Perceptual-visual-motor measures, reading and properties of eye movements of students with attention deficit hyperactivity disorder

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Abstract
This study is aimed to compare and relate the performance of students with Attention Deficit Hyperactivity Disorder (ADHD) and with good academic performance in the perceptual-visual-motor and reading processes, and to verify the eye movements' pattern of students with ADHD during reading. Twenty students from primary school, both male and female, and aged between eight and twelve years old, participated in this study. They were divided into two groups: Group I (GI): composed of 20 students with an interdisciplinary diagnosis of ADHD, and Group II (GII): composed of 20 students with an equal good academic performance according to gender, age group and education with GI. All students were submitted to the Reading Processes Assessment protocol (PROLEC), Developmental Test of Visual Perception 3 (DTVP 3). PROLEC text reading test was administered to the students, also through the computer support. During this activity, the Gazepoint GP3 Eye Tracker equipment was used, which records the eye movements and analyses their properties by using the Gazepoint Analysis UX Edition Software for capturing eye movement during reading. These procedures were applied individually with students from both groups. The results were statistically analyzed, and revealed that the difficulties of students with ADHD in the reading processes could be justified by the perceptual-visual-motor deficit, and the shorter fixing time for capturing the information of each word read. This compromises the ability to identify and decode words, leading to difficulty in accessing meaning at the level of words and texts.
Keywords: Learning, Reading, Attention, Eye Movements, Assessment, Didactic Planning, Inclusive Didactic

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1. Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is defined as a behavioral disorder with manifestations of inattention, hyperactivity and impulsivity (DSM-5, 2013). ADHD is associated with challenges for functioning in daily life. Studies (Bölte *et al*., 2018) underline how the functioning profile of a person with ADHD can significantly be distant from the demands of life contexts.

Several critical issues may concern academic success and vocational maturity (Arnold *et al*., 2020), social inclusion (Shea and Wiener, 2003; Nguyen and Hinshaw, 2020) and overall the levels of Quality of Life experienced by people with ADHD (Quintero *et al*., 2019). For this reason, an interdisciplinary approach is essential. This type of approach leads us beyond medical reading, and fosters a systemic vision of the contexts and to the design of supports for the person's Quality of Life (Giaconi, 2015).

By accepting a vision of ADHD that goes beyond the mere analysis of the symptoms, and that can give a broader and more complex vision of a functioning profile and its strengths, this study intends to detect specific contextual factors that can influence the school performance of a child with ADHD. The aim is to design new facilitators that can support the school performance of ADHD' students, and generate inclusive cultural contexts.

The studies by Jung (2014) and Huberle (2010) reported that children with ADHD have learning difficulties due to changes in visual skills compromising perception and visual temporal resolution responsible for the ability to copy and read, in addition to impaired balance skills, visual-motor and motor coordination and posture.

Students with ADHD present impairment in executive function, which encompasses all the processes responsible for planning, focusing, guiding, directing and integrating cognitive functions, including alertness, sustained and selective attention. As a result of these changes, students present difficulty in learning the phonological and metaphonological skills of language, thereby compromising future acquisitions, such as reading. Reading skills require: cognitive and perceptual-linguistic skills, which include attention directed to printed symbols and control of eye movements across the page, ability to focus, concentrate and follow instructions; ability to understand and interpret the language spoken in everyday life; auditory memory and ordering; visual memory and ordering; skills in word processing; structural and contextual analysis of the language; logical synthesis and interpretation of language; vocabulary development and expansion; fluency in reading (Oliveira *et al*., 2017).

However, to better understand the alterations that occur in students with

ADHD when reading, it is necessary to understand that reading is performed via eye movement and that among the main properties of this movement are the fixations and saccadic movements. Fixations are brief periods during which the eye examinates a small area of the stimulus. The movement that the eye performs to the fixation area is called a saccade. The primary function of fixation is to analyze the text in detail in the foveal field, where the information is more easily obtainable, in contrast to the parafoveal and peripheral regions (Raney *et al*., 2014).

In light of the above, this study is based on the hypothesis that the patterns of eye movements and altered visual skills in schoolchildren with ADHD may impair performance in decoding skills at the level of words, phrases and text, thus compromising their reading comprehension skills. The results show how these studies can be important for educational and didactic planning and the programming of the supports necessary for the choice of the visual organization supports, the organization of the reading page and the personalization of activities.

2. Eye tracking: a research with students with ADHD

This study aimed to compare and relate the performance of students with ADHD against those with good academic performance in the perceptual-visual-motor and reading processes and to verify the pattern of eye movements during reading by students with ADHD.

The Research Ethics Committee approved the project of the Faculty of Philosophy and Sciences, São Paulo State University "Júlio de Mesquita Filho" (UNESP), under protocol number 5873.1316.6.00005406.

The study is a prospective observational cross-sectional study with a comparison among groups. The sample was collected between August 2017 and February 2020 at Investigation Learning Disabilities Laboratory (LIDA) at the Department of Speech and Hearing Sciences, São Paulo State University "Júlio de Mesquita Filho" (UNESP), Marilia, São Paulo, Brazil.

The participants were twenty female and male students, aged 9 to 11 years and 11 months, who attended the 4th and 5th grade level of Elementary School I of the public school of Marília City, with a medium socioeconomic level. The children were divided into two groups:

- Group I (GI): composed of 10 students with an interdisciplinary diagnosis of ADHD carried out by an interdisciplinary team from the Learning Deviations Research Laboratory of the Specialized Center for Rehabilitation – CER II/FFC/UNESP – Marília-SP.
- Group II (GII): composed of 10 schoolchildren with good academic

performance paired according to sex, age group and education with GI students.

The students were evaluated in person, following the procedures of this research and following the guidelines described in the Normative Instructions Prope nº 01[1] concerning the spread of the Covid-19 virus, and following with the recommendations of the World Health Organization (WHO), regarding the correct use of equipment for personal protection (PPE) by the researcher, such as: goggles, face shield, surgical mask, impermeable long-sleeved apron and medical gloves.

All students in this study underwent individual application of the following procedures in a distraction-free, well-ventilated, well-lit, quiet and comfortable environment.

For the purposes of the study, the following tests and technologies were applied:

1. Developmental Test of visual Perception 3 (DTVP-3) (Hammill, Pearson, Voress, 2014);
2. Evaluation of Reading Processes – PROLEC (Capellini, Oliviera, Cuetos, 2010);
3. The capture of eye movements during reading.

The study started with the DTVP-3 test (Hammill, Pearson, Vorres, 2014). This test consists of a battery of five subtests that measure different visual skills. It can be applied for four purposes, namely: (a) identifying children with Visual-Motor Integration or visual perception problems; (b) determining the degree of severity of these problems; (c) verifying the effectiveness of intervention programs designed to correct problems; and (d) serve as a measurement tool in investigations and research. Each test measures a type of visual reception capacity and can be considered as motor-reduced skills subtest (Figure-Ground, Visual Closure and Form Constancy), General Visual Perception (copying, eye-hand coordination, Figure-Ground, Visual Closure, and Form Constancy), Visual-Motor Integration (copying and eye-hand coordination). The subtests composing DTVP-3 applied to the population of this study are shown below in Table 1.

The DTVP 3 Index is divided into: standard score, which is obtained from the gross score and its conversion using tables, and composite score, obtained by adding the standard scores and converting it into a classificatory quotient in relation to the general visual perception of motor-reduced perception skills and visual-motor integration. All evaluated functions allow the calculation of an age equivalent (AE), that is, for each evaluated function; the score obtained allows the calculation of an "age of visual perception".

[1] https://www2.unesp.br/portal#!/prope/apoio-ao-pesquisador/orientacoes-covid-19/.

After the Test of Visual Perception, students attend the Evaluation of Reading Processes – PROLEC (Capellini, Oliviera, Cuetos, 2010). This evaluation consists of four blocks distributed for the evaluation of four reading processes, as described below:

1. Administration of two tests: the letter identification test and the proof of equality and difference in words and pseudowords.
2. Administration of four tests: the lexical decision test, two word reading tests and test for the analysis of the use of phonological and lexical routes for reading.
3. Administration of two test: the grammatical structures test and the test of punctuation marks
4. Administration of two tests: comprehension of sentences and comprehension of texts.

Going inside the first block, the process is composed of two tests: the letter identification test aims to verify the student's ability to name the letters and the sound representing them. The proof of equal and different in words and pseudowords aims to verify the student's ability to identify, discriminate and recognize real and invented words as being equal/different.

The second block concerning the lexical processes is composed of four tests. In the lexical decision test, the student must recognize only real words in a list of both real and invented words. In the word reading tests, reading of pseudowords and reading of words and pseudowords, the student must perform the reading of real words and invented words, with the first test measuring the ability of the student to read real words and in the second, the ability to read invented words of different syllabic complexities, divided into CCV, VC, CVC, CVV, CCVC and CVVC. In the third test, the objective is to analyze the use of phonological and lexical routes for reading. For this, words and pseudowords belonging to six categories were used: short high-frequency words, long high-frequency words, short low-frequency words, long low-frequency words, short pseudowords and long pseudowords.

The third block concerning the syntactic processes is composed of two tests. In the grammatical structures test, the student's ability to choose a sentence from different syntactic structures is verified: active voice, passive voice and focused complement. In the test of punctuation marks, the ability of schoolchildren to use punctuation marks in a short text is verified.

The last block refers to the semantic processes and is composed of two tests: comprehension of sentences and comprehension of texts. In these two tests, the student's ability to understand simple orders, phrases and written texts is verified.

The GI students were submitted to the PROLEC text reading procedures presented on the screen of a desktop computer, where the Gazepoint GP3 Eye

Tracker equipment was attached, which recorded the eye movements during the reading of the texts. The Gazepoint Analysis UX Edition Software was used to analyze the parameters of eye movements such as: time viewed in seconds, time viewed as a percentage, number of fixations and revisits.

Before data collection, the equipment was calibrated with each student, in order to guarantee the effectiveness of the analysis. The capture fields were selected according to the lines of text that were presented. Each text presented was displayed on the screen for 60 seconds; after that time, another text was shown on the screen. After the presentation of the four texts, the analysis was automatically closed (Figure 1).

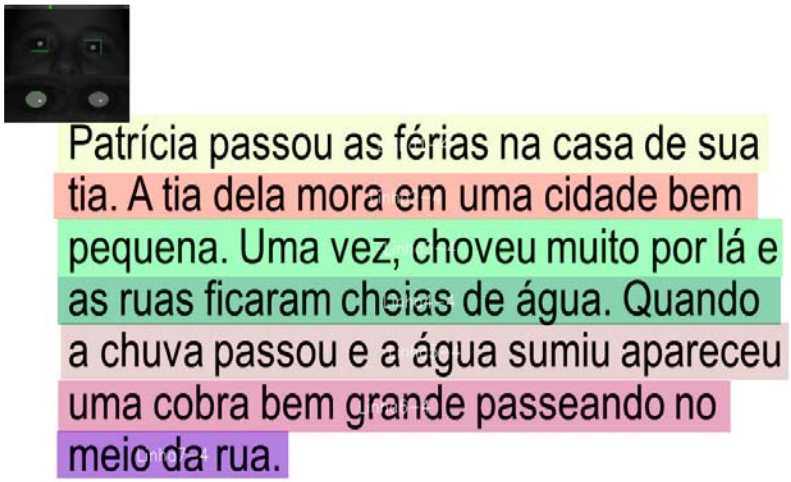

Fig.1 - Image generated by the Software Gazepoint Analysis UX Edition for capturing eye movements during reading

The data obtained were analyzed statistically in order to compare the intragroup and intergroup results. The program IBM SPSS Statistics (Statistical Package for the Social Sciences), version 25.0, was used to obtain and analyze the results.

The results were analyzed statistically using the following tests, Mann-Whitney Test, Likelihood Ratio Test, and Spearman's Correlation Analysis aiming to verify the intergroup differences studied for the variables of interest in the DTVP 3.

Spearman's Coefficient was used in the correlation analysis for variables with non-parametric distributions to measure the degree of association between two quantitative variables of interest. In this analysis, the coefficient varies from -1 to +1, and the closer to these two extremes, the greater the association between the variables. Positive direction indicates a linear relationship, that is,

the variables are directly proportional; negative direction indicates that when there is an increase in one variable, there is a decrease in the other, or that is, the variables are inversely proportional (Zou; Tuncali; Silverman, 2003).

The results were analyzed statistically at a significance level of 5% (0.050). The results that showed a statistically significant difference were highlighted with an asterisk (*)

3. Results and Discussion

Table 1 shows the data regarding the mean, standard deviation and p-value for comparing the visual-motor perceptual performance of schoolchildren in GI and GII.

Tab. 1 - Comparison of the performance of GI and GII students in the subtests of the Developmental Test of Visual Perception 3 (DTVP-3)

Subtests	Groups	Mean	SD	p Value
EH	I	7.80	3.29	0.057
	II	10.50	1.72	
CO	I	11.20	2.10	0.001*
	II	17.30	3.30	
FG	I	10.60	1.78	0.144
	II	12.20	2.44	
VC	I	8.60	2.76	0.170
	II	10.10	1.60	
FC	I	11.10	3.07	0.156
	II	12.80	1.87	
EH-AE	I	6.80	2.66	0.014*
	II	9.90	1.91	
CO-AE	I	9.90	2.18	0.019*
	II	11.80	0.63	
FGAE	I	9.10	2.81	0.005*
	II	12.00	0.00	
VC-AE	I	7.60	2.99	0.114
	II	9.60	2.32	
FC-AE	I	10.20	2.94	0.031*
	II	12.00	0.00	

EH-GVP	I	7.80	3.29	0.057
	II	10.50	1.72	
CO-GVP	I	12.20	3.08	0.006*
	II	17.30	3.30	
FG-GVP	I	10.60	1.78	0.144
	II	12.20	2.44	
VC-GVP	I	8.60	2.76	0.170
	II	10.10	1.60	
FC-GVP	I	11.10	3.07	0.156
	II	12.80	1.87	
FG-MRP	I	10.60	1.78	0.144
	II	12.20	2.44	
VC-MRP	I	8.60	2.76	0.170
	II	10.10	1.60	
FC-MRP	I	11.10	3.07	0.156
	II	12.80	1.87	
EH-VMI	I	7.80	3.29	0.057
	II	10.50	1.72	
CO-VMI	I	12.20	3.08	0.006*
	II	17.30	3.30	

Key - CMV- Visual motor coordination, EH- Eye-hand coordination, CO- Copying. FG- Figure-ground, VC- Visual closure, FC- Form constancy, GVP- General visual perception, MRP- motor-reduced visual perception, VMI- Visual-motor integration, AE- Age equivalent

With the application of the Mann-Whitney Test, it was possible to verify the inferior performance of GI in comparison to GII in the subtests of Copy, Age Equivalent, General Visual Perception and Visual Motor Integration, in the subtest of Eye-Hand Coordination as part of the Age Equivalent and the Figure-Ground subtest as part of the Age Equivalent

Table 2 presents the data regarding mean, standard deviation and p-value for comparing performance in the reading processes of the schoolchildren in GI and GII.

Tab. 2 - Comparison of the performance of students from GI and GII in the subtests of the Reading Processes – PROLEC

Subtests	Group	Mean	SD	p Value
LNS	I	18.10	2.60	0.030*
	II	20.00	0.00	

ED	I	16.20	5.45	0.005*
	II	20.00	0.00	
LD	I	22.50	8.95	< 0.001*
	II	30.00	0.00	
RW	I	24.80	8.48	0.013*
	II	30.00	0.00	
RPW	I	20.00	10.25	0.001*
	II	30.00	0.00	
RFW	I	16.30	4.60	0.002*
	II	20.00	0.00	
RNFW	I	16.30	4.81	0.002*
	II	20.00	0.00	
RPW2	I	15.40	5.48	0.002*
	II	20.00	0.00	
GS	I	10.20	4.49	< 0.001*
	II	15.00	0.00	
PM	I	11.70	5.85	0.103
	II	10.00	0.00	
SC	I	9.70	3.23	0.013*
	II	12.00	0.00	
TC	I	8.50	4.70	0.001*
	II	14.40	0.70	

Key - LNS- Letter name or sound, E-D- Equal and different, LD- Lexical decision, RW- Reading words, RPW- Reading pseudowords, RFW- Reading frequent words, RNFW- Reading non-frequent words, RPW2- Reading pseudowords 2, GS- Grammatical structure, PM- Punctuation marks, SC- Sentence comprehension, TC- Text comprehension.

With the Likelihood Ratio Test application, it was possible to verify inferior performance of GI in comparison to GII in all PROLEC tests except for the punctuation mark test.

Table 3 shows the data comparing the performance classification in the PROLEC reading processes of students from GI and GII.

Table 3 - Comparison of the performance classification in the PROLEC reading processes of GI and GII

Subtests	**Classification**	**Group**				**p Value**
		I		**II**		
		Freq.	**%**	**Freq.**	**%**	
LNS	VD	4	40.00	0	0.00	0.025*
	D	0	0.00	0	0.00	
	N	6	60.00	10	100.00	

ED	VD	5	50.00	0	0.00	0.014*
	D	1	10.00	0	0.00	
	N	4	40.00	10	100.00	
LD	VD	3	30.00	0	0.00	0.014*
	D	3	30.00	0	0.00	
	N	4	40.00	10	100.00	
WR	VD	3	30.00	0	0.00	0.082
	D	1	10.00	0	0.00	
	N	6	60.00	10	100.00	
RPW	VD	5	50.00	0	0.00	0.010*
	D	0	0.00	0	0.00	
	N	5	50.00	10	100.00	
RFW	VD	5	50.00	0	0.00	0.005*
	D	2	20.00	0	0.00	
	N	3	30.00	10	100.00	
RNFW	VD	2	20.00	0	0.00	0.036*
	D	3	30.00	0	0.00	
	N	5	50.00	10	100.00	
RPW2	VD	3	30.00	0	0.00	0.036*
	D	2	20.00	0	0.00	
	N	5	50.00	10	100.00	
GS	VD	3	30.00	0	0.00	0.060
	D	0	0.00	0	0.00	
	N	7	70.00	10	100.00	
PM	VD	0	0.00	0	0.00	0.305
	D	1	10.00	0	0.00	
	N	9	90.00	10	100.00	
SC	VD	3	30.00	0	0.00	0.036*
	D	2	20.00	0	0.00	
	N	5	50.00	10	100.00	
TC	VD	5	50.00	0	0.00	0.005*
	D	2	20.00	0	0.00	
	N	3	30.00	10	100.00	

Key-LNS- Letter name or sound, E-D- Equal and different, LD-Lexical decision, RW- Reading words, RPW-Reading pseudowords, RFW-Reading frequent words, RNFW-Reading non-frequent words, RPW2-Reading pseudowords 2, GS-Grammatical structure, PM-Punctuation marks, SC-Sentence comprehension, TC-Text comprehension, N- Normal, D-Difficult, VD- Very difficult.

With the application of the Likelihood Ratio Test, it was possible to determine the differences between the groups regarding the classification of the

PROLEC reading processes, revealing a statistically significant difference in the comparison between GI and GII. GII presents normal classification in all subtests compared to GI. In contrast, GI presents normal classification in the subtests of Letter name or sound, Lexical decision, Reading non-frequent words, Reading pseudowords 2, and Sentence comprehension.

However, Table 3 also reveals that the GI has a classification of great difficulty in the subtests of Equal and different, Reading frequent words and Text comprehension.

According to the national literature, schoolchildren with ADHD have motor-visual-perceptual alterations. The findings of this research corroborate other studies (Okuda *et al*., 2011; Pinheiro, Lourenceti, Santos, 2010; Metzner, Santos, Capellini, 2019) that pointed out the motor-visual-perceptual difficulties present in schoolchildren with ADHD when compared with the control group.

Jung and collaborators (2014) reported that children with ADHD have learning problems that may be due to changes in visual skills compromising the perception and visual-temporal resolution responsible for the ability to copy and read, in addition to impairment of visual-motor coordination abilities.

Students with ADHD have reduced inhibitory control and impairments in selective and sustained attention skills, working memory, and concentration to quickly process visual information (Cortez, De Souza, Pinheiro, 2019).

The same occurs when comparing the performance in the reading processes of schoolchildren with ADHD and the one of the control group: these students have inferior performance in comparison to students with good academic performance in tasks that involve the four reading processes (Letter identification, lexical, syntactic and semantic processes) (Oliveira, 2017).

The findings of this study proposed to go beyond a comparative study between groups to relate the motor-visual-perceptual findings and reading processes, in the attempt to seek an explanation for the reading difficulties among students with ADHD.

Tables 4 and 5 present the studies of the relationship between the variables of this research.

Table 4 shows study results of the relationship between the performance of GI students in the subtests of the Developmental Test of Visual Perception 3 and reading processes.

Tab. 4 – Distribution of the correlation between the performance of GI students in the subtests of the Developmental Test of Visual Perception 3 (DTVP-3) and reading processes (PROLEC)

Subtests	Correl. Coef.	EH-GVP	SC-GVP	FG-GVP	VC-GVP	FC-GVP	FG-MRP	VC-MRP	FC-MRP	EH-VMI	CO-VMI
LNS	Correl. Coef. (r)	0.243	-0.061	0.305	0.482	-0.289	0.305	0.482	-0.289	0.243	-0.061
	p Value	0.498	0.867	0.392	0.159	0.418	0.392	0.159	0.418	0.498	0.867

ED	Correl. Coef. (r)	0.184	0.682	0.577	0.524	0.044	0.577	0.524	0.044	0.184	0.682
	p Value	0.611	0.030*	0.081	0.120	0.904	0.081	0.120	0.904	0.611	0.030*
LD	Correl. Coef. (r)	0.576	0.685	0.796	0.498	-0.006	0.796	0.498	-0.006	0.576	0.685
	p Value	0.082	0.029*	0.006*	0.143	0.986	0.006*	0.143	0.986	0.082	0.029*
WR	Correl. Coef. (r)	0.402	0.105	0.275	0.720	< 0.001	0.275	0.720	< 0.001	0.402	0.105
	p Value	0.250	0.773	0.442	0.019*	1.000	0.442	0.019*	1.000	0.250	0.773
RPW	Correl. Coef. (r)	0.400	0.527	0.438	0.527	0.117	0.438	0.527	0.117	0.400	0.527
	p Value	0.253	0.117	0.206	0.118	0.748	0.206	0.118	0.748	0.253	0.117
RFW	Correl. Coef. (r)	0.525	0.585	0.508	0.576	0.006	0.508	0.576	0.006	0.525	0.585
	Valor de p	0.119	0.076	0.134	0.081	0.986	0.134	0.081	0.986	0.119	0.076
RNFW	Correl. Coef. (r)	0.458	0.531	0.487	0.614	0.037	0.487	0.614	0.037	0.458	0.531
	p Value	0.184	0.114	0.153	0.059	0.919	0.153	0.059	0.919	0.184	0.114
RPW2	Correl. Coef. (r)	0.428	0.561	0.461	0.553	0.161	0.461	0.553	0.161	0.428	0.561
	p Value	0.218	0.091	0.180	0.097	0.657	0.180	0.097	0.657	0.218	0.091
GS	Correl. Coef. (r)	0.431	0.671	0.619	0.623	0.120	0.619	0.623	0.120	0.431	0.671
	p Value	0.214	0.034*	0.056	0.054	0.742	0.056	0.054	0.742	0.214	0.034*
PM	Correl. Coef. (r)	0.771	0.553	0.739	0.634	-0.039	0.739	0.634	-0.039	0.771	0.553
	p Value	0.009*	0.098	0.015*	0.049*	0.915	0.015*	0.049*	0.915	0.009*	0.098
SC	Correl. Coef. (r)	0.632	0.492	0.421	0.403	0.150	0.421	0.403	0.150	0.632	0.492
	p Value	0.050	0.149	0.226	0.248	0.680	0.226	0.248	0.680	0.050	0.149
TC	Correl. Coef. (r)	0.539	0.198	0.717	0.922	-0.064	0.717	0.922	-0.064	0.539	0.198
	p Value	0.108	0.584	0.020*	< 0.001*	0.860	0.020*	< 0.001*	0.860	0.108	0.584

Key- LNS- Letter name or sound, E-D- Equal and different, LD- Lexical decision, RW- Reading words, RPW- Reading pseudowords, RFW- Reading frequent words, RNFW- Reading non-frequent words, RPW2-

Reading pseudowords 2, GS- Grammatical structure, PM- Punctuation marks, SC- Sentence comprehension, TC- Text comprehension, VMC- Visual motor coordination, EH- Eye-hand coordination, CO- Copying, FG- Figure-ground, VC- Visual closure, FC- Form constancy, GVP- General visual perception, MRP- motor-reduced visual perception, VMI- Visual-motor integration

With the application of Spearman's Correlation Analysis, it was possible to verify that there was a relationship between the subtests of PROLEC with the visual-motor skills of DTVP-3 in the students of GI.

In Table 4 it was possible to observe that there was a weak positive relationship between the skills of Equal and different and Copying, as part of the general visual perception and visual-motor integration, demonstrating that the ability to identify similarities and differences in words is related, even if weakly, with perception and details, which is a skill present in copying.

In the Lexical decision ability it was possible to verify that there was a weak positive relationship with Copying abilities, as part of the general visual perception and visual-motor integration, revealing, as in the Equal and different task, that the ability to identify similarities and differences between words and, specifically in the Lexical decision task, pseudowords also have a relationship, albeit weak, with perception and details, which is a skill required in copying.

However, between the lexical decision and figure-ground ability, as part of the general visual perception and visual-motor integration, there was a moderate positive relationship showing that the figure-ground skill is necessary to quickly decide whether a word is real or invented, when words are offered simultaneously to the child.

In the ability to Read words it was possible to verify that there was a weak positive relationship with the skills of Visual closure, as part of the general motor-reduced visual perception and skills, demonstrating that to perform the decoding task it is necessary to recognize each part of the letters forming the words.

In the grammatical structures ability it was possible to observe that there was a weak positive relationship with the ability to copy, as part of the general visual perception and visual-motor integration, revealing that the ability to identify sentences grammatically has a relationship, even if weak, with the perception and details, which is a skill present in the copying.

In the Punctuation marks skill, it was possible to verify that there was a weak positive relationship with the Eye-hand coordination skill, as part of the General visual perception and Visual-motor integration, with the Figure-ground ability, as part of the General visual perception and Reduced mobility, and with the ability of Visual closure, as part of the General visual perception, demonstrating that for the child to identify and use punctuation marks during reading, visual-motor coordination, image and parts of image recognition are necessary for insertion of the stimulus, in this case the punctuation, in a visual sensory context.

In the Text comprehension skills it was possible to verify that there was a weak positive relationship with the skills of Figure-ground, as part of General visual perception and motor-reduced skills, with the ability of visual closure as part of motor-reduced skills and general visual perception, showing that, to understand a read text it is necessary to recognize each part of the letters that form the words to perform the decoding, at the same time that it is necessary to select a single image, in this case the word, in a visual sensory context for consecutive extraction of the meaning..

Table 5 shows the results of the study of the relationship between the capture variables and the eye movements of GI.

Tab. 5 – Distribution of the correlation between the variables for capturing of eye movements in GI

Variables	Correlation	Time to 1st View (sec)	Time Viewed (sec)	Time Viewed (%)	Fixations
Time Viewed (sec)	r	-0.012			
	p Value	0.888			
	N	138			
Time Viewed (%)	r	-0.012	1.000		
	p Value	0.886	< 0.001*		
	N	138	138		
Fixations	r	-0.049	0.923	0.923	
	p Value	0.568	< 0.001*	< 0.001*	
	N	138	138	138	
Revisits	r	-0.129	0.830	0.830	0.944
	Sig. (p)	0.132	< 0.001	< 0.001	< 0.001
	N	138	138	138	138

r = Pearson's correlation coefficient

Following the application of Spearman's Correlation Analysis, it was possible to verify that there was a strong negative relationship between the time viewed and the time viewed in seconds; between fixations and time viewed in seconds and the time viewed; and between revisits and time viewed in seconds, the time viewed and fixations.

These findings show that students with ADHD present lower letter capture, shorter fixations and lower number of revisits, demonstrating that the longer the time and the percentage of visualization, the shorter the time of fixing the word during the reading, probably due to changes in inhibitory control.

The data from the study of the relationship between the performance of GII students in the subtests of the Developmental Test of Visual Perception 3 and

reading processes were constant for all variables; therefore, it is not necessary to present them here.

Based on the findings of the relationship studies, it is important to consider that the reading input system is the visual system and, therefore, that there is a relationship between the investigated skills which can offer better foundation and knowledge about the type of educational or clinical intervention that can be performed for schoolchildren with ADHD.

This study reveals that the perceptual-visual-motor deficit can explain the difficulties of students with ADHD in the reading processes, and the shorter fixation time for capturing the information of the word read. That difficulty compromises the ability to identify and decode the words, causing difficulty in accessing meaning at the level of words and texts.

A study carried out by Metzner, Santos, Capellini (2019) demonstrated that students with attention problems have a lower performance in perceptual-visual tasks, due to changes in visual processing that are typical of this diagnosis.

Students with ADHD present changes in the executive function, encompassing all the processes responsible for planning, focusing, guiding, directing and integrating cognitive functions, including alertness, sustained and selective attention. As a result of these changes, these students have difficulty in learning the phonological and metaphonological skills of language, compromising later acquisitions, such as reading. Reading skills require cognitive and perceptual-linguistic skills, which include attention directed to printed stimuli and control of eye movements across the page, ability to focus attention, concentration and following instructions; ability to understand and interpret the language spoken in everyday life; auditory memory and ordering; visual memory and ordering; skill in word processing; structural and contextual analysis of the language; logical synthesis and interpretation of the language; vocabulary development and expansion; fluency in reading (Oliveira, 2011, Capellini. Metzner, 2020).

However, to better understand the changes occurring in the reading of students with ADHD, it is necessary to understand that reading is performed from the eye movement and that among the main properties of this movement are the fixations and saccadic movements. Fixations are brief periods of time during which the eye remains examining a small area of the stimulus. The movement that the eye performs to the fixation area is called a saccade. The main function of fixation is to analyze the text in detail in the foveal field, where information is more easily obtainable, unlike the parafoveal and peripheral regions (Raney *et al*., 2014; Gräf *et al*., 2019).

After the analysis of the findings, we can see that the hypothesis of this study was confirmed, as it proved that the patterns of eye movements and altered perceptual-visual-motor skills in schoolchildren with ADHD can compromise

performance in word-level decoding skills of the phrases of the text, thus compromising their reading comprehension skills.

4. Conclusion and reflections for an inclusive planning

The results were statistically analyzed, and revealed that the difficulties of students with ADHD in the reading processes can be explained by the perceptual-visual-motor deficit, and the shorter fixing time for capturing the information of the word read, which compromises the ability to identify and decode words, causing difficulty in accessing meaning at the level of words and texts.

While ADHD is predominantly operationalized in terms of its symptoms, the inter-individual differences in the functioning profiles of people with ADHD and their strengths suggest the importance of proceeding with the detection of the different contextual factors capable of supporting their performance and address the personalization of training programs (Giaconi *et al*., 2019). The results of the study allow us to conduct interesting pedagogical-didactic reflections. Especially in the Italian context, the attention to the realization of didactic planning awake of the diversity of students [specifically of the personalized didactic plans (PDP), aligned with curricular programming, in case of students with ADHD], allows us to get to the heart of the issue of inclusive education (Giaconi and Capellini, 2015).

The role of eye movements in reading processes and, in particular, the correlation between reading difficulties and the alteration of eye movements are dimensions well illustrated by the literature of the sector (Huettig and Brouwer; Robertson and Gallant, 2019; Prabh and Bhargavi 2020; Rivero-Contreras, Engelhardt and Saldaña, 2021) and in which our studio is also part.

Specifically, these findings are important for both assessment and intervention protocols for children with ADHD (Lev *et al*., 2020; Levantini *et al*., 2020; Siqueiros Sanchez *et al*., 2020), and for the preparation of inclusive educational projects at school.

This last issue, less studied in the literature, enables the inclusion of specific aspects in teachers' training courses and support teachers. In this way, it will be possible to design inclusive teaching paths and personalization paths for students who show these difficulties in eye movements.

In this last direction, the results of our study can also provide useful information on how:

- re-adapt the written text on a reading page;
- re-adapt the combination of the written text and the images present in a reading page;

- choose the organized visual supports used during the lessons;
- provide support indications to the students themselves who are going to personalize their study method and to choose by their own the better visual organization support.

Within the research perspectives, investigation protocols are being designed. These will also allow teachers to acquire information on the eye movements of the pupils in a class in order to act with targeted didactic strategies. After the observation tests, the main areas of intervention concern the aspects of re-adaptation of the written text and its organization; the identification of the visual organization supports (e.g. concept maps) most relevant for the understanding of the concepts; the planning of paths that allow the students themselves to customize, based on their needs, the text to read and to study, as well as the visual organization support to be used to facilitate the elaboration of the different concepts studied.

Finally, particular attention will be placed on the construction of tools for self-assessment in such a way as to favour the self-determination (Del Bianco, 2019) of the students themselves in the personalization process towards an effective and efficient study method (Giaconi *et al*., 2019) useful along the study path from school to University.

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