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An Objectively Used Device Designed to Measure Eye Movements

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ABSTRACT

Introduction and Purpose: Eye movements essential for proper eye function include:

1. Smooth Pursuits – the ability to stabilize gaze and follow a moving object with the eyes accurately.
2. Saccades – the ability to move eyes accurately from one target to another. Saccades are necessary for tracking skills while reading or copying information. In order to process visual information properly, the eyes must move smoothly and quickly from one object to another.
3. Convergence/Divergence – the ability of the eyes to move inward/outward in order to focus on an object and keep it single as it moves near/far.

In oculomotor dysfunctions, a person may have difficulty reading. He may lose place while reading or repeat sentences. He may also have difficulty with balance, depth perception, sports, or hand eye coordination. Children suffering from autism spectrum disorder haveproblems with eye contact and also have eye movement disorders.

Currently validated procedures to measure oculomotor abilities require verbalization, cognition and comprehension on the part of the subject. This is done in the form of reading out the numerals/alphabets subjectively and or/ follow instructions of the examiner. This becomes difficult for subjects who are unable to communicate and comprehend. An objective, non-verbal software was designed to objectively evaluate the ocular movements.

Methods: Commercial Tobii eye tracker was used with a software (developed to objectively measure ocular movements). This was validated against NSUCO, which is a validated procedure. NSUCO, however requires understanding and comprehension.

Results: The equipment was designedand validated against NSUCO. It was found to correlate well with it. Repeatability, inter and intra observer reliability was tested and found to be good.

Conclusion: Thenew equipment allows an eye care professional to objectively and quantitatively evaluate eye movements innon-communicating individuals.

Key Words: Pursuits, Saccades, Tracker, Oculomotor dysfunction, NSUCO

INTRODUCTION

There are various eye movements that our eyes perform. They are:

1. Pursuits
2. Saccades
3. Ductions
4. Versions
5. Vergence

The movements are initiated by stimulation of the respective cranial nerves controlling different extraocular muscles. This stimulation is in collaboration with the vestibular inputs from the semi circular canals in the inner ears. The movements of the body and the head are compensated by the movements of the eyes to maintain a steady gaze.

The purpose of these eye movements is to track an object, jump from one object to another visually, to fixate at an object and visualize it as a single and clear object and also to maintain a steady gaze without losing sight or changing orientation of the object. Eye movements are affected in a number of cases leading to ocular motor dysfunctions.

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It has been found that saccades and pursuits of children with autism spectrum are not appropriately coordinated (Lai, 2014; Kemner, 1998; Falck – Ytter et al, 2013 and Navabet al, 2012). In the absence of appropriate and accurate tracking skills, their visual motor controls are affected leading to poor academic pursuits and various other activities requiring visual motor coordination.

Reading is a highly complex task and is essential for academic learning. When one reads, there is stimulation in the back of the brain by the visual features of the letters, the angular gyrus, where print is converted into language and Wernickes region, which assess meaning of whatever one has read. The nouns are processed in the left temporal parietal region and the verbs are processed in the frontal lobe (Ludlow et al, 2009). Appropriate functioning of the eyes is crucial for the development of reading skills (palmer, 2002). Even in the absence of refractive errors or strabismus, a condition known as binocular instability is noted in many cases (Ciuffreda, 2002). This is characterized by low fusional reserves and fluctuating heterophoria(Ciuffreda, 2002). Appropriate binocular coordination during eye movements is essential for the development of reading ability. By identifying eye movement discrepancies and providing appropriate therapies we could expect an improved reading ability and in turn an improved academic performance in children on the autism spectrum and otherwise. In the case of autistics, poor eye movement skills can possibly be attributed to poor eye contact, gaze aversion, excessive head movements etc.

In order to assess eye movements quantifiable diagnostic and interventional protocol is required. Oculomotor deficiencies can be rectified or at least the deficits can be minimized by appropriate optometric vision therapy (Streff, 2011 and Gallaway, 2007). These therapies can be performed on children with ASD to try and improve their visual behavior.

OCULAR MOTOR DYSFUNCTION AND ITS MEASUREMENT

Ocular motor dysfunction is a sensory and motor anomaly of the ocular system. The features noticed in this anomaly are inaccurate pursuits, saccades and ocular fixations. This anomaly is characterized by the following signs:

a) Skipping words
b) Missing lines while reading
c) Using finger while reading
d) Transpositions
e) Inability to copy from the board
f) Poor attention
g) Increased head/body movements

A number of diagnostic tests are being used to diagnose ocular movement disorders. All of them fall under the following categories:

a) Psychometric tests - King Devick test, Developmental eye movement test
b) Observational test - NSUCO (Northeastern State University College of Optometry) oculomotor test
c) Computer based tests – Visagraph and Readalyzer

In all the above tests except NSUCO oculomotor test (Maples, W.C., 2012), the subject is required to recognize and verbalize numerals, letters or words. Though all the tests quantify oculomotor parameters, they (except NSUCO oculomotor test) cannot be run on subjects who cannot read or verbalize. NSUCO test has the advantage as mentioned above, but is a subjective test based on the observations of the examiner. However, it requires the subject to comprehend instructions. This may not be possible in very young children and also in cases where understanding instructions is an issue.

REVIEW OF LITERATURE

Gesell mentioned how vision is integrated with the motor system like posture, motor skills etc and also intelligence (Gesell et al, 1949) He discussed the prenatal anatomical development and found how the visual system coordinates with the motor and vestibular controls. In 1986, Cron et al discussed the visual development in a child (Cron et al, 1986). They described different behavioural and non-behavioural methods to measure various parameters including eye movements. They mentioned that it is important to use both i.e. behavioural and non - behavioural methods of measurements. In 2002, Palmer a physical therapist threw light on the importance of motor development and vestibular control in visual development and academics (Palmer, 2002).

AUTISM AND VISUAL BEHAVIOUR

(Viola et al, 2009) concluded that in children with ASD there are changes in the neurological chemistry affecting neuro physiology, cognition, oculo motor system, perception and visual information processing. This in turn leads to deficient processing of the information.

THERAPY AND VISUAL SKILLS

(Fischer et al, 2009) concluded in that fixation instability may contribute to the issues of visual processing and thus affecting academics and learning. (Ciuffreda et al, 2009) gave a guideline for oculomotor, vergence and accommodative training in people with mild traumatic brain injury. (Tassinari, 2007) concluded that the children with oculomotor dysfunction do not normalize on their own without proper optometric vision therapy.

RESEARCH GAPS:

a. Developmental eye movement test (DEM) (Garzia et al, 1990) which is the gold standard test to check eye movements is a verbal test and also requires the

subject to be able to read out numbers. All autistics may not be able to read and also verbalize. Moreover, DEM is normed for 6 – 13 years of age (Kulp et al, 1997).

b. There is no objective, nonverbal test to measure eye movements.

RESEARCH OBJECTIVES:

To device a nonverbal equipment to measure eye movements and validate it against the existing standard procedures.

Methods:

Inclusion and exclusion criteria:

a. Neurotypical children 5 to 13 years of age
b. They had at least 20/25 monocular corrected visual acuities for both distance and near
c. They had at least 30 seconds of arc of stereopsis
d. Accommodative or non strabismic binocular dysfunction was not a disqualifying factor
e. They were be strabismic or amblyopic
f. They had no neurotropic disorders

Sample size:

For correlating the new equipment against NSUCO (existing gold standard procedure for measuring eye movements) and also to find the correlation and test retest, inter observer and intra observer reliability, a purposive sample size of 32 neurotypical children was used. They were selected after ascertaining the inclusion criteria on a random basis.

All the existing procedures and equipment require the subject to comprehend and verbalize the provided targets, we required an objective procedure / equipment to quantify eye movements. This warranted utilization of an equipment which could capture the pupils automatically, project them on the computer screen and move the captured points on the computer screen with the movement of the subject's eyes.

Tobii Pro X3 120, a commercially available eye tracker fulfilled all the requirements and was used. This is a validated eye tracker and is generally used in any research involving eye tracking. This was connected to a CPU and a 21 inches LED monitor. The system was used to capture the pupils and track them as the eyes moved.

We wanted to project different targets, which were projected on the screen for varying durations. A software application was created, which projected pictures of objects like fruits, human faces etc on different parts of the screen for a given interval, Fig. 1- (newly designed eye tracking equipment). The subject viewed the monitor from a distance of 40 cm. The software calculated the exact distance between the centre of the projected target and the position of the tracked eyes and also the mean distance.

Procedure:

a. 32 Neurotypical children, who fulfilled the inclusion criteria underwent Northeastern State University College of Optometry Oculomotor test (NSUCO), under normal room lighting conditions, with the Wolff wands, 40 cm in front of the child. NSUCO is a standard clinical test against which we wanted to validate the new equipment. Fig. 2: NSUCO test being performed on a child.
b. After undergoing NSUCO test, they were tested on the new equipment. Fig. 3: A child working on the new equipment
c. The test was repeated for each child by the same observer and also another observer at the interval of 2 days. This was done to check the following:
    1. Test – retest reliability
    2. Inter observer reliability
    3. Intra observer reliability

RESULTS

NSUCO scores ranged from 11 to 15 (15 being the best score) tracker scores with the first observer ranged from 3.38cm to 7.52cm (Table 1). Lower tracker scores are better as that indicates the distance between fixation point of the subject's eyes and the centre of the projected object. For the second observer tracker scores ranged from 3.29cm to 7.64cm (Table 1). When the procedure was repeated by the first observer, scores ranged from 3.39cm to 7.6cm.

Mann Whitney test was performed to correlate NSUCO with the new procedure. P value was found to be < 0.001 for both the observers (Table 1).

Internal consistency of the observations made by observers were checked (Table 2). Alpha coefficients were found to be high, indicating that the observations have high internal consistencies.

- Pearson's correlation was performed between NSUCO values and values of first observer on tracker. R was found to be -0.96 and had a negative linear relationship (Fig. 4).
- Test retest values were tested for correlation and R was found to be 0.9987 (Fig. 5).
- Inter observer relationship was calculated. R value was found to be 0.9933 (Fig. 6).
- Correlation between second observer and the repeated values of the first observer was calculated and R value was found to be 0.9945 (Fig. 7).

Reliability of the observations made by both the observers and also with the repeated observations of the first observer was tested between each other and was found to be reliable (Table 3). Observation values obtained by the first and the second observer were plotted on a graph and were seen to be reliable. (Figs. 8, 9 and 10).

DISCUSSION

The equipment fulfilled all the requirements to measure the eye movements in non verbal population objectively. Apart from the objective of measuring ocular movements, the new equipment could have a number of other implications.

1. The tracking equipment and the designed software will be highly useful in understanding, diagnosing and treating disorders like
   - Strabismus
   - Nystagmus
   - Learning and reading disabilities
2. It will also be a good tool for understanding visual midline shift in paretic individuals
3. It will help in understanding behavioral issues in cases like ASD and thus treating them
4. This device will aid in teaching and documenting eye movements. Visagraph and Readalyzer are being used to measure eye movements, but this equipment will allow the same in non verbal subjects too.
5. This will help in teaching the behavior of the subjects. It can be a good tool for psychologists in teaching and training as the targets can be designed as per the requirements.

CONCLUSION

An objective equipment to measure eye movements was designed and validated against clinically proven NSUCO procedure. The new equipment was found to correlate well with NSUCO and had good reliability on test – retest, inter observer and intra observer trials.

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Conflicts of interest

There are no personal conflicts of interest or commercial interest in any of the products or procedures used in this work.

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Table 1: NSUCO values of the 2 observers.

NSUCO	15 (n = 14)		11–14 (n = 18)		
	Mean +/- SD	Min. – Max.	Mean +/- SD	Min. – Max.	P value
1st observer	3.90 ± 0.27	3.38 – 4.2	5.47 ± 0.98	4.34 – 7.52	< 0.001
2nd observer	3.91± 0.36	3.29 – 4.38	5.48 ± 0.99	4.32 – 7.64	< 0.001

Table 2: Reliability data.

Reliability Cronbach Alpha: Internal consistency	
First observer	0.9972
First observer repeated	0.9966
Second observer	0.9993

Table 3: Inter and intra observer reliability report.

Reliability report:	
First Observer with first observer repeated	0.9987
First Observer and second observer	0.9933
Second Observer and repeated values of first observer	0.9945

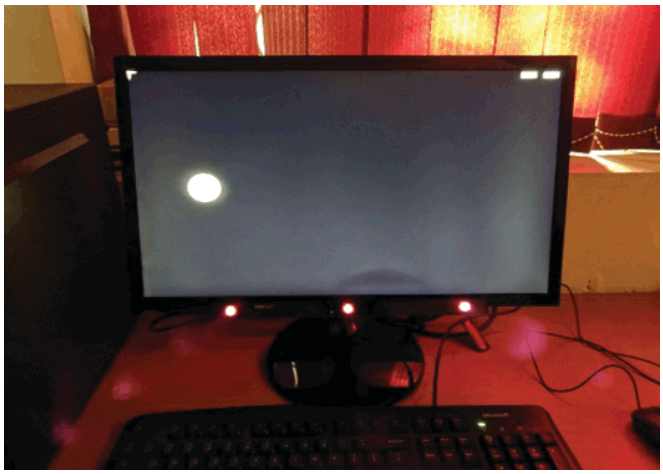

Figure 1: Newly designed equipment to measure eye movements.

Figure 2: A child undergoing NSUCO test.

Figure 3: A child being evaluated on the tracking equipment.

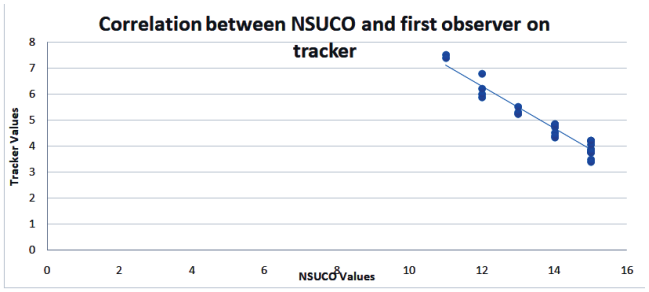

Figure 4: Correlation between NSUCO and tracker values.

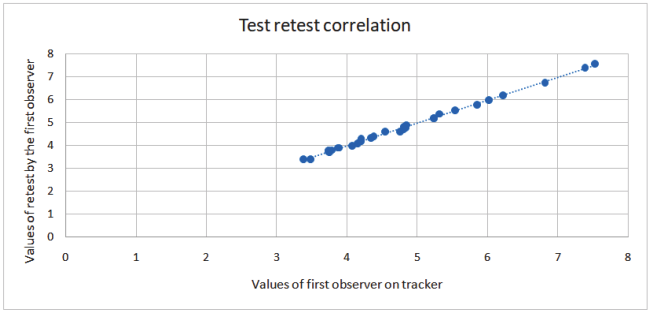

Figure 5: Test – retest correlation.

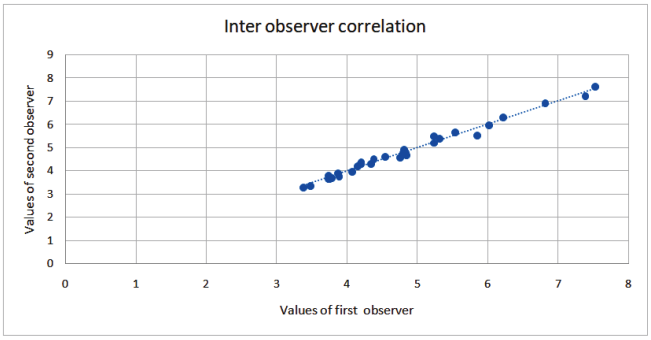

Figure 6: Correlation between values obtained by 2 observers.

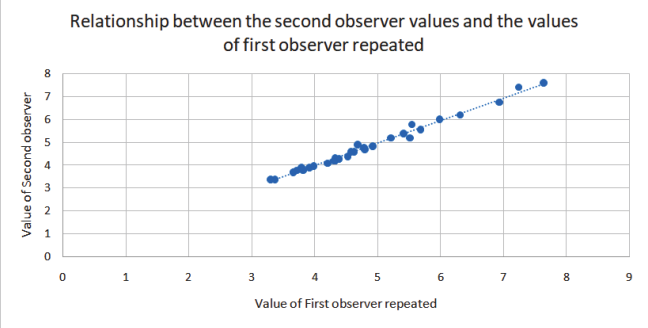

Figure 7: Repeatability of the test.

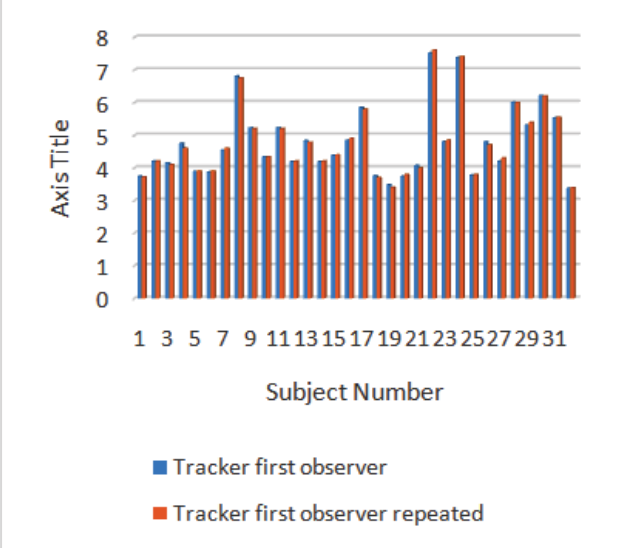

Figure 8: Repeatability of the values by first observer

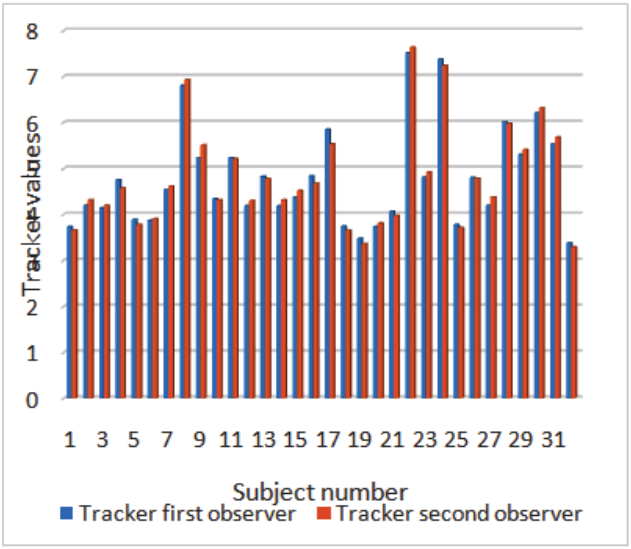

Figure 9: Inter observer test results.

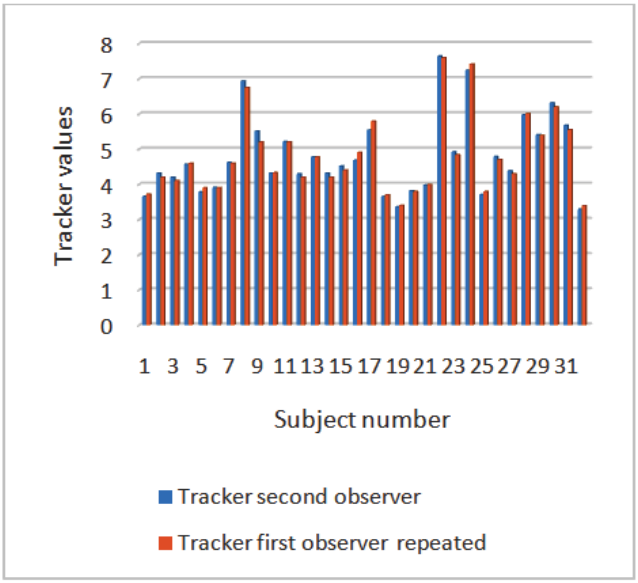

Figure 10: Repeatability of values by second observer.