = 0.279).

Pursuit ability

Poor ability of the pursuit eye movements was found to be 12.5% in the mainstream compared to 9.9% in the learning-disabled group. There was no significant relationship between children in the mainstream school and poor ability of pursuit eye movements since $p = 0.789$.

Saccadic eye movements

In evaluating the saccadic eye movements, of the 192 respondents involved in the study only one child was not evaluated due to the child not being cooperative. Moderate-to-large head movements were found in 13.6%, poor accuracy in 11% and poor ability in 12% of the two groups combined. A prevalence of 16.3% of moderate-to-large head movements was reported in the mainstream compared to 11.7% in the learning-disabled group.

The percentage of respondents with poor saccadic accuracy was found to be high in the learning-disabled group (15.3%) and 5% in the mainstream group (refer to Table 2). The prevalence of respondents with poor ability to perform saccadic eye movements was found to be 13.5% in the learning-disabled group compared to 10% in the mainstream group.

A high percentage of moderate-to-large head movement was observed in the mainstream group, but no relationship was found to exist between the two variables ($p = 0.549$). The same applies to saccadic ability, although a high percentage of poor saccadic ability was observed in the learning-disabled group, the relationship between the variables was found not to exist ($p = 0.742$). However, a statistically significant association was found to exist between poor saccadic accuracy and the learning-disabled group ($p = 0.000$) (refer to Table 3). Cramer's V measure of association was found to be medium (0.343) indicating a medium relationship between the nominal variables (refer to Table 4).

TABLE 2: The prevalence of saccadic (accuracy) in the mainstream and the learning-disabled groups.

Crosstab	Prevalence	(R) Saccadic: Accuracy			Total
		1–3	4	5	
Learning disabled	Count	17	49	45	111
	% Within group	15.30	44.10	40.50	100.00
Mainstream	Count	4	16	60	80
	% Within group	5.00	20.00	75.00	100.00
Total	Count	21	65	105	191
	% Within group	11.00	34.00	55.00	100.00

Discussion

In the mainstream school, a high prevalence of poor fixation ability, poor pursuit ability and moderate-to-large head movements were reported when pursuit and saccadic eye movements were evaluated, but no significant associations were determined between the nominal variables. In the learning-disabled group, no association was determined between poor pursuit accuracy and poor saccadic ability. However, a significant relationship was found to exist between poor saccadic accuracy and the learning-disabled children. This relationship between the two nominal variables was found to be medium. The current study supports previous research reports demonstrating that children with learning problems seem to exhibit erratic eye movements. The other studies further emphasised that the eye movements of poor readers (or when text is difficult to decipher in normal cases) are characterised by increased fixation duration, increased forward saccade frequency reduced in length and increased regression frequency.[5,8,9,12] One of the limitations of this study was that no collective eye movements were evaluated, and this contributed to only marginal significant relations revealed.[5] The same method (direct observation) as that of this study was used by Hoffman[9] to investigate oculomotor efficiency in children with learning disabilities ($n = 107$) and no learning disabilities ($n = 25$). The findings of this study supported Hoffman's[9] findings in which 94% and 24% of children with and without learning disabilities were found to have poor ocular motilities, respectively. This study therefore provided more evidence that the prevalence of poor ocular motilities especially poor saccadic accuracy appears to be higher in children with learning disabilities than in children without learning disabilities.

TABLE 3: The relationship between poor saccadic (accuracy) eye movements and the learning disabled.

Chi-square tests	Value	*df*	Asymptotic significance (two-sided)
Pearson chi-square	22.506†	2	0
Likelihood ratio	23.318	2	0
Linear-by-linear association	19.885	1	0
Number of valid cases	191	-	-

†, 0 cells (0%) have expected count less than 5. The minimum expected count is 8.80.

TABLE 4: Cramer's V test: The relationship between saccadic accuracy and the learning disabled.

Symmetric measures	Test	Value	Approximate significance
Nominal by nominal	Phi	0.343	0
	Cramer's V	0.343	0
Number of valid cases	-	191	-

†, not assuming the null hypothesis; ‡, using the asymptotic standard error assuming the null hypothesis.

Poor pursuit accuracy in the learning-disabled group was found to be high compared to the mainstream group. But the association between the two nominal variables was found to be weak. The findings of this study are therefore in agreement with Judge *et al.*[20] who investigated the concurrent smooth pursuit eye movements and phonological difficulties on performance and literacy skills among dyslexic adults.[20] In this study, although 37% had poor pursuit eye movements, the incidence of phonological difficulties were found to be severe, affecting 89%. However, this study had limitations regarding the categorisation of learning-disabled children and those from the mainstream schools, with phonological difficulties not investigated in either group; therefore, that could influence the outcome of this study.

Interestingly, the mainstream group was found to present with high rates (17.5% and 16.3%) of head movements when both the pursuits and saccadic eye movements were evaluated compared with the learning-disabled group with 6.3% and 11.7%, respectively. The prevalence of poor pursuit ability and fixation ability was also found to be higher (12.5% for both) in the mainstream compared to the learning-disabled group (9.9% and 6.3%, respectively). However, the high prevalence of this poor performance in the mainstream group when these ocular movements were evaluated was attributed to chance because no significant relationship was found to exist between the variables.

Conclusion

In conclusion, the results of this study showed that poor ocular motilities (saccades, pursuit and fixation ability), which can impact negatively on the learning proficiency of children, do exist in both the mainstream and learning-disabled schools. Findings from this study suggests that vision screening including ocular motilities tests can help identify school children with poor ocular motilities, as screening results relying only of visual acuity assessments were reported not to necessarily indicate the normal eye status. Therefore, inclusion of evaluation of ocular motilities among children of school-going age will be beneficial in the identification of barriers to reading performance, as they affect visual attention span abilities in the early extraction of orthographic information for both the reading and copying tasks.[14]

Acknowledgements

The authors thank Mr Anthony Carlson for his support and technical advice.

Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

Authors' contributions

I.T.M. was the principal researcher of this article with J.T.F. acting as supervisor.

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Appendix 1

BOX 1-A1: Northeastern State University College of Optometry scoring criteria: Direct observation of pursuits.

Ability:	
Points	**Observation**
1	Cannot complete ½ rotation in either clockwise or counter clockwise direction
2	Completes ½ rotation in either direction
3	Completes one rotation in either direction but not 2 rotations
4	Completes 2 rotations in one direction but less than 2 rotations in the other direction
5	Completes 2 rotations in each direction
Accuracy:	
Points	**Observation**
1	No attempt to follow the target or requires greater than 10 fixations
2	Refixations 5 to 10 times
3	Refixations 3 to 4 times
4	Refixations 2 times or less
5	No refixations
Head and body Movements:	
Points	**Observation**
1	Large movement of the head or body at any time
2	Moderate movement of the head or body at any time
3	Slight movement of the head or body (> 50% of time)
4	Slight movement of the head or body (< 50% of time)
5	No movement of head or body

BOX 2-A1: Northeastern State University College of Optometry scoring criteria: Direct observation of saccades:

Ability:	
Points	**Observation**
1	Completes < 2 roundtrips
2	Completes 2 roundtrips
3	Completes 3 roundtrips
4	Completes 4 roundtrips
5	Completes 5 roundtrips
Accuracy: (Can the patient accurately and consistently fixate so that no noticeable correction is needed?)	
Points	**Observation**
1	Large over- or undershooting noted 1 or more times
2	Moderate over- or undershooting noted 1 or more times
3	Constant slight over- or undershooting noted (> 50% of time)
4	Intermittent slight over- or undershooting noted (< 50% of time)
5	No over or undershooting noted
Head and body movements: (Can the patient accomplish the saccade without moving his/her head?)	
Points	**Observation**
1	Large movement of the head or body at any time
2	Moderate movement of the head or body at any time
3	Slight movement of the head or body (> 50% of time)
4	Slight movement of the head or body (< 50% of time)
5	No movement of head or body

Source: Adapted from Scheiman MM, Wick B. Diagnostic testing: Clinical management of binocular vision. 4th ed. New York: Lippincott Williams & Wilkins, 2014; p. 25–31