Some Aspects Related to the Behaviour of the Visual Function during Reading

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Abstract. *The eyes are equipped with a high-precision motor that allows them to orient themselves in any direction with great precision. These movements are maintained even if the sight of one eye is absent. The movements of the eyes are thus coordinated to make binocular vision possible, that is, to allow the recording of a single image, so that the two eyes actually form a single organ. In reality, all eye movements are binocular and the harmonious nature of these movements is conditioned by maintaining a satisfactory binocular vision and avoiding diplopia. Physiologically, binocular movements are divided into voluntary movements and reflex movements (automatic-reflex). Voluntary or reflex eye movements aim to produce associated movements, to ensure a function and not to cause isolated contractions of one or more eye muscles. The eyes can voluntarily orient themselves in any part of the gaze horizontally, vertically or obliquely. Eye movements produced in the same direction can also be considered guided and continuous movements or movements during reading. This movements are eye movements with saccades from one fixation to another. The behaviour of the visual function varies depending on the quality of the text, the degree of culture of the subject, the neuro-vegetative system, age, etc. This paper aims to present a synthetic study on the behaviour of vision during reading.*

Keywords: Visual Function, Eye Movements, Reading.

Introduction

The eyes are equipped with a high-precision motor that allows them to orient themselves in any direction with great precision. These movements are maintained even if the sight of one eye is absent. The movements of the eyes are thus coordinated to make binocular vision possible, that is, to allow the recording of a single image, so that the two eyes actually form a single organ (Cernea, 1981).

Eye motility is provided by six muscles for each eye, namely four straight muscles and two oblique muscles. The right muscles are: the upper right, the lower, the inner and the outer. The oblique muscles are the large oblique or upper oblique and the small oblique or lower oblique. The action of the muscles in the eyeball depends on several elements: the line and the plane of action; position of the visual axis in relation to the action plan; position of the ocular insertion in relation to the centre of rotation (Tamhankar, 2019) (Figure no. 1).

During the most stable fixation, the eye is animated by clinically imperceptible movements but which can be detected by special techniques (Roger, 2007). Among these movements are three aspects that are components of physiological nystagmus: rapid movements or sequelae; slow drift movements; very fine movements, more or less regular, of smaller amplitude than the first two (Klein& Ettinger, 2019).

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Fast movements with a short duration of 25 milliseconds and amplitudes ranging from 1-20 minutes arc of a circle, occur at regular intervals, on average one per second (Cernea, 1981).
Drifting movements are slow movements that separate two saccades. The amplitude is 4 minutes of arc per second and they are often in the opposite direction to fast movements (Roger, 2007).
Fine oscillations are more or less regular, resembling a "background noise", with an amplitude of 0.3 seconds arc of a circle and a frequency of 100 per second(Roger, 2007).
The role of these movements has been interpreted differently (Cernea, 1981):
- would translate into a fundamental instability of the oculomotor system;

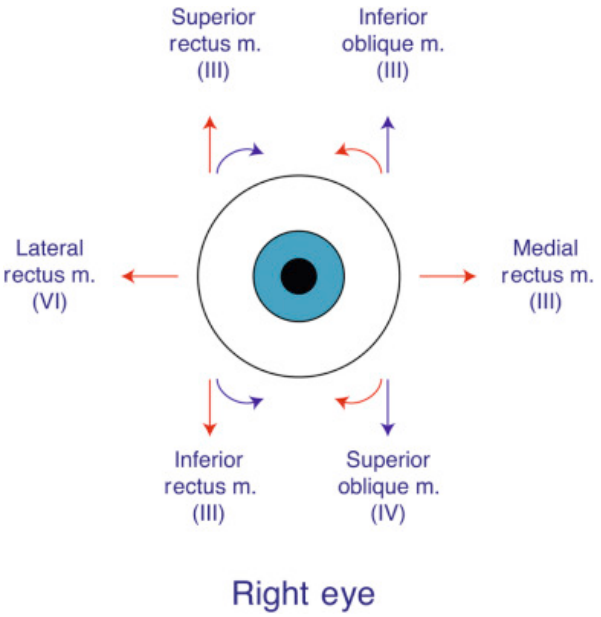

Figure no. 1. The action of the muscles on the right eye
Source: [Tamhankar, 2019]

- would avoid that the retinal image during fixation is always made on the same photoreceptor cells;
- would maintain the retinal image on a central elective area of 6 minutes arc of a circle.
For example, in amblyopia, when it is fixed with the weak eye, a stable fixation is only exceptionally found and an oculographic route with nystagmiform sequelae can be recorded (Grădinaru et al., 2020).

Literature review

The movement of the gaze consists in the conjugated movement of the eyes in order to fix an object that appears in the visual field and draws attention outside the point of fixation. It can be triggered by a pure reflex of an optical, acoustic, sensitive nature, or by a conditioned reflex, such as movements during reading, when the eyes go from one end to the other of the respective line, then pass to the next line; by will and is performed at a high speed in the direction of the fixed object (Rayner, 1998).
In amblyopia, the movements of the eyes become irregular with a nystagmiform appearance. There are inaccurate movements, interrupted by disordered or nystagmic movements that constantly seek to be corrected. There is a concordance between the instability of fixation and the inaccuracy of gaze movements (Klein& Ettinger, 2019). The greater the amblyopia, the greater the disturbances of the gaze movements.
Von Noorden & Burian (1958) show that darkness leads to a normalization of eye movements, as can be seen by eye examinations. There is also an improvement in eye movements after the recovery of visual acuity. Reading movements have a more particular behaviour, because they can remain abnormal for a long time, although amblyopia has been cured with the recovery of visual acuity (Krieber et al., 2016). Even if the path normalizes, the reading movements remain lower than those of the normal subject (Figure no. 2).Voluntary reading training can improve movement even if the visual acuity of the amblyopic eye remains low.

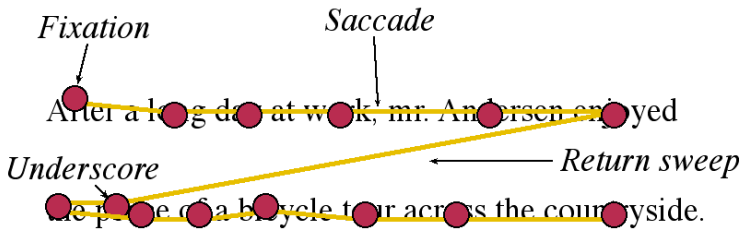

Figure no. 2. Eye movements during reading of a text
Source: [Holmqvist &Warteberg, 2005]

The tracking movement is a conjugated movement of the eyes in order to keep on the retinal surface the fixation of the image of a moving object. The accuracy of this movement depends on the speed of the object. Above a certain critical value, the tracking movement disappears, being replaced by a succession of gaze movements (Holmqvist & Warteberg, 2005).
In strabic amblyopia, the tracking movements are irregular and the critical speed from which they turn into eye movement is lower than normal (Rayner, 1998). Adaptation to darkness brings the appearance of the curve of the amblyopic eye closer to that of the normal eye. There is no correlation directly proportional to visual acuity and fixation behaviour (Krieber et al., 2016). That's mean that the reduction of the visual acuity of a normal eye by optical means does not alter the tracking movements (Rayner, 1998).
Yang & McConkie (2001) demonstrated that as people read continuous text, on occasional single eye fixations the text was replaced by one of six alternate stimulus patterns. Frequency distributions of the durations of these fixations were used to test predictions from four types of theories of saccadic eye movement control. The results about show that the subjects' perusing was quite typical in show disdain toward of the appearance disturbances, resulting in a 73.2% of adjust rate of replying four-item multiple-choice comprehension questions. For the Normal+ (control) condition the cruel length of critical fixations was 212 msec., cruel taking after saccade length was 7.7 letter positions and the recurrence of the following saccade being a relapse was 23%. These values are inside extend anticipated of college students, though relapse recurrence is or maybe higher (Yang & McConkie, 2001).
Healthy human subjects move their eyes during readings on average about 0.25 sec., followed by sending new information to the brain each time the eyes remain fixed during the pause of movement (Rayner, 1998). In the case of normal subjects, this is a fixed duration between 150 and 250 msec. up to the values of 100 and even 700 msec. In this phase the eyes move in each saccade the reading distance varies between 1 and 20 characters, which usually moves between 7 and 9 characters and the execution of the saccade takes about 20-50 msec. (Rayner, 1998).
In healthy readers, this information is used to select the next reading area and to determine the size of the next saccade, so that the distance between the last fixation on a word and the next fixation on the right is defined as an output saccade (Fernandez et al., 2013).
Some research shows that the number of characters that healthy readers are going to move their eyes to the right continuing the reading process depends, in part, on the difficulty of processing the previously fixed word, so the easier it is to process, the longerthe output saccade is (Wei & Pollastek, 2013).
As it appears from (Valsecchi et al., 2013), reading a text is a complex process of the oculomotor system characterized by an alternative between eye fixation and saccade eye movements. In this paper we investigated the oculomotor behaviour while reading texts that move horizontally or vertically at different speeds. According to previous

research, moving texts were read through an alternative visual line tracking and saccade eye movements, and the paper presented different interactions between them (Valsecchi et al., 2013). The paper demonstrated that reading drifting texts is achieved through an alternative of continuous and saccade eye movements (Valsecchi et al., 2013). They observed that these eye movements are not performed in isolation, but interact with each other so that the gain in the tracking movement is highlighted after running a saccade, so the amplitude of the previous saccade determines the duration of the next tracking episode, as in reading static texts (Valsecchi et al., 2013). The paper shows that the maximum speed of the saccades is lower for the text drifting horizontally, as an expression of the sum of the continuous smooth movements with the saccade ones. Also, the preferred reading location and the optimal inverted reading are shifted to the right if the text is horizontally drifting, but they are very similar to vertically drifting text and static ones(Valsecchi et al., 2013).
The results presented in the paper (Gaertner et al., 2013) do not show differences in the duration of fixation for patients and the group of control children. It had previously been shown that the duration of fixation decreased with age in relation to improved reading skills (Rayner, 1998). Other research has shown that during reading, children aged 6 and 7 needed a longer fixation than adults. Bucci & Kapoula (2006) reported similar results during a single-word reading task in 7-year-olds. The reading abilities of the children tested in this study are well developed and this could explain why we did not report any difference in the duration of fixation in the two groups of children studied (Gaertner et al., 2013).

Methodology

To improve the hand-eye coordination skills needed for young children learning to read, we used a visual training board inspired by the Bernell model.
The training technique with the help of these plates is as follows: the subject follows with the marker / coloured pencil the contour of the infinite sign, starting from the centre of the symbol, to the smallest circle on the left, back to the centre, then to the smallest circle on the right. The process continues like this with all the successive circles, always ending the contour in the centre.

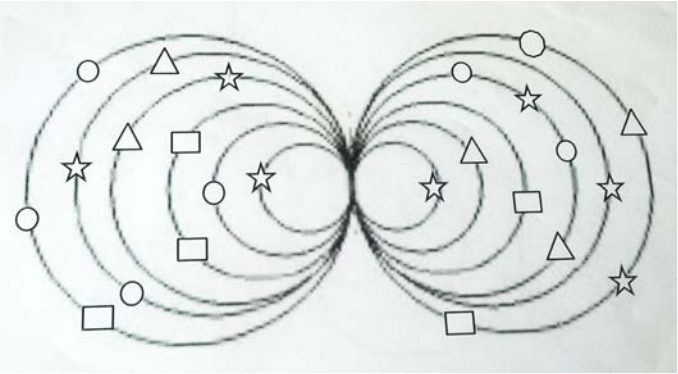

Figure no. 3. Lazy eight board (after Bernell model)
Source: Authors' own research

The boards can be used glued on a vertical surface, or on a horizontal one. Following the experience we had during the test, we noticed that sitting on the table, the board did not train the child's skills as effectively, due to the freedom he has to rotate and permanently change his position towards it (Barbu & Plesa, 2015).
During the exercise, the subjects were explained what the activity consists of, then they drew the outline on the first board, the learning board. After about 5 minutes, in which the way in which the subjects understood the instructions was followed, we moved on to the second plate, on which they performed two types of exercises: drawing the contour, from the smallest circles to the largest circles; colouring all the triangles on the board (with a colour of your choice) and all the stars (with yellow).
Through the first activity, we followed the tracking movements that the subject makes,

hand-eye coordination, and head and body position.
The second exercise required the subject's attention to the details of the board, the scanning skills of the space, looking for a specific subject, the chromatic vision (where the level of training was quite advanced - they knew the colours).
As a results, first of all, it should be mentioned that, out of the total of 45 children, only those aged between 4-6 years participated in the activity. Also, the first observation we made after this activity was that, although it seems like a relatively easy exercise, children need more time to learn to do it correctly. The best way to do it would be for the optometrist to take care of each child, in an individual training session, with patience and perseverance.

Figure no. 4. Children testing
Source: Authors' own research

Results
Of the children aged 5-6, most managed to execute the instructions correctly, but there were some of them who failed to draw the contour or did not recognize the geometric shapes. Most subjects failed to draw the contour continuously without lifting the pencil from the sheet, which suggests that tracking eye movements and hand-eye coordination are not fully developed. But this can also be explained by the reduced learning time of the exercise they had at their disposal.
Among the children under 5 years old, at least half of them did not perform the contour drawing at all, which suggests that the exercise in this form has too much difficulty for this age group.
A more appropriate shape for the age of 3-5 years would be the one in which the children execute this contour with the finger or if the board would have a friendlier shape. For example, it could be built in the form of a road, and the child will "draw" this outline with the help of a toy car.
The objective of this activity is for the subject to practice until he manages to draw the contour of the board through a uniform and continuous movement.

Conclusion

Eye movements produced in the same direction can also be considered guided and continuous movements or movements during reading, which are eye movements with saccades from one fixation to another. The behaviour of the visual function varies depending on the quality of the text, the degree of culture of the subject, the neuro-vegetative system, age, etc. There is a series of research showing eye behaviour during reading for different groups of people depending on these categories. This paper proposes a method of visual training for children learning to read. We thank the children for their involvement and devotion and Mrs. Ileana Plesa for the support offered in the development of this study.

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