University of South-Eastern Norway
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Paper Based DEM vs Computerized DEM test

Printed and computerized DEM test in Nepali adults in varying directions of reading.

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This thesis is worth 30 study points

Summary

<u>Background:</u> Measurement of an eye movements during reading provides an optometrist with a piece of valuable information about visual information processing. Developmental eye movement test (DEM) is a number naming paper-based saccadic eye movements test that has been developed for children between 6-14 years old. The goal of our study was first to compared paper-based and computer-based DEM test in young adults' population. Secondly, to establish a relationship between the DEM test result and eye movements parameter that was measured using an eye tracker. Finally, to addresses the impact of reading direction on DEM performance.

<u>Methods:</u> It is a cross-sectional study comprising 23 young Nepali adults studying in Norway. The participant's age was between 25-32 with a mean age 27.56±1.92. Participants who meet our study criteria were enrolled for the study. All participants completed both paper and computer DEM tests. Eye movements measurement were recorded with SMI Remote Eye-tracking Device (RED) at a sampling rate of 250 Hz.

<u>Result:</u> No highly significant correlation was found between paper and computer DEM except for DEM subtest C. Highly significant correlation (r=0.83) was found between Test C, tested on the right to left reading direction. A moderate correlation was found between the DEM test result and eye movement parameter (i.e total number of fixation and total fixation duration). There was statistically significant difference in DEM result (i.e. Test C time and ratio score) between left to right (L-R) and right to left (R-L) reading direction.

<u>Conclusion:</u> This study suggests that the paper and computer DEM test is not appropriate to use interchangeably. Secondly, the study establishes that the DEM test performance is fast in habitual reading direction. The fixational (i.e. number and duration) and saccadic (i.e. number and duration) eye movements parameters are higher in unhabitual reading direction. Finally, this study shows that using eye-tracker DEM test could be a useful tool for investigating the fixational eye movement parameter (total number of fixation and total fixation duration). Further research with a large sample size is necessary to establish this relationship.

Keywords: DEM test, Reading direction, eye tracker, fixational eye movements, saccadic eye movements

Contents

Foreword

This thesis has been an essential part of my master's study. It is that platform that compiles all your two years of academic understanding. It was not a simple task to run along a zig-zag path followed by huge challenges and problems during this project. I guess this outstanding value of thesis in students' career is mainly because of complexities and challenges while pursuing it.

I could not have completed this thesis on my own. I have got many bits of help from others during all the phases. I would like to thank, Trine Langaas, my supervisor for helping and inspiring me in every possible way. She is the one to come up with this beautiful idea. Similarly, I would like to show my gratitude to all the people who have participated in my study. I appreciate their time and energy for this thesis. Finally, I would like to thank my family and friend for their love and support.

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List of tables

List of figures

List of abbreviations

DEM: Developmental Eye Movement Test

RAN: Rapid Automaticity Naming

RED: Remote Eye-tracking Device

SMI: SensoMotoric Instruments

L-R: Left to right reading direction

R-L: Right to left reading direction

LogMAR: Logarithm of the Minimum Angle of Resolution

1 Introduction

Eye movements are an important part of a visual system. The coordination of the oculomotor system helps us to move eyes in different direction, making it possible to fixate on a different object. One of the crucial functions of eye movements are to direct the object of interest into the fovea, the highest visual acuity centre in the retina. Eye movements have an association with many activities that are a part of natural human behaviour (Poletti, Listorti, & Rucci, 2013). Two major independent and interactive system of oculomotor are versional and vergence system (Ciuffreda & Barry, 1995). The versional system is responsible for eye movements in same direction whereas vergence system moves eyes in opposite direction. Both of the system interaction can shift eyes horizontally, vertically and cyclorotary in all direction of gaze and distance (Ciuffreda & Barry, 1995). These two systems along with their sub systems are described in table below (Ciuffreda & Barry, 1995).

Table 1. Versional Eye Movement

Subsystem	Stimuli	Function
Fixational	Stationary target	Stabilize target onto fovea
Saccadic	Step of target displacement	Acquiring an eccentric target onto fovea.
Pursuit	Target velocity	Matching eye velocity with target velocity and to stabilize retinal image.
Optokinetic	Target or field velocity	Maintaining stable image during sustained head movement.
Vestibular	Head acceleration	Maintaining stable image with the target on the fovea during transient head movement.

Table 2. Vergence Eye Movement

Subsystem	Stimulus
Disparity/ Fusional	Target disparity
Accommodative	Target Blur
Proximal	Apparent nearness or perceived distance of target.
Tonic	Baseline neural innervation

The examination of the eyes and vision involves the assessment of the stability of fixation, saccadic function, and pursuit function. Testing can be done using the following tests: direct observation of eye movements, visual-verbal format test, and objective eye movements recording using electrooculographic devices (Scheiman & Wick, 2015).

Some modern objective eye movements recording techniques are electrooculography, limbal tracking, video oculography, and magnetic search coil system(Bedell & Stevenson, 2013). Visual-verbal formats test like Pierce Saccade, King-Devick, and Developmental Eye Movement Test (DEM) tests are easily administered, inexpensive, and provides the quantitative evaluation of eye movements in the reading environment (Scheiman & Wick, 2015). However, Pierce Saccade, and King-Devick, fail to differentiate between saccadic problems and difficulty in naming numbers by children (Scheiman & Wick, 2015). DEM test is a test of choice because it addresses both saccadic and number naming skills. (Garzia, Richman, Nicholson, & Gaines, 1990; Richman, 1987).

1.1 Developmental Eye Movement Test

Good reading skill is essential to acquire knowledge. Reading is a task that comprises a huge complexity, including both physiological and psychological processes (Richman, 1987). Eye movements that are responsible for reading process are fixations, saccades and regressions (Ciuffreda & Barry, 1995). Fixations are the measure of total number of stop that eyes make while reading. In each fixation, perception and meaning of word occurs. Saccades are the rapid eye movements that occurs between fixation points. Return-sweep saccades are large right-to-left saccades that are oblique in nature and directs eye from end of one line to the beginning of the next line. Regressions are backward movement that occurs while reading (Beelders & Stott, 2018; Ciuffreda & Barry, 1995). Measuring eye movements during reading and no- reading can provide an optometrist with essential information on visual information processing on that particular state (Richman, 1987). Rapid Automaticity Naming skill measures the ability of a subject to name optotypes quickly and correctly (Richman, 1987; Tassinari & DeLand, 2005). The DEM test measures the Rapid Automaticity Naming skill (RAN) deficit and an Oculomotor dysfunction (Tassinari & DeLand, 2005). It was first introduced in 1987 by Jack E. Richman and Ralph P. Garzia (Garzia et al., 1990; Richman, 1987). The DEM test has the subtests arranged in a vertical and horizontal array. During vertical subtest testing, the requirement of a saccadic eye movements is minimum. Therefore, this subtest is highly dominated by the RAN ability of a subject. A slow reader with poor RAN skill will have a slower reading speed on both vertical and horizontal subtests but will have a normal Horizontal/ Vertical ratio (Garzia et al., 1990; Richman, 1987). During horizontal subtest testing, saccadic eye movements requirement is high. So, horizontal subtest evaluates the oculomotor function of a subject. A subject with a poor saccadic function will have longer reading time and a lower horizontal/ vertical ratio (Garzia et al., 1990; Richman, 1987). DEM test is also used for evaluating visual information processing while reading, therefore, it is widely used for evaluating children with a reading problems (Xie et al., 2016). The DEM test has 3 Subtests. Firstly, a pretest which consists a single row of 10 numbers. This test is done at the beginning and is used for explaining the test to the patient. It is also helpful in confirming that the patient can recognize and read the numbers. Secondly, a vertical test comprised of subtest A and B. Each subtest A and B have two columns, consisting of 20 numbers in each column. These subtests provide the vertical time that is the time recorded to read all the 80 numbers. Lastly, a horizontal test comprised of 80 number arranged in 16 rows with 5 numbers in each row. Five random gaps separate these five numbers in each row (Ayton, A. L. Abel, R. T. Fricke, & A. N. McBrien, 2009; Baptista, De Sousa, De Morais Guerra Casal, Marques, & Da Silva, 2011; Garzia et al., 1990; Powell, 2006; Richman, 1987). Mainly four errors can occur during testing (i.e. substitution (s), omission (o), addition (a), and transposition (t). Test C time is defined as the total time recorded to complete test C. The omission and addition error can alter the Test C time. The Vertical time is calculated by adding the time to complete Test A and B. Error are not so frequent during a vertical test, so the error adjustment is not necessary. The formula for calculating adjusted horizontal time is mentioned below.

Adjusted Horizontal time: Test C timeX $[80/(80 - o - a)]$

Adjusted horizontal time and vertical time ratio is also known as DEM ratio. Adding all the errors gives the total error count for the test. (Ayton et al., 2009; Baptista et al., 2011; Garzia et al., 1990; Powell, 2006; Richman, 1987).

The DEM ratio score are used to classify the four clinical behaviors (Garzia et al., 1990; Richman, 1987)

Table 3: DEM test behavior types

Behaviour Type	Details of DEM test behaviour	Condition
Type 1	Normal performance on horizontal time, vertical time and ratio	Normal
Type 2	Normal vertical test, abnormally increased horizontal time and high ratio	Oculomotor Dysfunction
Type 3	Increased both horizontal and Vertical test time, normal ratio	Automaticity problem
Type 4	Increased both horizontal and Vertical test time, high ratio	Oculomotor dysfunction And automaticity problem

The Developmental Eye Movement Test was developed for children under 14 years of age (Powel, Brik, Cummings, & Ciol, 2005; Powell, 2006; Richman, 1987). Sampedro et al. on 2003 developed an adult version of this test. The design of the test was almost identical to the DEM test. It also consists of the same three subtests (i.e. Test A, B and C). However, in A-DEM double-digit number was used instead of a single-digit number. The testing distance for A-DEM was 33 cm, which is similar to the established DEM test (Sampedro, Richman, & Pardo, 2003).
DEM test was introduced with a standardized norm for English speaking children between the age of 6-13 years (Garzia et al., 1990). It has been used on children up to 14 years of age (Powel et al., 2005; Powell, 2006). By the age of 13, the horizontal score and vertical score on DEM test approach almost identical. So, after the age of 13, DEM ratio becomes 1 (Garzia et al., 1990). Adults horizontal/vertical ratio score on the DEM test is close to 1 (Powell, 2006). Several other studies have used the DEM test on adults for accessing saccadic function (Grisham, Powers, & Riles, 2007). Some other studies have used the DEM test for examining saccadic function in adults especially, after brain injury (Gallaway, Scheiman, & Mitchell, 2017; Kapoor & Ciuffreda, 2018). Adult version of DEM test is only validated for Spanish speakers (Sampedro et al., 2003). In a study by Sampedro et al. they found an average increase of 29.29% in vertical time for the older adult group (age 39-68 years). Similarly, horizontal times were higher for subjects older than 43 years. The A-DEM ratio was within normal limit, and the horizontal and vertical scores have a high correlation of 0,98. They concluded that saccadic error is not responsible for high horizontal time; rather, impaired language processing automaticity due to aging might be the major reason behind reduced horizontal and vertical A-DEM scores (Sampedro et al., 2003). Visual-verbal processing speed, lexical access, and other mental processes might degrade in the process of ageing. (Gorman & Fisher, 1998; Rastatter

& McGuire, 1990; Salthouse, 2000). The result obtained from Sampedro et al. were not compared to the objective measurement of the oculomotor system such as an eye tracker. Furthermore, the authors recommended to determining validity and reliability of the test (Sampedro et al., 2003).
Reliability of DEM test studied during its development shows that the intra-subject test-retest reliability for vertical time (r= 0,89), horizontal time (r=0,86), ratio (r= 0,57) and errors (r=0,07) (Garzia et al., 1990; Richman, 1987). These findings indicate a good reliability for vertical and horizontal time, medium for ratio, and low for errors. Similarly, the study performed by Rouse and colleague on a group of 30 third grade children showed fair to good repeatability for the vertical and adjusted horizontal time while the ratio score was poor (Rouse, Nestor, Parot, & Deland, 2004).
Another study done on more than 180 subjects, tested in two sessions, for each session evaluated three times also showed the fair to good correlation between session for both vertical and horizontal score, whereas poor correlation coefficient for ratio and error (Orlansky et al., 2011).
The study performed by Tassinari and colleague for investigating DEM test reliability and relationship between DEM results and symptom associated with oculomotor disorder on two groups of children (i.e. vision therapy group and school children) found that DEM test shows good intra-subject test-retest reliability for all subtest when used in vision therapy office setting. This study also shows that DEM performance is related with the oculomotor disorder symptoms (Tassinari & DeLand, 2005). A recent study conducted on 115 children from second to fifth grade found high reliability for vertical (r=0,93) and adjusted horizontal time(r=0,90), medium to high for ratio(0,66) and medium for errors (0,69) (Facchin & Maffioletti, 2018).
The authors of the DEM test have provided four validity parameters in the DEM manual: raw scores and chronological age, internal consistency, relationship to the achievement test, and result of learning disabled children (Richman, 1987). A study done on the validity of the DEM test on the Italian population, found the suitability of all four types of validity approaches presented in the DEM manual. Additionally, this study has concluded that the DEM test provides valid ocular movement assessment and helps to differentiate ocular movements deficits and rapid naming number deficits (Facchin, Maffioletti, & Carnevali, 2011). The other way of accessing the validity of the DEM test could be to compare objective eye movement parameters while the subject performs the test.
A comparative study on 158 children (Age: 8-11 years) between DEM test and objective eye movement recording obtained using 100 HZ limbal tracking system fails to show any correlation between DEM results and eye movements parameters (i.e. latency, gain asymptotic peak velocity and numbers of corrective saccades) (Ayton et al., 2009). In the same study, a significant correlation was seen among DEM result, (i.e. horizontal score) and reading performance, and with visual processing speed.

Similarly, the inter saccadic interval (ISI) was significantly correlated in the RAN task presented on computerized DEM (Ayton et al., 2009).In this study they have used both paper and computer based DEM test. However, they did not compare the printed and computerized DEM results.

1.2 Saccades

Saccades are a rapid conjugate eye movements that plays an vital role in positioning a target of interest into a fovea for high definition vision (Wong, 2008). They are the fastest type of eye movements (about 500 degrees per second), and it is initiated very rapidly (less than 100 milliseconds) (Termsarasab, Thammongkolchai, Rucker, & Frucht, 2015). Although saccades speed is involuntary, it depends on the size of the movement. Larger saccades have a higher peak velocity (Wong, 2008). The number of saccades that a person makes is estimated to be more than 100,000 a day (Wong, 2008). Mainly, saccades are either normometric or dysmetric. A normometric saccades have single, accurate movements comprising appropriate gain and dynamics, whereas dysmetric saccades might be either single step or multiple step movements (Ciuffreda & Barry, 1995). Dysmetric saccades can be either too large (hypermetric) or too small (hypometric) concerning target position (Ciuffreda & Barry, 1995).

The saccades are initiated after a pulse is generated due to the increased firing of excitatory burst neurons in the brain stem that results from increased phasic activity in agonist extraocular muscle (Van Gisbergen, Robinson, & Gielen, 1981).
Reading task comprised a saccade of different amplitudes and directions that are initiated and followed by fixation of variable duration (Vinuela-Navarro, Erichsen, Williams, & Woodhouse, 2017). Generally, saccade length is measured in terms of character space and it is usually 7-9 characters on average for the English language (Beelders & Stott, 2018). Saccadic eye movements are usually initiated in forward direction, but occasionally, it can be backward (regression) for refixation (Vinuela-Navarro et al., 2017). Good readers have a better ability to use regression so that they can reposition their eyes to acquire more understanding and clarity. In contrast, poor readers struggle to use regressions more effectively and make continuous regressions while reading (Beelders & Stott, 2018). While reading , children make shorter saccades and more fixations that are longer in duration (Parker, Slattery, & Kirkby, 2019). Many studies support the notion-that

saccadic dysfunction is one of the crucial factors associated with the reading disorder (Okumura, Wakamiya, Suzuki, & Tamai, 2006; Powers, Grisham, & Riles, 2008). Developmental eye movement test was regarded as an indicator of a horizontal saccades (Tassinari & DeLand, 2005) but in a study conducted to investigate DEM results and objective eye movements result measured with an eye tracker, and it was found that DEM test results do not predict any saccadic function (Ayton et al., 2009). In a study to investigate objective eye movements using eye tracker while performing the DEM test in Dyslexic and non-dyslexic children showed no difference in number and amplitude of saccades among these groups (Moiroud, Gerard, Peyre, & Bucci, 2018).

1.3 Fixation

Fixational eye movements are not merely an absence of a visible eye movements but is an active process (Wong, 2008). During fixations, slow and rapid small-amplitude eye movements (micro eye movement occurs. However, the image of an object still appears within the functional foveal locus (approximately ± 30 minutes of arc)(Ciuffreda & Barry, 1995). Typically, the average fixation duration lasts for 200-300 millisecond, but it depends upon the task (Beelders & Stott, 2018). While reading in English, the mean fixation duration is about 225-250 milliseconds (Beelders & Stott, 2018). Normal fixation consists of 3 types of micro movements.

Microsaccades: They occur at shallow rate of 1-2 per second (Ciuffreda & Barry, 1995; Rucci & Poletti, 2015). Their amplitude is less than 26 min of an arc with an average amplitude of 6 min of arc (Wong, 2008). Microsaccades are always binocular, and their amplitude is highly correlated (0.6-0.9) between the eyes (Ciuffreda & Barry, 1995). Its mean frequency is approximately 120 Hz (Wong, 2008).

Microdrift: It is a low-velocity movement occurring less than 20 min of arc per second (Wong, 2008). They help in preventing the stable image from fading (Wong, 2008). Its amplitude is about 1-5 min of arc, and the movement is irregular and have a low frequency (<0,5 Hz) (Ciuffreda & Barry, 1995). Its amplitude may increase slightly when retinal errors are produced only from far and near the retinal periphery (Ciuffreda & Barry, 1995). Drifts contribute more than 95% of one total fixation time (Ciuffreda & Barry, 1995).

Microtremor: It is a high-frequency movement ranging in between 30-100 Hz (Ciuffreda & Barry, 1995; Wong, 2008). The average amplitude is approximately about 20 sec of arc (appx. One cone diameter size) and can range in between 5-30 seconds of arc (Ciuffreda & Barry, 1995; Wong, 2008).

In a study to investigate objective eye movement using eye tracker while performing DEM test in Dyslexic and non-dyslexic children, it was found that fixation duration was recorded high in dyslexic children as compared to non-dyslexic children.(Moiroud et al., 2018). Similarly, other studies showed that poor fixation quality in dyslexic children is more likely due to attentional deficit rather than reading activity (Eden, Stein, Wood, & Wood, 1994; Tiadi, Gerard, Peyre, Bui-Quoc, & Bucci, 2016). While reading, fixation plays an important role in recognition and perceptual span of the words (Ciuffreda & Barry, 1995; Rayner, 1985). It is important that reading researchers should equally give an importance to both saccades and fixational eye movements parameters (Rayner, 1985).

1.4 Eye Tracking

Eye-tracking is an ocular movements measuring procedure that is based on a theory that eye movements are necessary to bring an object of interest into the individual central visual field to have a high-resolution detail image (Ashraf et al., 2018). According to the latest study and research on eye tracking, it has been found that eye tracking has huge research benefits with an application on various aspects of healthcare education (Ashraf et al., 2018). Infrared light is generally used in a camera of an eye tracker because visible spectrum lights are more likely to generate specular reflection. Similarly, visible spectrum lights are not able to provide more contrast; this will leads to low accuracy measurement (Farnsworth, 2019). Eye trackers are broadly classified into remote and head-mounted eye trackers. Remote eye trackers have the sensor embedded into the screen, whereas in head-mounted eye trackers, the sensor is present in the glasses worn by subject (Nivvedan, 2013). Many researchers working on the eye-tracking are mainly focusing on improving identification of the saccades and fixation with high accuracy by an eye tracker (Komogortsev, Gobert, Jayarathna, Koh, & Gowda, 2010; Liu, Zhao, Ren, Wang, & Zheng, 2018). In our experiment, we have used Remote Eye-tracking Device (RED) 250. It measures the eye movements without being in close contact with eyes and has inbuilt automatic head movement compensation. Head movement is compensated by tracking the corneal reflex (SMI, 2011).

1.5 Reading Direction

Reading a language written in left to right reading direction follow these eye movements patterns; short saccades, usually on left to right direction which is followed by fixations in between and occasionally regressions in right to left direction (Ciuffreda & Barry, 1995). There are few studies done on the impact of reading directions (i.e., left to right and right to left) in the DEM test. A study on English reader (43 children, 20 adults) who are habitually reading from left to right direction, were found to read faster from left to right reading direction as compared to right to left. In contrast, the same study found that the Arabic adult subject who are trained to read from both directions since childhood showed no significant differences between two reading directions with either the original DEM test chart or the designed Arabic DEM chart for the study. However, 6 Arabic children who were not trained in the English language shows significant faster reading from right to left direction (Medland, Walter, & Woodhouse, 2010). In our study, we have tested DEM (subtest C) in each participant on both left to right (L-R) and right to left (R-L) reading directions.

2 Aim and Research Questions

Our study will compare computerized DEM (presented on the computer) and paper-based DEM test performance under clinical condition vs. an objective infra-red (IR) 250 Hz eye tracker in a cohert of native Nepali speakers.

The following research questions and hypotheses will be examined (H_0 refers to the null hypothesis, and H_a refers to the alternate hypothesis):

Do adults perform similarly in paper DEM vs. computerized DEM test?

H_0: Adults perform similarly on both tests (DEM ratio and Computer DEM ratio are not significantly different).

H_a: Adults do not perform similarly on both test (DEM ratio and Computer DEM ratio are significantly different).

Are DEM results and computerized DEM saccadic parameters results interchangeable?

H_0: The DEM ratio, horizontal score is interchangeable to DEM saccadic eye-tracking parameters.

H_a: The DEM ratio, horizontal score is not interchangeable to DEM saccadic eye-tracking parameters.

Are DEM and computerized DEM ratios in Nepali readers similar in the right to left vs. left to right directions?

H_0: The DEM ratio and DEM horizontal score in the right to left direction are not significantly different than the DEM ratio and DEM horizontal score in the left to right direction.

H_a: The DEM ratio and DEM horizontal score in the right to left direction are significantly different than the DEM ratio and DEM horizontal score in the left to right direction.

3 Methods

3.1 Study Design

This is a clinical cross-sectional study. It will compare computerized DEM and paper-based DEM test performance under clinical condition vs. an objective infra-red (IR) 250 Hz eye tracker in 23 native Nepali speakers.

3.2 Patient Selection

The subjects included in this study were native Nepali readers and speakers who are pursuing their master's degrees from Norway. A total of 25 adults form age 25-35 (mean age, 27.60 years) have participated in the study. Consent (appendix A) was obtained from each participant before the examination. The distance and near visual acuity of 6/7,5 or better was included in the study. The average distance and near visual acuity measured with LogMAR chart were 0,006 and -0,02, respectively. The other inclusion criteria for the study were normal binocular vision finding as supported by some binocular vision findings; no Strabismus and history of vision therapy (CT: normal), NPC: 5/7 cm with RAF rule, Stereopsis: 60 second of arc or lower (TNO test), and amplitude of accommodation: normal range using push away method (15-0,25 X age). Similarly, anisometropia not larger than 2 D spherical equivalent between 2 eyes were included in the study. Systemic and ocular disease (MG, MS, keratoconus), pregnancy, diagnosed ADHD, and specific learning disorder were the exclusion criteria for the study. An approval from the national ethics committee was obtained before starting the sample collection. All clinical procedure were performed in a designated examination room at the Department of optometry, radiography and light design optometry clinic.

3.3 Examination

The examination was completed in two phases.

3.3.1 Baseline Examination

The baseline examination duration was scheduled to take approximately 30 minutes. This examination includes the test that is part of routine eye examination in an optometric practice. Initially, before clinical evaluation, all the participants were asked some questions (Appendix B) to rule out any systemic, ocular, and learning disorder. The examinations that were performed during baseline examination are presented in the table below.

Table 4: Overview of the test performed under baseline examination (Colenbrander, 2002; Scheiman & Wick, 2015).

Test	Details on examination procedure	Normal values	Inclusion Criteria
Visual acuity (distance)	Patient reports when the letter on the logmar chart get unreadable. Done monocular and binocular with habitual correction.	0.1 to -0.02 (logmar) 6/7.5 to 6/4 (Snellen)	6/7,5 (0.097 logmar) or better acuity.
Visual acuity (near)	Patient reports when the letter on the logmar chart get unreadable. Done monocular and binocular with habitual correction.	0.1 to -0.02 (logmar) 6/7.5 to 6/4 (Snellen)	6/7,5 (0.097 logmar) or better acuity.
Cover Test (distance)	With habitual correction, participant looks at the distance target at 6 m. Target is 2 line above BCVA in logmar chart.	1 exophoria ±2 PD	Magnitude <1 esophoria and <3 exophoria.
Cover Test (near)	With habitual correction, participant looks at the near target at 40 cm. Target is 6/9 VA on fixation stick.	3 exophoria ±3 PD	Exophoria <6 and esophoria all excluded.
Near point of convergence (NPC)	Participant reports the vertical line on a RAF rule get double. Done 2-3 times and the average break value is noted.	2,5cm ±2,5	Values <5-7 cm

Amplitude of Accommodation (push away method)	Participant reports when the number gets clear in the RAF rule. Done monocularly and binocularly with habitual correction.	18-1/3 of age ± 2 DS	Values obtained using Hofstetter normal age range formula (15-0,25X age)
Stereopsis (TNO stereotest)	Participant reports when the objects on the test plates are visible. Participants are asked to use red green glasses and is performed at 40 cm.	≤120 second of arc	60 second of arc or lower

3.3.2 Main Examination

Examinations under this section were the paper-based and computerized DEM examination. The duration of this examination was scheduled to take approximately 60 minutes. This examination was performed in a designated experimental room at the Department of optometry, radiography, and light design. The surrounding environment and the lighting condition were similar for each participant. The examinations that were conducted are explained below.

3.3.2.1 Paper based DEM Test

The participant who was recruited for this examination had passed all the baseline examinations. All the 23 participants have undergone this test. The same examiner administered the test on every participant. DEM test (Bernell Corp, Mishawaka, Indiana) consisting of four test plates (Pre-test, A, B, and C) was used for the examination. The participant was asked to sit on a chair, holding the DEM test plate at 33 cm from them. Participants were asked to keep their head still and straight during the examination. The first testing plate on a DEM test was pre-test. We used the pre-test for explaining each participant about the task. It consists of 10 single digits of even spacing numbers. This plate is not used for diagnostic purpose rather used to determine whether the subject has an ability for naming the numbers correctly. The actual testing began with test A. Both test A (figure 1) and B (figure 2) have a two-column, consisting of 20 number in each column. This subtest provides the vertical time that is the time recorded to read all the 80 numbers. Participants were asked to read aloud all those numbers as quickly as possible. They were instructed to maintain their working distance, keeping their head straight and continue their reading regardless of any mistake during the test. After completion, test B was performed in a similar manner. Test A and B are collectively called Vertical test. Horizontal test (Test C) comprised of 80 number arranged in 16 rows with five numbers in each row. Test C was performed in two horizontal directions (left to right and right to left). After test B completion, participants were directed in which order they will be performing the test C. After completing that order, they were directed to repeat the test in the opposite direction. Half of the participants performed the test C in right to left direction (R-L) first, while other half performed in left to right direction (L-R). All the tests were performed twice for each participant. The test time was recorded with an iPhone stopwatch and the time was rounded to the nearest second. The error that might happen while testing was addition, omission, transposition, and substitution. Vertical time was obtained by adding test A and B time. Adjusted horizontal time was obtained by using the formula present in the manual of the DEM test.

Adjusted horizontal time: Test C timeX $[80/(80 - o - a)]$

O: omission error

A: addition error

The DEM ratio was then obtained by dividing adjusted horizontal time by vertical time.

The vertical time, horizontal time and ratio and error was recorded on DEM scoresheet (Appendix D) for each participant.

TEST A

3	4
7	5
5	2
9	1
8	7
2	5
5	3
7	7
4	4
6	8
1	7
4	4
7	6
6	5
3	2
7	9
9	2
3	3
9	6
2	4

Figure 1: DEM Subtest A

TEST B

6	7
3	9
2	3
9	9
1	2
7	1
4	4
6	7
5	6
2	3
5	2
3	5
7	7
4	4
8	6
4	3
5	7
2	5
1	9
7	8

Figure 2: DEM subtest B

TEST C

2 5 9 4 3
4 5 2 7 8
3 5 7 4 9
8 7 9 5 7
3 7 1 4 5
6 1 4 6 2
9 3 7 2 6
7 2 4 6 3
6 3 2 9 1
7 4 6 5 2
5 3 7 4 8
4 5 2 1 7
7 9 3 9 2
1 4 7 6 3
2 5 7 4 6
3 7 5 9 8

Figure 3: DEM subtest C

3.3.2.2 Computer based DEM Test

Computer DEM is similar to Paper DEM, but the only difference is that it is projected onto a computer screen. Department of Optometry and Vision Science, Hadassah Academic college, Jerusalem provided the pdf format of the DEM test. This pdf format was then browsed to SMI Experiment Centre™ version 3,7 software installed in Dell laptop(window 7 version). The testing procedure was precisely the same as paper DEM. Eye-tracker was not calibrating on the 33 cm, so the testing distance was fixed to the 40 cm for the entire examination process. The distance between the computer screen and the participant chair was fixed to 40 cm. Participant was asked to keep their head still and straight during examinations.

3.3.2.3 Eye Movement Recording

Eye movements were recorded using the SMI Remote Eye-tracking Device (RED) 250. It measures the eye movement without being in close contact with eyes and has inbuilt automatic head movement compensation. Head movement is compensated by tracking the corneal reflex (SMI, 2011). This eye tracker works on a computer system called iView X . This computer system utilizes a dark pupil eye-tracking system. In this system, images of the eyes are analyzed in real-time by detecting the pupil, calculating the center, and eliminating artifacts (SMI, 2011). The output data are obtained in the form of the binary iView data file (IDF), which can be further extracted into the various useful kind of data, such as pupil size and position, gaze position, saccades, and fixation, etc. (SMI, 2011). Our experimental setup of the SMI RED250 eye tracker was done under a single PC system. The stimulus monitor, and operator PC are interconnected using a PC internal socket connection. As an operator PC, Dell laptop (windows 7) was used. The operator PC has the three major software (SMI Experiment Centre™, SMI iView X™, and SMI BeGaze) for connecting eye tracker and PC. The SMI RED 250, used in this study have following characteristics: stimulus screen resolution (1680X 1050), calibration method (5 point RED), sampling rate (250 Hz), eye tracking mode (binocular), gaze position accuracy (<0,5 degree), spatial resolution (0,03 degree), Dimension (119X54X36 mm), eyewear compatibility (works with most glass and lens) (SMI, 2011). Participants were seated 40 cm from the computer screen. Prior to clinical testing, the eye tracker performs the calibration. The 5-point calibration system was used for this examination. The calibration was done binocularly. The sampling rate of the eye tracker was fixed to 250 Hz for every test. The eye movement was recorded during the following task.

Number task: During this task, the computer DEM chart was used. Eye movement recording was obtained for each DEM subtest (A, B, and C). Each DEM subtest was presented on the computer screen, and the participants were asked to read the number. Eye movement recording for test C was obtained in both right to left and left to right direction. Half of the participant was asked to read from left to right (L-R) at first, and another half started with right to left (R-L).
Eye movement variable obtained from the eye tracker were listed in the table 5.

Table 5: Variable measured from SMI Red250 IR eye tracker

Variable	Definition of Variable
Total number of fixations	Total number of fixations recorded for each DEM subtest (i.e. A, B, and C)
Total fixation duration	Total time recorded to complete all fixation for each DEM subtest (i.e. A, B, and C)
Total number of saccades	Total number of saccades recorded for each DEM subtest (i.e. A, B, and C)
Total saccade duration	Total time recorded to complete all saccades for each DEM subtest (i.e. A, B, and C)

3.4 Ethical Consideration

All the tests that was conducted for the study purpose were non-invasive, and most of them were all routine eye examination that is performed in regular eye examination in optometric practice.
All the participants have gone through the initial routine eye examination with the standard non-invasive procedure. If pathology has been detected, then they would have been referred to the appropriate health care providers. The examination procedure does not include any use of eye drop. The test was simply paper-based test where the participant is asked to read the text while performing examination. Informed consent was presented to each participant prior to the clinical examination (Appendix A). All the information, regarding the study was described on the consent form. It was compulsory for all the participants to sign the informed consent before inclusion on the participant. Participants were informed of their right to quit the study at any point of time without any further explanation. This study was performed according to the Declaration of Helsinki. Every participant status was kept anonymous, and their name was replaced with the unique identification number. This number was kept secret in order to keep their sensitive personal information safe.

3.5 Data Analysis

All the data obtained during this study were analysed using SPSS V.24. Before processing the data for analysis, a test for normality was conducted for each variable using SPSS. Kolmogorov-Smirnov and Shapiro-Wilk test for normality were conducted. Skewness and kurtosis value obtained from SPSS was also taken into consideration for determining normal distribution. It was found that all the variables are normally distributed, therefore parametric statistics were used for analysis. All the tables and graphs were made using SPSS V.24 and Excel 2016.

Paper and computer DEM were compared using paired t-test and Pearson correlation analysis. Similarly, a comparison between left to right (L-R) and right to left (R-L) was done using a paired t-test. SMI Red250 IR eye tracker outcome (i.e. total number of fixations, total number of saccades, total fixation duration, and total saccade duration) were compared with DEM test results using linear regression analysis. While performing linear regression, total number of fixations, total number of saccades, total fixation duration, and total saccade duration were used as a dependent variable and DEM ratio and, Test C as a predictor variable. A p-value of <0.05 was considered significant for all hypothesis testing. We did not compare test A and B result with eye movement parameter because it has been claimed that vertical number arrangement on test A and B does not contribute for oculomotor analysis instead they are designed to point out the reading skill deficit. (Grazia , Borsting, Press, Scheiman, & Solan, 2008; Richman, 1987)

4 Results

A total of 23 Nepalese students participated in the study. The number of male and female were 20 and 3 respectively, age ranging from 25-32 with a mean age 27.56±1.92. Out of 23, only 4 had a habitual glass correction for a distance while the rest of the 20 participants does not have any habitual correction either with glass or a contact lens. Those 4 participants were all myopic with a spherical equivalent in right eye: -1,00 D, -4,00 D, -2,75D and -3,25 and a spherical equivalent in left eye: -0,75D, -4,00D, -3,25D and -3,00, respectively. All the participants had at least 0.0 logmar distance and near acuity. The average distance and near acuity for all participants were 0.0064±0.049 and -0,026±0.05 respectively. The average break point for NPC, which was measured using RAF rule, was 5.91±0.90 cm. Regarding stereopsis, all the participants had 60 seconds of arc measurement. Similarly, the amplitude of accommodation measured using RAF rule, both monocularly and binocularly shows the average measurement of 10±90 D, 10±90D, 10±62 D, for OD, OS, and OU, respectively. The cover test measurement in the distance was ortho for all participants. In 10 participants, exophoria was measured during near cover test. The average exophoria among 10 participants was 2.4±0.69 PD. One participant had a 3 PD esophoria at near. To rule out the presence or absence of any systemic or ocular disease such as multiple sclerosis, myasthenia gravis, keratoconus and ADHD or any learning disability, a questionnaire was used during clinical testing. None of the participants reported the presence of any systemic and ocular disorder.

Table 6: Overview of the clinical examination with their findings

Test	Observed Values Mean±SD	Min	Max
Visual Acuity (Distance)	0.0064±0.049	-0.1	0.09
Visual Acuity (Near)	-0.026±0.05	-0.1	0.09
Near point of convergence (NPC)	5.91±0.90 cm	5 cm	7 cm
Amplitude of Accommodation (OD)	10±0.90 D	9 D	12 D
Amplitude of Accommodation (OS)	10±0.90 D	9 D	12 D
Amplitude of Accommodation (OU)	10±0.62 D	9 D	12 D
Cover test (Distance)	Orthophoria for all participants	orthophoria	orthophoria
Cover Test (Near)	Exophoria (2.4±0,69 PD) for 10 participants Esophoria (3 PD) for 1 participant Orthophoria for 12 participants	orthophoria	Exo: 4 PD Eso: 3 PD
Stereopsis	40±0 sec of arc	----	60 sec of arc

4.1 Paper DEM Vs. Computer DEM

The first hypothesis of this study was to find out whether there were differences in the measurements between paper DEM and the computer DEM test. The results support the null hypothesis, as there was no statistically significant difference between paper and computer DEM test results (p>0.05). Details of those analyses are presented in the table below.

Table 7: An overview of mean vertical time, mean horizontal time, ratio, and error for each DEM test along with comparative statistical values (i.e t-value, p-value, degree of freedom, 95% CI, and Pearson correlation).

Test	Subtest	Time (secs) Mean± SD	Paired t test (T-value)	p-value	Df	95% CI	Pearson's Corr coeff (r)	P-value
Paper based DEM	A	14.21±1.27	-0.435	**0.668**	22	-0.845, 0.552	0.092	0.667
Computer based DEM	A	14.36±1.11						
Paper based DEM	B	14.09±0.97	-0.998	**0.329**	22	-0.738, 0.258	**0.421**	0.045
Computer based DEM	B	14.33±1.14						
Paper based DEM	C (L-R)	28.19±2.14	0.627	**0.537**	22	-0.523, 0.976	**0.613**	0.002
Computer based DEM	C (L-R)	27.97±1.69						
Paper based DEM	C (R-L)	31.84±2.83	-1.017	**0.320**	22	-1.20, 0.412	0.802	0.000004
Computer based DEM	C (R-L)	32.24±3.07						
Paper based DEM	Ratio (L-R)	0.99±0.05	1.603	**0.123**	22	-0.006, 0.04	0.186	0.397
Computer based DEM	Ratio (L-R)	0.97±0.04						
Paper based DEM	Ratio (R-L)	1.12±0.09	0.114	**0.910**	22	-0.044, 0.049	0.324	0.123
Computer based DEM	Ratio (R-L)	1.12±0.09						

There was a significant correlation between paper and computer DEM while testing test C from left to right reading direction (r=0.613, p<0.05). Similarly, a significantly high correlation was found while performing test C from right to left reading direction (r=0.802, p<0.05). A mild correlation was found between paper and computer subtest B (r=0.421, p<0.05). A statistically significant correlation was not seen between Paper and computer subtest A (r=0.092, p>0.05). Similarly, ratio score between paper and computer DEM do not exhibit significant correlation. (r_{L-R}=0.186, r_{R-L}=0.324, p>0.05).

Another interesting finding was that during paper and computer DEM testing, none of the errors (i.e. omission, substitution addition, and transposition) were recorded.

4.2 Reading Direction

The DEM subtest C of both paper and computer DEM was tested on both left to right and right to left reading direction. The comparison was made between left to right (L-R) and right to left (R-L) reading direction. The findings support our alternate hypothesis. There was a statistically significant difference in the time to complete test C in left to right (L-R) and right to left (R-L) reading direction ($p<0.05$) for both paper and computer DEM. The performance of each participant on test C was faster on L-R reading direction as compared to R-L. In paper DEM, participants were taking approximately 3 second less time on average to complete test C from L-R direction as compared to R-L. In computer DEM, it was around 4 second less on average in L-R direction as compared to R-L. The ratio score for paper DEM in left to right direction and right to left direction was significantly different ($t(22)=-8.449$, $p<0.001$). Similarly, for computer DEM the ratio score in left to right and right to left reading direction was significantly different ($t(22)=-7.60$, $p<0.001$). Average ratio score in L-R reading direction was close to 1 in both paper and computer DEM. In contrast, the average ratio score in R-L direction was 1.12 in both paper and computer DEM (table 7).

Table 8: An overview of mean time in left to right vs right to left direction in both DEM test along with comparative statistics (i.e. T-value, Degree of freedom, 95% CI and p value.

DEM Type	Test C Time Second (mean±SD)		T-value (paired t test)	Degree of freedom	95% CI		P value
					Lower	Upper	
	L-R (Left to right)	R-L(Right to left)					
Paper DEM	28.19±2.14	31.84±2.83	-8.698	22	-4.520	-2.779	p<0.05
Computer DEM	27.97±1.69	32.24±3.07	-7.526	22	-5.451	-3.095	p<0.05

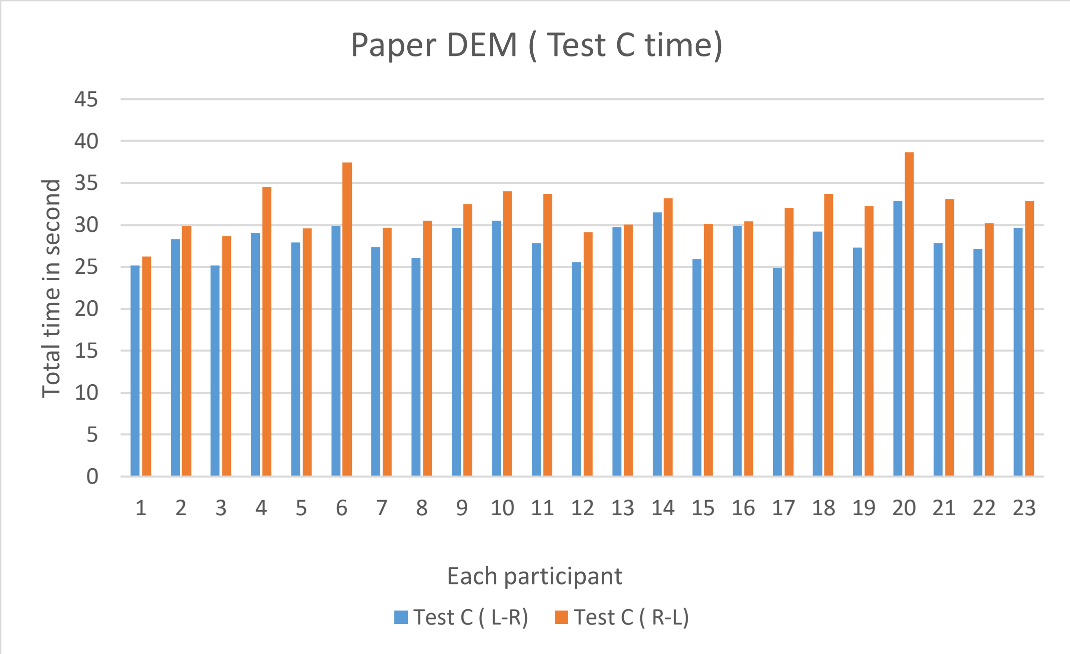

Figure 4: Mean test C time for each participant in left to right (L-R) and right to left (R-L) reading direction.

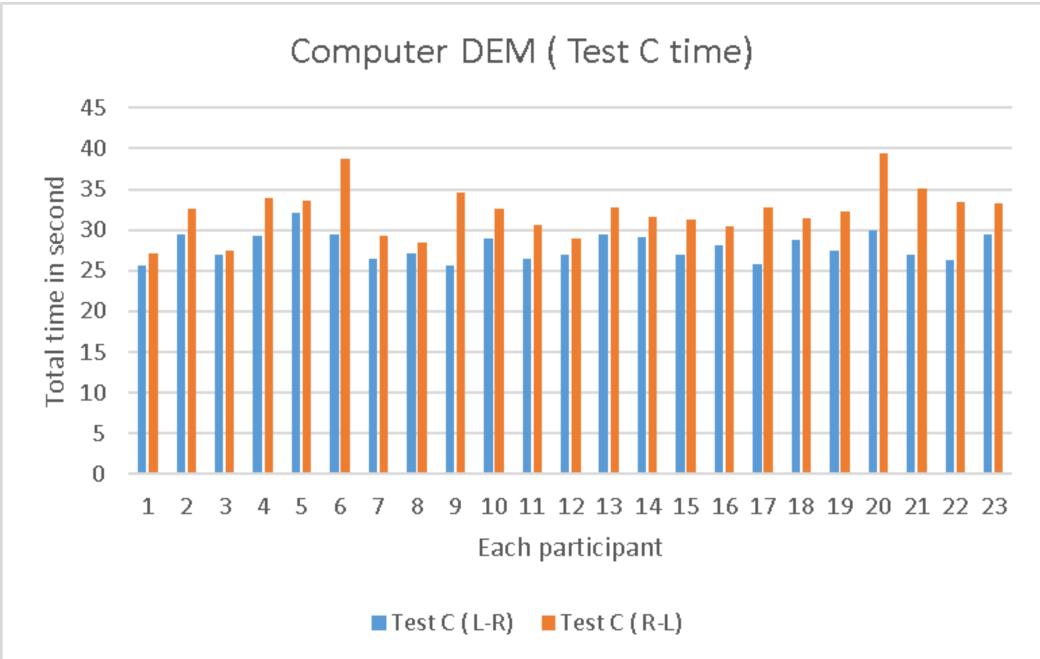

Figure 5: Mean test C time for each participant in left to right (L-R) and right to left (R-L) reading direction.

The bar diagram represents the mean paper (figure 4) and computer (figure 5) DEM test C time in left to right direction (L-R) and right to left direction (R-L). There are differences on the effect of reading direction, for example each participant test C time score on paper and computer DEM is higher in R-L direction (orange bar) as compared to L-R direction (blue bar). Observing figure 4 (paper DEM) closely, we can see that participants 6 and 20 were taking more seconds (appx. 37, and 38 seconds) while performing test C from R-L direction. Rest of the participants have finished test C, below 35 second on R-L reading direction. Regarding L-R reading direction, participants 20 and 14 were taking more seconds (appx. 33, and 31 seconds). Rest of the participants have finished test C, below 30 second on L-R reading direction.

Similarly, in computer DEM (figure 5) participant 6 and 20 were taking more seconds (appx. 38, and 39 seconds) to complete test C in R-L direction. All other participants have completed test C below 35 seconds on right to left reading direction (R-L). Regarding L-R reading direction, participants 5 is the only one to complete test C over 30 second (appx. 32 second). Rest of the participants have finished test C, below 30 second on L-R reading direction.

Participant 13 had completed paper DEM subtest C on exactly same time (appx. 30 seconds) on both L-R and R-L reading direction. Similarly, in computer DEM, participant 3 have completed test C on exactly same time (appx. 27 seconds) on both L-R and R-L reading direction.

Participant 1 was the only one to complete both DEM test C taking less second while testing on both L-R and R-L directions.

4.3 Computer DEM and Saccadic Eye Tracking Parameters

The eye movements were recorded while each participant was performing a computer DEM test. All subtests on computer DEM (A, B and C) were used as a target stimulus for initiating eye movements. The DEM test result ratio and test C score (table 7) was compared with the eye movement variables (total number of fixations, total number of saccades, total fixations duration, and total saccades duration) using linear regression analysis. The mean, along with a standard deviation of eye movements variable, are presented in table 9.

Table 9 : An overview of the test stimuli and eye movement variable recorded from eye tracker.

Task Stimuli	Description of Stimuli	Total number of fixation (mean±SD)	Total number of saccades (mean±SD	Total fixation duration (mean±SD)	Total saccades duration (mean±SD)
Test A	Sets of 20 numbers arranged vertically	53.08±11.24	50.95±7.95	25.84±2.58	2.28±0.83
Test B	Sets of 20 numbers arranged vertically	56.04±11.15	49.52±9.28	25.33±2.72	1.91±0.47
Test C (L-R)	Sets of 80 numbers arranged horizontally	185.34±23.05	193.47±32.31	40.18±5.29	7.87±1.44
Test C (R-L)	Sets of 80 numbers arranged horizontally	205.13±25.25	215.47±33.18	48.49±8.25	8.53±1.50

There was no significant correlation between DEM outcome (i.e. ratio and horizontal score) and the total number of saccades (Table 11). Similarly, no significant correlation was seen between DEM outcome and total saccades duration (Table 13).

There was a significant correlation found between test C score on the left to right direction (L-R) and the total number of fixations recorded while using test C as a number task for both left to right ($r= 0.432$, $p<0.05$) and right to left ($r=0.469$, $p<0.05$) direction. (Table 10). The average fixations number in L-R and R-L direction were 185.34±23.05 and 205.13±25.25. This shows that participants, total fixation count were higher on R-L as compared to L-R reading direction.

Similarly, another significant correlation was seen between test C score on the left to right direction (L-R) and total fixation duration ($r=0.56$, $p<0.05$) recorded while using test B as a number task (Table 12).

Table 10: Correlation between mean test C time (in seconds) and ratio with the total number of fixations in each DEM subtest.

	Target Stimuli			
	Test A	Test B	Test C (L-R)	Test C (R-L)
Total Number of Fixation (Mean and SD)	53.08±11.24	56.04±11.15	185.34±23.05	205.13±25.25
Linear Regression				
DEM Ratio: Left to right	$r^2=0.034$, $p=0.4002$ $r=0.184$	$r^2=0.007$, $p=0.6934$ $r=0.083$	$r^2=0.029$, $p= 0.4352$ $r=0.170$	$r^2=0.001$, $p=0.8712$ $r=0.031$
DEM Ratio: Right to Left	$r^2=0.031$, $p=0.4194$ $r=0.176$	$r^2=0.0007$, $p=0.9022$ $r=0.026$	$r^2=0.0003$, $p=0.9363$ $r=0.017$	$r^2=0.0001$, $p=0.9616$ $r=0.01$
Test C: Left to right	$r^2=0.015$, $p=0.5710$ $r=0.122$	$r^2=0.073$, $p=0.2092$ $r=0.270$	$r^2=0.1869$, $p=0.039$* $r=0.432$	$r^2=0.2200$, $p=0.0239$* $r=0.469$
Test C: Right to Left	$r^2=0.1067$, $p=0.1281$ $r=0.326$	$r^2=0.0252$, $p=0.4688$ $r=0.158$	$r^2=0.1381$, $p=0.0807$ $r=0.371$	$r^2=0.0821$, $p=0.1849$ $r=0.286$

Table 11: Correlation between mean test C time (in seconds) and ratio with the total number of saccades in each DEM subtest.

Target Stimuli				
	Test A	Test B	Test C (L-R)	Test C (R-L)
Total Number of Saccades (Mean and SD)	50.95±7.95	49.52±9.28	193.47±32.31	215.47±33.18
Linear Regression				
DEM Ratio: Left to right	r^2=0.0002, p=0.9473 r=0.01	r^2=0.0022, p=0.8308 r=0.04	r^2=0.0178, p= 0.5433 r=0.13	r^2=0.017, p=0.5529 r=0.13
DEM Ratio: Right to Left	r^2=0.073, p=0.2107 r=0.27	r^2=0.016, p=0.5641 r=0.12	r^2=0.0051, p=0.7453 r=0.07	r^2=0.0013, p=0.867 r=0.03
Test C: Left to right	r^2=0.038, p=0.3689 r=0.19	r^2=0.0076, p=0.6917 r=0.08	r^2=0.0752, p=0.2051 r=0.27	r^2=0.068, p=0.2274 r=0.26
Test C: Right to Left	r^2=0.008, p=0.6731 r=0.08	r^2=0.038, p=0.3694 r=0.19	r^2=0.091, p=0.1608 r=0.30	r^2=0.066, p=0.2351 r=0.25

Table 12: Correlation between mean test C time (in second) and ratio with the total fixations duration (in seconds) in each DEM subtest.

Target Stimuli				
	Test A	Test B	Test C (L-R)	Test C (R-L)
Total Fixation duration (Mean time and SD)	25.84±2.58	25.33±2.72	40.18±5.29	48.49±8.25
Linear Regression				
DEM Ratio: Left to right	r^2=0.0083, p=0.6790 r=0.09	r^2=0.0156, p=0.5693 r=0.12	r^2=0.000, p= 0.9673 r=0.0	r^2=0.0359, p=0.3860 r=0.18
DEM Ratio: Right to Left	r^2=0.0360, p=0.4242 r=0.18	r^2=0.1435, p=0.074 r=0.37	r^2=0.003, p=0.8022 r=0.05	r^2=0.0110, p=0.6326 r=0.10
Test C: Left to right	r^2=0.2397, p=0.017 r=0.48	r^2=0.073, p=0.2115 r=0.27	r^2=0.0001, p=0.9562 r=0.01	r^2=0.0761, p=0.2025 r=0.27
Test C: Right to Left	r^2=0.036, p=0.3801 r=0.18	r^2=0.3164, p=0.0052* r=0.56	r^2=0.0028, p=0.8101 r=0.05	r^2=0.0320, p=0.4137 r=0.17

Table 13: Correlation between mean test C time (in second) and ratio with the total saccades duration (in seconds) in each DEM subtest.

Target Stimuli				
	Test A	Test B	Test C (L-R)	Test C (R-L)
Total Fixation duration (Mean time and SD)	2.28±0.83	1.91±0.47	7.87±1.44	8.53±1.50
Linear Regression				
DEM Ratio: Left to right	r^2=0.005, p=0.7466 r=0.07	r^2=0.0004, p=0.9254 r=0.02	r^2=0.0187, p= 0.5337 r=0.13	r^2=0.00005, p=0.9125 r=0.007
DEM Ratio: Right to Left	r^2=0.018, p=0.5370 r=0.13	r^2=0.000, p=0.9945 r=0.0	r^2=0.0119, p=0.6191 r=0.10	r^2=0.008, p=0.6841 r=0.08
Test C: Left to right	r^2=0.025, p=0.4659 r=0.15	r^2=0.0118, p=0.6204 r=0.10	r^2=0.087, p=0.1716 r=0.29	r^2=0.1587, p=0.0596 r=0.39
Test C: Right to Left	r^2=0.0011, p=0.8778 r=0.03	r^2=0.0074, p=0.6952 r=0.08	r^2=0.1303, p=0.0905 r=0.36	r^2=0.1148 p=0.1136 r=0.33

5 Discussion

5.1 Paper DEM Vs. Computer DEM

The purpose of this study was to investigate the adult performance on the commercially available paper-based developmental eye movement test versus the digital format of the same test, which has been incorporated into the computer screen. Secondly, to investigate whether there exists a correlation between the DEM test result and the eye movement parameters recorded from the SMI RED250 eye tracker. Finally, to examine the impact of reading direction in adults with a habitual left to right (L-R) reading direction.

The first finding of this study was that all the participants in this study performed similarly in both paper and computer DEM test. We had compared each outcome (vertical time, horizontal time, and ratio) of both DEM with each other and found that there was no statistically significant difference between them. The computer DEM mean vertical time (test A and B time in second) were slightly higher than the paper DEM vertical time but the difference was not statistically significant. The paper DEM mean horizontal time was slightly higher than computer DEM on L-R reading direction. In contrast, on R-L reading direction, computer DEM horizontal time was slightly higher. Both DEM horizontal time did not exhibit statistically significant differences ($p>0.05$). The paper L-R mean ratio was slightly higher than the computer L-R mean ratio (0.99 vs 0.97) but the differences was not statistically significant ($p>0.05$). The paper and computer mean ratio scores on R-L reading direction did not exhibit any statistically significant differences. However, paper and computer DEM test shows highly significant correlation among horizontal subtest (Test C) in both L-R ($r=0.61$, $p<0.05$) and R-L ($r=0.80$, $p<0.05$) reading directions. These findings are consistent with Ayton et al. (Ayton, Abel, Fricke, & McBrien, 2008). They have conducted a pilot study on 24 children (8-11 years) to investigate the correlation between paper version and the computer version of the DEM test. They had only made the comparison among the horizontal subtest (test C time on habitual L-R reading direction) and error and found a high correlation ($r=0.96$, $p<0.0001$), ($r=0.85$, $p<0.0001$) respectively. Regarding vertical subtest, our study did not found correlation between paper and computer subtest A whereas subtest B exhibit moderate correlation ($r=0.42$, $p<0.05$). There are not many other studies that have compared the paper and computer version of DEM test. However, a study by Powel et al. compared DEM and Adult DEM test on 50 older subjects (average age 79.2 years)(Powell, 2006). Adult DEM test is identical to DEM test but the adult DEM has double digit numbers instead of single digits (Sampedro et al., 2003). The main purpose of the study by Powel et al. was to find out any performance difference on these two test formats (i.e DEM and Adult DEM) (Powell, 2006).They found that the average ratio scores on the two DEM tests were not significantly different (p=0.19) but found only moderate correlation (r=0.44) between ratio scores. Being based on this finding, they suggested that DEM and adult DEM test format cannot be used interchangeably. These comparisons are consistent and results similar to our study. The ratio scores for paper and computer DEM did not show statistically significant difference (p>0.05), but on the other hand the ratio scores between paper and computer DEM did not show significant correlation at all (r=0.18, p>0.05). This might show that our study did not demonstrate the degree of statistical similarity between paper and computer DEM required for using these tests interchangeably. We did not find a strong correlation coefficient (i.e. 0.8 to 0.9) between paper and computer DEM subtest except for horizontal score. Another interesting finding of our study was that we did not record any errors made during both DEM testing. We used a DEM test that was intended for a child up to age 14, which is likely to explain no errors while DEM testing. In a study, on an older population, 74% and 64% of the subjects did not show errors while performing vertical and horizontal tests on DEM and adult DEM paper-based tests, respectively (Powell, 2006)

5.2 Reading Direction

Another important finding of our study was both DEM performance was significantly different on L-R and R-L reading directions. Every participant average test C time in paper (31.84 vs 28.19 seconds) and computer (32.24 vs 27.97 seconds) DEM was more in R-L as compared to L-R reading directions respectively. It was consistent with Medland et al., that compared two reading direction (i.e L-R and R-L) using paper DEM test and found that English readers whose habitual reading direction was L-R completed subtest C quickly on L-R direction. Similarly, the same study showed the Arabic adults who were trained to read from both directions since childhood did not exhibit any time difference between reading directions. In contrast, Arabic children who were not trained in the English language showed significantly faster reading from right to left direction (Medland et al., 2010). The average ratio score for 20 native English reader age ranging from 20-38 years was (1.06±0.09) in L-R direction and (1.19±0.11) in R-L reading direction (Medland et al., 2010). In our findings, the average ratio score for paper DEM in L-R direction and R-L reading direction was 0.99±0.05 and 1.12±0.09, respectively. In both results, the L-R ratio is close to 1, while the R-L ratio seems more than 1. The higher test C time in R-L reading direction might have contributed for the high ratio scores in that reading direction. DEM ratio is calculated by dividing adjusted test C time with vertical time (Garzia et al., 1990). It has been proposed that after age 13, the DEM ratio approaches 1 (Powell, 2006). The average ratio of 1 was expected in our study because all the participants had normal visual acuity, normal binocular vision, and no reading and learning problem. An average ratio of 1.05±0.10 was found in the older adults (average age:79.2) while testing with DEM in L-R direction (Powell, 2006). Nepali adult's habitual reading direction is like native English readers. It might be the reason behind getting a shorter time on Test C L-R direction. Early research on oculomotor function has claimed that lack of interest or practice in reading might prevent the oculomotor system from proper training (Poynter, Schor, Haynes, & Hirsch, 1982). The DEM test authors have mentioned that the ratio decreases as the age increases (Richman, 1987) but they have not clarified in term of increased eye movement training as the child age increases. Medland et al. have suggested that increased eye movement training might be the one factor responsible for faster reading time in L-R reading direction for English subjects (Medland et al., 2010). This finding might explain the reason behind the faster reading time in our study population as well.

5.3 Computer DEM and Saccadic Eye Tracking Parameters

The comparison between DEM test results (Test C and ratio) and eye movement parameters (number of saccades, fixations and total duration for fixation, and saccades) were significantly, but not strongly correlated. Each computer DEM subtest (A, B, and C) were used as stimulus for initiating eye movement. Test C time on L-R (27.97±1.69 sec) was found to be moderately correlated (r=0.43 and r=0.46) with test C total number of fixation (185±23.05 and 205.13±25.25) on left to right and right to left reading direction respectively.

The average fixation number for each DEM (A, B and C (L-R) and C(R-L) subtest were 53.08±11.24, 56.04±11.15, 185.34±23.05 and 205.13±25.25 respectively. The averages show the almost identical number of fixation numbers between test A and B. This was expected because the test A and B are identical, and both have 40 numbers arranged vertically in two columns. In contrast, the number of fixations on test C are almost 4 times although there are only double of numbers (80 numbers). This might be due to the differences on spacing between the number in each row. In test C, 16 rows of number, each row consisting 5 numbers are arranged with a different spacing between numbers. The increase in text length/spacing gives rise to high number of fixation (Ciuffreda & Barry, 1995). The number of fixations is higher in R-L reading direction as compared to L-R reading direction. This gives us an idea that on habitual reading direction participants are fixating less as compared to unhabitual reading direction. A study conducted to investigate DEM test and eye movement relationship on 13 dyslexic and non-dyslexic children (mean age 10.4 years) also evaluates the number of fixations while testing test C on their habitual L-R direction (Moiroud et al., 2018). The average number of fixations for dyslexic, reading age matched, and chronological age matched were 150±14, 134±10, and 114±7 respectively. If we compare this result with our total number of fixation findings, it shows that our subjects are making a lot of fixation during test C testing. Excessive number of regression (refixation) could be one of the reasons behind more fixation in our study. Generally, 10-15% of saccades or fixation are regressive in nature (Ciuffreda & Barry, 1995). Another significant correlation (r=0.56) was found between test C (R-L) time (32.24±3.07 seconds) and test B total fixation time (25.33±2.72 seconds) in our study. It is consistent to a study by Moiroud et al. on three groups of children (i.e. dyslexic, reading age matched, and chronological age matched) children that shows a positive correlation between duration of fixation and test C time in all groups (Moiroud et al., 2018). The strong correlation was seen among dyslexic children (r=0.73) on that study. The average fixation duration for vertical subtest (test A and B) are almost identical whereas the duration for test C is almost double than test A and B. The average fixation duration for test C on L-R and R-L direction were 40.18±5.29 seconds and 48.49±8.25seconds, respectively. Dividing an average fixation duration to complete all the numbers in test C (40.18 seconds) in L-R direction by the total numbers in test C (80 numbers) , we can get a gross idea that each participant is fixating half a second in each numbers. Normally, average fixation duration is approximately 225 milliseconds but its magnitude depends upon the complexity of a text (Ciuffreda & Barry, 1995). The fixation duration in our study shows differences on reading direction. The fixation duration was longer in R-L reading direction.

Saccadic parameters (i.e. number of saccades and total duration) did not correlate with test C time and ratio score in our study. It is consistent to the findings by Ayton et al. who found that it is not reliable to use DEM test for measuring eye movement because DEM test result (ratio score and Test C time) did not correlate with any of the eye movement saccadic parameter (gain, peak velocity, number of corrective saccades and saccadic latency) (Ayton et al., 2009). A study conducted to investigate eye movements while using DEM test on dyslexic and non-dyslexic children did not find any significant difference between those groups of children on the saccadic parameter (saccade amplitude and the number of backward saccades). Study by Power et al. suggested that the DEM test could be an instrument for only accessing eye movement behaviour during reading (Powers et al., 2008). In another study conducted to investigate visual fixation in dyslexic children they showed that the number of saccades during fixation in dyslexic children is higher than non-dyslexic children, and the number of saccades during fixation decreases with increasing age in non-dyslexic children (Tiadi et al., 2016).

The average number of saccades is almost identical in Test A and B. The average number of saccades on test C is almost 4 times greater than test A and B. The average number of saccades for test C in L-R and R-L direction are 193.47±32.31 and 215.47±33.18, respectively. The total saccade duration on test C is much higher than test A and B combined. If we compared the average number of fixations and saccades, on Vertical test (test A and B), fixation number are more than saccades whereas on Horizontal test (test C) saccades number are more than fixation. The saccade duration is always less than fixation duration in all DEM subtest (A,B and C). All the fixation and saccades parameter are higher in R-L reading direction as compared to L-R.

Several studies done on DEM test and eye movement relationship are performed on normal children(N. L. Ayton, A. L. Abel, R. T. Fricke, & A. N. McBrien, 2009) , poor readers children(Powers et al., 2008) or dyslexic children (Moiroud et al., 2018) but there is no other study done on the relationship between eye movement parameters and DEM test on the adults population.

Our study did not find a strong correlation between DEM test results and the eye movement parameters. Further research with a larger population size and age variation is needed to establish a proper relationship between DEM result and eye movement parameter in adult's population

5.4 Limitation of Study

The current study has several limitations. Firstly, the age range is very narrow, and the gender distribution is not normally distributed (male:20 and female:3). Similarly, a sample size of 23 is not appropriate to conclude complex process like oculomotor function. The study was done on Nepali students studying in Norway. Due to the limited Nepali student and lack of advertisement and promotion of study, we were not able to get enough sample size for our research project. All the student enrolled for the study was studying at Oslo, but our experiment was conducted at the department of optometry, radiography, and light design at Kongsberg. Due to the long traveling time, the participant who had accepted for participation later withdraw from the study.

6 Conclusion

This study mainly focused on drawing a result for paper and computer DEM test interchangeability and the reading direction impact on DEM results. Similarly, some aspect of objective eye movement findings was compared with the DEM test result. The findings of this study suggest that paper and computer DEM result are not appropriate to use interchangeably. This study also shows that the habitual reading direction is more comfortable and faster while reading than unhabitual reading direction. Similarly, the fixational (i.e. number and duration) and saccadic (i.e. number and duration) eye movement parameters are higher in unhabitual reading direction. Despite, small sample size this study shows that DEM test could be a useful tool for investigating fixational eye movement parameter (total number of fixation and total fixation duration). Further research with a large sample size is necessary to establish this relationship.

References/bibliography

Ashraf, H., Sodergren, M. H., Merali, N., Mylonas, G., Singh, H., & Darzi, A. (2018). Eye-tracking technology in medical education: A systematic review. *Medical Teacher, 40*(1), 62-69. doi:10.1080/0142159X.2017.1391373

Ayton, Abel, A. L., Fricke, R. T., & McBrien, A. N. (2009). Developmental Eye Movement Test: What is it Really Measuring? *Optometry and Vision Science, 86*(6), 722-730. doi:10.1097/OPX.0b013e3181a6a4b3

Ayton, L. N., Abel, L. A., Fricke, T. R., & McBrien, N. A. (2008). Does the Developmental Eye Movement (DEM) Test Actually Measure Eye Movements? Validation of a Clinical Saccade Test. *Investigative Ophthalmology & Visual Science, 49*(13), 1810-1810.

Ayton, N. L., Abel, A. L., Fricke, R. T., & McBrien, A. N. (2009). Developmental Eye Movement Test: What is it Really Measuring? *Optometry and Vision Science, 86*(6), 722-730. doi:10.1097/OPX.0b013e3181a6a4b3

Baptista, A. M. G., De Sousa, R. A. R. C., De Morais Guerra Casal, C. C., Marques, R. J. R., & Da Silva, C. M. L. R. (2011). Norms for the Developmental Eye Movement Test for Portuguese Children. *Optometry and Vision Science, 88*(7), 864-871. doi:10.1097/OPX.0b013e3182195dae

Bedell, H. E., & Stevenson, S. B. (2013). Eye movement testing in clinical examination. *Vision Research, 90*, 32-37. doi:https://doi.org/10.1016/j.visres.2013.02.001

Beelders, T., & Stott, A. (2018). Eye Movements during Barking at Print. Retrieved from https://www.intechopen.com/online-first/eye-movements-during-barking-at-print/

Ciuffreda, J. K., & Barry, T. (1995). *Eye Movement Basics For Clinician.*: 1995.

Colenbrander, A. (2002). *VISUALSTANDARDS ASPECTS and RANGS of VISION LOSS with Emphasis on Population Surveys*. Retrieved from Sydney: http://www.icoph.org/downloads/visualstandardsreport.pdf

Eden, G. F., Stein, J. F., Wood, H. M., & Wood, F. B. (1994). Differences in eye movements and reading problems in dyslexic and normal children. *Vision Res, 34*(10), 1345-1358. doi:10.1016/0042-6989(94)90209-7

Facchin, A., & Maffioletti, S. (2018). The Reliability of the DEM Test in the Clinical Environment. *Frontiers in Psychology, 9*(1279). doi:10.3389/fpsyg.2018.01279

Facchin, A., Maffioletti, S., & Carnevali, T. (2011). Validity reassessment of developmental eye movement (DEM) test in the italian population. *Optom Vis Dev, 42*(3), 155-167.

Farnsworth, B. (2019). What is Eye Tracking and How Does it Work? Retrieved from https://imotions.com/blog/eye-tracking-work/

Gallaway, M., Scheiman, M., & Mitchell, G. L. (2017). Vision Therapy for Post-Concussion Vision Disorders. *Optom Vis Sci, 94*(1), 68-73. doi:10.1097/opx.0000000000000935

Garzia, R. P., Richman, J. E., Nicholson, S. B., & Gaines, C. S. (1990). A new visual-verbal saccade test: the development eye movement test (DEM). *J Am Optom Assoc, 61*(2), 124-135.

Gorman, M. F., & Fisher, D. L. (1998). Visual search tasks: slowing of strategic and nonstrategic processes in the nonlexical domain. *J Gerontol B Psychol Sci Soc Sci, 53*(3), P189-200. doi:10.1093/geronb/53b.3.p189

Grazia , R. P., Borsting, E. J. N., Steven B, Press, L. J., Scheiman, M. M., & Solan, H. A. (2008). Optometric Clinical Practice guideline: Care of the Patient with Learning Related Vision Problem (2nd ed): American Optometric Association. Retrieved from aoa.org/documents/optometrists/CPG-20.pdf

Grisham, D., Powers, M., & Riles, P. (2007). Visual skills of poor readers in high school. *Optometry - Journal of the American Optometric Association, 78*(10), 542-549. doi:10.1016/j.optm.2007.02.017

Kapoor, N., & Ciuffreda, K. J. (2018). Assessment of neuro-optometric rehabilitation using the Developmental Eye Movement (DEM) test in adults with acquired brain injury. *J Optom, 11*(2), 103-112. doi:10.1016/j.optom.2017.01.001

Komogortsev, O., Gobert, D. V., Jayarathna, S., Koh, D., & Gowda, S. M. (2010). Standardization of Automated Analyses of Oculomotor Fixation and Saccadic Behaviors. *Biomedical Engineering, IEEE Transactions on, 57*, 2635-2645. doi:10.1109/TBME.2010.2057429

Liu, B., Zhao, Q.-C., Ren, Y.-Y., Wang, Q.-J., & Zheng, X.-L. (2018). An elaborate algorithm for automatic processing of eye movement data and identifying fixations in eye-tracking experiments. *Advances in Mechanical Engineering, 10*(5). doi:10.1177/1687814018773678

Medland, C., Walter, H., & Woodhouse, J. M. (2010). Eye movements and poor reading: does the Developmental Eye Movement test measure cause or effect? *Ophthalmic Physiol Opt, 30*(6), 740-747. doi:10.1111/j.1475-1313.2010.00779.x

Moiroud, L., Gerard, C. L., Peyre, H., & Bucci, M. P. (2018). Developmental Eye Movement test and dyslexic children: A pilot study with eye movement recordings.(Research Article)(Report). *PloS one, 13*(9), e0200907. doi:10.1371/journal.pone.0200907

Nivvedan, S. (2013). Literature Survery on Eyetracking. . Retrieved from http://www.cfilt.iitb.ac.in/resources/surveys/eye-tracking-nivvedan-may14.pdf

Okumura, T., Wakamiya, E., Suzuki, S., & Tamai, H. (2006). [Saccadic eye movements in children with reading disorders]. *No To Hattatsu, 38*(5), 347-352.

Orlansky, G., Hopkins, K. B., Mitchell, G. L., Huang, K., Frazier, M., Heyman, C., & Scheiman, M. (2011). Reliability of the developmental eye movement test. *Optom Vis Sci, 88*(12), 1507-1519. doi:10.1097/OPX.0b013e318230f03a

Parker, A. J., Slattery, T. J., & Kirkby, J. A. (2019). Return-sweep saccades during reading in adults and children. *Vision Research, 155*, 35-43. doi:https://doi.org/10.1016/j.visres.2018.12.007

Poletti, M., Listorti, C., & Rucci, M. (2013). Microscopic eye movements compensate for nonhomogeneous vision within the fovea. *Current biology : CB, 23*(17), 1691-1695. doi:10.1016/j.cub.2013.07.007

Powel, J. M., Brik, K., Cummings, E. H., & Ciol, M. A. (2005). The need for adult norm on the Developmental Eye Movement Test (DEM). *Journal of Behavioral Optometry, 16*(2), 38-41.

Powell, J. M., Fan, M., Kiltz, P.J., Bergman, A.T., Richman, J. (2006). A Comparison of the Developmental Eye Movement Test (DEM) and a Modifieds Version of the Adult Developmental Eye Movements Test (A-DEM) with Older Adults. *Journal of Behavioural Optometry, 17*(3).

Powers, M., Grisham, D., & Riles, P. (2008). Saccadic tracking skills of poor readers in high school. *Optometry - Journal of the American Optometric Association, 79*(5), 228-234. doi:10.1016/j.optm.2007.07.014

Poynter, H. L., Schor, C., Haynes, H. M., & Hirsch, J. (1982). Oculomotor functions in reading disability. *American journal of optometry and physiological optics, 59*(2), 116-127. doi:10.1097/00006324-198202000-00002

Rastatter, M. P., & McGuire, R. A. (1990). Some effects of advanced aging on the visual-language processing capacity of the left and right hemispheres: evidence from unilateral tachistoscopic viewing. *J Speech Hear Res, 33*(1), 134-140. doi:10.1044/jshr.3301.134

Rayner, K. (1985). Do faulty eye movements cause dyslexia? *Developmental Neuropsychology, 1*(1), 3-15. doi:10.1080/87565648509540294

Richman, J. E., Grazia, R. P. (1987). *Developmental Eye Movement Test (DEM). Version 1*.

Rouse, M. W., Nestor, E. M., Parot, C. J., & Deland, P. N. (2004). A reevaluation of the Developmental Eye Movement (DEM) test's repeatability. *Optom Vis Sci, 81*(12), 934-938.
Rucci, M., & Poletti, M. (2015). Control and Functions of Fixational Eye Movements. *Annual review of vision science, 1*, 499-518. doi:10.1146/annurev-vision-082114-035742
Salthouse, T. A. (2000). Aging and measures of processing speed. *Biol Psychol, 54*(1-3), 35-54. doi:10.1016/s0301-0511(00)00052-1
Sampedro, A., Richman, J. E., & Pardo, M. (2003). Developmental eye movement test (A-DEM): a tool for saccadic evaluation in adults. *jouranl of behaviour optometry, 144*(4), 101-105.
Scheiman, M., & Wick, B. (2015). *Clinical Management of Binocular Vision Heterophoric, Accommodative and Eye Movement Disorder.* (4 ed.).
SMI. (2011). iView X System Manual. Retrieved from https://drive.google.com/file/d/0B0hDAb1qZQkRcDBreG15eVFkajA/view
Tassinari, J. T., & DeLand, P. (2005). Developmental Eye Movement Test: reliability and symptomatology. *Optometry - Journal of the American Optometric Association, 76*(7), 387-399. doi:https://doi.org/10.1016/j.optm.2005.05.006
Termsarasab, P., Thammongkolchai, T., Rucker, J. C., & Frucht, S. J. (2015). The diagnostic value of saccades in movement disorder patients: a practical guide and review. *Journal of Clinical Movement Disorders, 2*(1), 14. doi:10.1186/s40734-015-0025-4
Tiadi, A., Gerard, C. L., Peyre, H., Bui-Quoc, E., & Bucci, M. P. (2016). Immaturity of Visual Fixations in Dyslexic Children. *Front Hum Neurosci, 10*, 58. doi:10.3389/fnhum.2016.00058
Van Gisbergen, J. A., Robinson, D. A., & Gielen, S. (1981). A quantitative analysis of generation of saccadic eye movements by burst neurons. *J Neurophysiol, 45*(3), 417-442. doi:10.1152/jn.1981.45.3.417
Vinuela-Navarro, V., Erichsen, J. T., Williams, C., & Woodhouse, J. M. (2017). Saccades and fixations in children with delayed reading skills. *Ophthalmic and Physiological Optics, 37*(4), 531-541. doi:10.1111/opo.12392
Wong, A. M. F. (2008). *Eye movement disorders*. In.
Xie, Y., Shi, C., Tong, M., Zhang, M., Li, T., Xu, Y., . . . Chi, X. (2016). Developmental Eye Movement (DEM) Test Norms for Mandarin Chinese-Speaking Chinese Children. *PloS one, 11*(2), e0148481-e0148481. doi:10.1371/journal.pone.0148481

Appendix

A: Informed Consent for each participant

B: Questionnaire for inspecting the ocular and systemic health status

C: Clinical examination sheet

D: Developmental eye movement score sheet

<u>Appendix A: Informed Consent for each participant for explaining the purpose of study</u>

Universitetet i Sørøst-Norge

REQUEST FOR THE PARTICIPATION IN RESEARCH PROJECT

EYE MOVEMENT MEASUREMENTS USING DEM AND EYE TRACKER

This is a request for you to participate in a research project to investigate eye motor skills in adults with Norwegian or Nepalese as their native language. The purpose of the project is to validate a paper-based test of ocular motor skills in comparison to objective eye motor measurements. Students at the University of Southeast Norway, or other young healthy Nepali adults are invited to participate.

Principle Investigator for the research project: Trine Langaas, Associate Professor, National Center for Optics, Vision and Eye Health, Faculty of Health and Social Sciences, University of Southeast Norway.

Other investigator: Yadav Raut, Master Student, University of Southeast Norway

WHAT DOES THE PROJECT INCLUDE

You are asked to participate in this project because you are a young, Nepali adult student studying in Norway, or a Norwegian student at the University of Southeast Norway. You have learned to read from left to right since childhood. Results will be compared to a similar group of subjects in Israel who have learned to read from right to left. The purpose of this is to investigate if previous reading experience affects the ability of accurate eye motor skills.

The project involves an eye examination to evaluate that each participant meet the inclusion criteria for the research study and a measurement of eye motor skills. The vision testing takes approx. 30 minutes, and the measurement of eye motor activity takes between 30 and 60 minutes. An optometry research student will perform the vision examinations, usually a master's student. In the project we will collect and record the type of visual defects, degree of depth perception and a description of the vision. You will know the results of the eye examination but in the case where the vision testing are being carried out by an international student who does not held an Norwegian authorization, a formal prescription note will not be given.

POTENTIAL BENEFITS, DISCOMFORT AND RISKS

Benefits of participation include that you get an examination of the visual function and you will know if you are nearsighted or far-sighted and what kind of depth perception and binocular status you have. The procedures involve no risks. Disadvantages may be the time it takes, which may cause fatigue or boredom.

There are no payment or compensation to take part in this project.

INSURANCE

Pasientskadeerstatningsordningen.

SUPPLY OF INFORMATION TO OTHERS

By participating in the project, you also agree to that the information from the eye examination and the ocular motor eye tracking can be provided to a foreign institution. This can be a country with laws that do not meet European privacy laws. The information shared is anonymous, and it is not possible to recognize your identity, the code that links you to your personal identification information will not be disclosed. A similar project is being conducted at a collaborating university in Israel, where the test subjects have a native language where they read from right to left.

GODKJENNING

NSD – Norsk senter for forskningsdata AS / The Norwegian Center for Research Data AS has considered that the processing of personal data in this project is in accordance with the privacy policy.

VOLUNTARY PARTICIPATION AND OPPORTUNITY TO WITHDRAW FROM THE PROJECT

Participation in the project is voluntary. If you wish to participate, sign the consent statement on the last page. You can withdraw your consent at any time and without giving any reason.

- If you withdraw from the project, you may require to have deleted collected samples and information, unless the information has already been entered into analyzes or used in scientific publications. If you later want to withdraw or have questions about the project, please contact Trine Langaas, National Center for Optics, Vision and Eye Health, Faculty of Health and Social Sciences, University of Southeast Norway, Hasbergsvei 36, 3616 Kongsberg, phone 31008928, email address trine.langaas@usn.no.
- Your rights:
  As long as you can be identified in the data material, you are entitled to:
  - insight into what personal information that is registered about you
  - get personal information about you corrected
  - get your personal information deleted
  - get a copy of your personal data (data portability)
  - to send a complaint to the Datatilsynet about the processing of your personal data
- What gives us the right to process personal information about you? We process information about you based on your consent.
- If you have any questions about anything, you may also contact NSD - Norsk senter for forskningsdata AS/ Norwegian Center for Research Data AS, by email (personverntjenester@nsd.no or by phone: 55 58 21 17.

STATEMENT OF CONFIDENTIALITY

The information recorded about you should only be used as described in the intent of the study. You have the right to access the information that is registered about you and the right to correct any errors in the information that is registered.

All information will be processed without a name and a national identity number or other directly recognizable information. An anonymous code is the only link to your information through a name list kept separate from other data in a locked cabinet.

The project manager is responsible for the day-to-day running of the research project and that information about you is treated in a safe manner. Information about you will be anonymized or deleted no later than five years after the end of the project.

CONCENT TO PARTICIPATE IN THE STUDY

I AM WILLING TO PARTICIPATE

Your signature below means that you have received the information, have asked the question you currently have about the research and those question have been answered.

By signing this consent form, you indicate that you are voluntarily choosing to take part in this research.

Place and date — Signature of subject

Subject name in capital letters

Your signature below means that you have explained the research to the subject and have answered any questions that he/she have about the research.

Place and date — Signature of investigator

Part in the prosject

Appendix B: Questionnaire for inspecting the ocular and systemic health status

Diagnostic history of participant

Diagnosis	Question asked to participant	Participant answer
Strabismus	Have you ever noticed the inward or outward turning of your eye?	0: not noticed 1: noticed
Ocular disease	Have you ever been diagnosed with Keratoconus?	0: not diagnosed 1: diagnosis conformed
Systemic disease	Have you ever been diagnosed with a disease like myasthenia gravis and multiple sclerosis?	0: not diagnosed 1: diagnosis conformed
ADHD/ learning disability	Have you ever been diagnosed with ADHD or learning disability?	0: not diagnosed 1: diagnosis conformed

Appendix C: Clinical examination sheet

Name: Age:

DOB: Sex:

History:

VA (Logmar) OD: OS: BIN:

VA(Near) OD: OS: BIN:

Cover Test (Light Target) Distance: Near:

Cover Test (Accommodative) Distance: Near:

NPC:

Stereopsis (TNO test):

Amplitude of accommodation: OD: OS: BIN:

Retinoscopy: OD: OS:

Autorefractometer: OD: OS:

Subjective Refraction: OD: OS:

Appendix D: Developmental Eye Movement Test scoresheet

DEM SCORESHEET

NAME__________________ DOB________________ AGE_______ GRADE_____

ARTICULATION PRE-TEST Y N NUMBER KNOWLEDGE PRE-TEST Y N

/ = substitution error
a = addition error
o = omission error
< or > = transposition error

TEST A		TEST B	
3	4	6	7
7	5	3	9
5	2	2	3
9	1	9	9
8	7	1	2
2	5	7	1
5	3	4	4
7	7	6	7
4	4	5	6
6	8	2	3
1	7	5	2
4	4	3	5
7	6	7	7
6	5	4	4
3	2	8	6
7	9	4	3
9	2	5	7
3	3	2	5
9	6	1	9
2	4	7	8

_____sec _____sec

TOTAL TIME: _____sec
ADJ TIME: _____sec
ERRORS: _____

TEST C				
3	7	5	9	8
2	5	7	4	6
1	4	7	6	3
7	9	3	9	2
4	5	2	1	7
5	3	7	4	8
7	4	6	5	2
9	2	3	6	4
6	3	2	9	1
7	4	6	5	2
5	3	7	4	8
4	5	2	1	7
7	9	3	9	2
1	4	7	6	3
2	5	7	4	6
3	7	5	9	8

TIME: _______sec

_____s errors _____o errors

_____a errors _____t errors

$$\text{ADJ TIME} = \text{TIME} \times \frac{80}{(80 - o + a)}$$

ADJ TIME = _______sec

TOTAL ERRORS (s + o + a + t) = _______

$$\text{RATIO} = \frac{\text{HORIZONTAL ADJ TIME}}{\text{VERTICAL ADJ TIME}} = \_\_\_\_\_\_$$

DEM1