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Eye tracker, binocular vision and oculomotor balance—exploratory study

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Abstract. We have analysed the vision direction with the Eye Tracker System ASL-model 504 of individuals with alterations of oculomotor balance or binocular vision, comparing them with individuals without those kinds of alterations. The sample was composed by 40 individuals, men and women, with ages between 18 and 23. They were distributed as follows: individuals with normal binocular vision (NBV) in binocular and monocular condition and with convergence insufficiency (CI). Significant differences were found between the studied groups, pointing out that the absence of binocularity, as the existing of convergence insufficiency, entail clearly a quality loss of the visual pursuit.

Keywords: Eye tracking; Binocular vision; Monocular vision; Convergence insufficiency; Fixation

1. Introduction

It is not clearly determined if vision provokes movement or if it is movement itself that provokes and propitiates the visual search and exploration. There is a multiplicity of data, supporting that the development of the motor sensory aspects are more rapidly and firmly acquired when there is a precise coordination between vision and movement [1].

Lack of concentration phenomena, localization mistakes and excessive visual effort is associated with binocular functions alterations and therefore they can restrict or even turn the daily routine in the different areas of the human activity impossible. The study of visual tracking will enable us to characterize the fixation and saccadic movement.

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2. Objective

The study aims to analyse the eye tracking of individuals with alterations of oculomotor balance or of the binocular vision, by comparing them with individuals without these alterations.

3. Methodology

The individuals' selection followed the criteria in Table 1.

The sample consisted of 40 individuals, men and woman, with ages between 18 and 23. They were divided into two groups. The first one was composed by individuals with normal binocular vision (NBV) evaluated in two different conditions (binocular and monocular). The second group was composed by individuals with convergence insufficiency (CI) (Table 2).

The Eye Tracker System ASL-504 was used to study the eye tracking behaviour of the two groups. The register process was based in the size of the pupil and in the corneal reflection [2]. The individuals were placed in front of a computer monitor at 50-cm distance, observing a small white target in a black background, moving in four directions (left–right; right–left; up–down; down–up).

To analyze eye tracking behaviour we used the following variables: number of fixations (left–right LRF; right–left RLF; up–down UDF; down–up DUF), number of inversions (left–right LRI; right–left RLI; up–down UDI; down–up DUI), mean duration of the fixation in seconds (left–right LRMD; right–left RLMD; up–down UDMD; down–up DUMD), mean saccadic amplitudes in visual angle degrees (left–right LRMA; right–left RLMA; up–down UDMA; down–up DUMA). The values of the variables were obtained from the data analysis using the EYENAL program.

The first part of our study includes the analyses of the above mentioned variables concerning the NBV group and CI group. The second one was concerned with the analyses of the two different conditions of NBV group (binocular and monocular).

4. Results

Using the Kolmogorov-Smirnov-Lilliefors and Shapiro-Wilk, we observed that the variables (LRMD, LRMA, RLMD, RLMA, UDMD, UDMA, DUMD, DUMA), had a normal distribution. A parametric test (t-test) was then used.

Concerning the variables LRF, LRI, RLF, RLI, UDF, UDI, DUF, DUI, a nonparametric test (Mann–Whitney, Wilcoxon) was used. The significance level used was $p \leq 0.05$.

Table 1
Including criteria

NBV Group	CI Group
Age ≥ 18 and ≤ 25	Age ≥ 18 and ≤ 25
V. Acuity RE and LE $\geq 8/10$	V. Acuity RE and LE $\geq 8/10$
Near convergence point ≤ 8 cm	Asthenopic symptoms
Near convergence $\geq 25^{\Delta}$ and $\leq 40^{\Delta}$	At least one of the following:
Near divergence $\geq 8^{\Delta}$ and $\leq 4^{\Delta}$	Near convergence point ≥ 11 cm
Near stereopsis $\leq 40''$	Near convergence $\leq 19^{\Delta}$
Maddox wing $\leq 4^{\Delta}$ X or E	Maddox wing $\geq 6^{\Delta}$ E

Table 2
Sample characterization

	Total sample			NBV Group			CI Group		
	N	Percent (%)	Mean age	*N*	Percent (%)	Mean age	*N*	Percent (%)	Mean age
Men	4	10	21.3	3	15.8	22.0	1	4.8	19
Women	36	90	20.3	16	84.2	20.1	20	95.2	20.6
Total	40	100	20.4	19	100	20.4	21	100	20.5

Table 3
Number of fixations and inversions—NBV and CI group

	Mann–Whitney test							
	LRF	LRI	RLF	RLI	UDF	UDI	DUF	DUI
Mann–Whitney *U*	111.500	189.500	68.500	127.500	156.500	198.500	160.000	198.500
Wilcoxon *W*	301.500	379.500	258.500	317.500	346.500	388.500	350.000	388.500
Z	−2.419	−0.320	−3.577	−2.129	−1.185	−0.029	−1.080	−0.030
Asymp. Sig. (2-tailed)	0.016	0.749	0.000	0.033	0.236	0.977	0.280	0.976

As for the comparison between the NBV group and CI group no significant differences were found in all variables except for the number of fixations from left–right and right–left directions, in the number of inversions from the right–left, as we can observe in Table 3, and in the variables mean duration of fixation and mean saccadic amplitudes (Table 4).

Table 4
Mean duration of fixation and mean saccadic amplitudes—NBV and CI group

t-test for equality of means			
Variables	*t*	df	Sig. (2-tailed)
LRMD	1.774	38	0.084
LRMA	2.254	38	0.030
RLMD	4.128	38	0.000
RLMA	1.043	38	0.303
UDMD	0.985	38	0.331
UDMA	0.897	38	0.376
DUMD	0.314	38	0.755
DUMA	0.114	38	0.910

Table 5
Number of fixations and inversions—NBV group binocular and monocular conditions

	Wilcoxon test							
	LRF2 LRF1	LRI2 LRI1	RLF2 RLF1	RLI2 RLI1	UDF2 UDF1	UDI2 UDI1	DUF2 DUF1	DUI2 DUI1
Z	−2.652 (a)	−1.485 (a)	−2.872 (a)	−0.796 (a)	−0.567 (a)	−0.225 (b)	−1.284 (a)	−1.551 (a)
Asymp. Sig. (2-tailed)	0.008	0.138	0.004	0.426	0.571	0.822	0.199	0.121

Table 6
Mean duration of fixation and mean saccadic amplitudes—NBV group binocular and monocular conditions

t-test-paired samples				
Variables		*t*	df	Sig. (2-tailed)
Pair 1	LRMD1-LRMD2	2.854	18	0.011
Pair 2	LRMA1-LRMA2	2.684	18	0.015
Pair 3	RLMD1-RLMD2	2.582	18	0.019
Pair 4	RLMA1-RLMA2	3.296	18	0.004
Pair 5	UDMD1-UDMD 2	0.923	18	0.368
Pair 6	UDMA1-UDMA 2	1.374	18	0.186
Pair 7	DUMD1-DUMD 2	1.074	18	0.297
Pair 8	DUMA1-DUMA 2	−0.564	18	0.580

In the last two variables (mean duration of fixation and mean saccadic amplitudes), we observed a significant difference in the saccadic amplitudes concerning the left–right direction and the mean duration of fixation in the opposite direction, right–left (Table 4).

Regarding the comparison between the two conditions of the NBV group (binocular and monocular), we observed the existence of significant differences in the number of fixations from left–right and right–left directions, as shown in Table 5.

Concerning the variables mean duration of fixation and mean saccadic amplitudes we also observed a significant difference in the saccadic amplitudes concerning the left–right and the right–left direction and the mean duration of fixation in the same two directions (Table 6).

5. Conclusions

The analysis of the studied variables showed that the absence of binocularity or the alterations of that condition, as in the convergence insufficiency, entail clearly a loss of the quality of visual pursuit.

In monocular conditions or in the presence of a convergence insufficiency, the mean duration of the fixations as well the saccadic amplitude is diminished.

In relation to the NBV group in binocular conditions the number of fixations and inversions presents lower values than the CI group and NBV group, in monocular conditions. Similar results concerning the number of fixations and inversions were found in a dyslexic children group when compared with a normal reading children group by Biscaldi [3].

It seams, thus, that binocular condition fixations and saccadic movements are more stable, showing that visual pursuit had a better accuracy when synergy and synchronism of the eyes are present as Pigassou-Albouy [4] pointed out.

A normal binocular vision guarantees a physiological answer in the movements of pursuit of the gaze, which contributes to added quality.

The maintenance or the re-establishment of normal binocular vision is fundamental for adequate visual comfort in the performance of daily life activities. The absence of normal binocular vision or other disturbances of the equilibrium of the oculomotor system require special attention because of the repercussions in the quality of life.

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