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The relationship between neurodevelopmental factors and written elaboration by children at elementary school

Relação entre fatores do neurodesenvolvimento e a elaboração escrita em crianças do ensino fundamental

Relación entre factores de neurodesarrollo y escritura en niños de la educación primaria

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Angela Cristina Pontes Fernandes[1]
Marielle Martins Santos[2]
Patrícia Aparecida Zuanetti[3]
Ana Paula Andrade Hamad[4]

The objective of this study was to analyze whether the cognitive skills of executive and visuospatial control are related to impaired performance in the writing of elementary school children, with school complaints (behavioral or learning). Seventy medical records of children aged 6 to 10 years attended in a specialized outpatient clinic, from 2013 to 2018 were analyzed. Forty out of seventy children were considered. They were divided into two subgroups, with and without difficulty in writing. Characterization data, neuropsychomotor development, previous interventions and performance in neuropsychological assessment were collected regarding executive and visuospatial control skills. Logistic regression with LASSO was used in the statistical evaluation. The results suggest a positive relationship between the history of language integrity/reading development and the coherent construction of the narrative and the school experience as an important variable in the process of improving the level of written coherence. The non-linguistic variable (visuospatial ability) was not directly associated with the processing of writing.
Descriptors: Child development; Handwriting; Neuropsychology.

O objetivo deste estudo foi analisar se as habilidades cognitivas de controle executivo e visuoespacial se relacionam a desempenho prejudicado na elaboração da escrita em crianças do ensino fundamental, com queixa escolar (comportamental ou de aprendizagem). Foram analisados 70 prontuários de crianças de 6 a 10 anos, atendidas em ambulatório especializado, de 2013 a 2018. Desse total, foram consideradas 40 crianças, as quais foram divididas em dois grupos, com e sem dificuldade na elaboração escrita. Coletaram-se dados de caracterização, desenvolvimento neuropsicomotor, intervenções prévias e desempenho na avaliação neuropsicológica quanto às habilidades de controle executivo e visuoespaciais. A regressão logística com o LASSO foi utilizada na avaliação estatística. Os resultados sugerem uma relação positiva entre o histórico de integridade da linguagem/desenvolvimento da leitura e a construção coerente da narrativa e, a experiência escolar como variável importante no processo de aprimoramento do nível de coerência escrita. A variável não linguística (habilidade visuoespacial) não se mostrou diretamente associada ao processamento da escrita.
Descritores: Desenvolvimento infantil; Escrita manual; Neuropsicologia.

El objetivo de este estudio fue analizar si las habilidades cognitivas del control ejecutivo y visoespacial están relacionadas con el rendimiento deficiente en la escritura de niños de primaria, con quejas escolares (conductuales o de aprendizaje). Se analizaron setenta registros médicos de niños de 6 a 10 años, atendidos en una clínica ambulatoria especializada, de 2013 a 2018. De este total, se consideraron 40 niños, que se dividieron en dos grupos, con y sin dificultad para escribir. Los datos de caracterización, el desarrollo neuropsicomotor, las intervenciones previas y el rendimiento en la evaluación neuropsicológica se recopilaron en términos de habilidades de control ejecutivo y visoespacial. La regresión logística con LASSO se utilizó en la evaluación estadística. Los resultados sugieren una relación positiva entre la historia de la integridad del lenguaje / desarrollo de la lectura y la construcción coherente de la narrativa, y la experiencia escolar como una variable importante en el proceso de mejorar el nivel de coherencia escrita. La variable no lingüística (capacidad visoespacial) no se asoció directamente con el procesamiento de la escritura.
Descriptores: Desarrollo infantil; Escritura manual; Neuropsicobiología.

1. Psychologist. Specialist in Neuropsychology. Master in Philosophy and Methodology of Sciences. PhD in Psychology. Professor at Universidade Paulista (UNIP), Ribeirão Preto, SP, Brazil. ORCID: 0000-0002-0852-2538 E-mail: angela.fernandes1@docente.unip.br
2. Psychologist. Ribeirão Preto, SP, Brazil. ORCID: 0000-0002-7801-6219 E-mail: mari.martiins@hotmail.com
3. Speech therapist. Language Specialist. Master in Ophthalmology, Otorhinolaryngology and Neck Surgery. PhD in Psychobiology. Speech therapist at Hospital das Clínicas, Ribeirão Preto Medical School, University of São Paulo (HC-FMRP-USP) - Ribeirão Preto, SP, Brazil. ORCID: 0000-0002-9847-2246 E-mail: pati_zua@yahoo.com.br
4. Doctor. Specialist in Child Neurology. Specialist in Epilepsy and Clinical Neurophysiology. Specialist in Pediatric Epilepsy. Specialist in Clinical Neurophysiology (Electroencephalography). Specialist in Neurology. Master and PhD in Neurology and Neurosciences. Professor at FMRP, Ribeirão Preto, SP, Brazil. ORCID: 0000-0002-1884-7264 E-mail: anahamad@fmrp.usp.br

INTRODUCTION

Writing skills are of paramount importance in the lives of all human beings who are in a literate society, one of the most remarkable intellectual and cultural achievement of humanity[1]. Writing efficiently involves learning the technique of writing as well as its social use which makes the use of language and the propagation of culture possible[2].

Writing was and is primarily important for human beings since the time of caves, when man could express himself through cave paintings with a sense of informing about something that had happened. This form of communication can be compared to the drawing of a child who has not yet acquired writing and can be expressed through somewhat symbolic doodles[3].

In this sense, the ability to write occurs long before the first time a child begins to learn to write inside a classroom and, for that, one must be aware of how this process starts in a child's life until the moment of literacy at school[4].

The acquisition and development of writing is not linear and comes from the child's need to be inserted in society. Thus, it would be necessary to understand the writing acquisition process of the child before submitting him to the systematic process of literacy and, therefore, for a child to be able to have appropriate writing skills, it is necessary to have been exposed to other previous stages in life[5].

In Brazil, government statistics show that reading and writing difficulties persist as one educational problem that has not been overcome yet. In 2017, the survey of the Basic Education Assessment System - SAEB pointed out that only 11.9% of Brazilian children had an adequate level of reading and writing in the 5th year of elementary school and that this difficulty was accentuated in high school with only 1.6% of adolescents in an adequate level of development in the Portuguese language[6].

As a human cognitive function, language, whether oral or written, can only be understood through the study of the brain[7]. Neuropsychological functions, including writing, began to be seen as something that develops in the interdependence of several factors, through a dynamic and continuous interaction of social, environmental and biological experiences[8]. Writing represents not only the last and most complex skill acquired during the development process, but also the most vulnerable to damage, loss and adverse genetic influences[9].

The process of learning to write requires a level of activation and attention, surveillance and selection of information. Without an integrated brain organization intra and inter neurosensorial, adequate learning is not possible[9].

From six to ten years old, during the so-called period of “third childhood”, children are at school age and can be considered free of “face to face” communication, since they can already produce written communication and express ideas, thoughts and feelings on paper[10]. The acquisition of writing skills occurs in parallel with the development of reading, as neurons are able to learn and recycle, prompting internalization and storage[11].

However, for the writing acquisition to occur, neuropsychological functions related to reading performance must be present, since the child needs to identify what is written through reading. In addition, the child must perform word recognition to read properly, after having acquired phonological processing skills such as phonological awareness, working memory - phonological loop[12] and processing speed[13].

Complementary to phonological awareness, there should be an understanding of oral language, psychomotor skills, non-verbal memory, working memory, vocabulary, phonological verbal fluency tasks or executive functions skills such as cognitive flexibility and nomination speed[14].

In the early school years, the child learns that letters, as graphic symbols, correspond to sound segments (coding). Thus, it starts to make the phoneme/grapheme conversion. After the graphophonemic relationship is established, we begin to teach how to transform simple sentences into complex ones through planning that will bring coherence to what is being written[15], that is, the child learns how to use the structural components in his text, thus

demonstrating the complexity to develop a written production so that it has a meaning[16]. Consistency qualifies the text, making it not a set of ideas without an objective, thus providing the power of interpretation[17].

The realization of written words requires "central" (cognitive or linguistic) processes and "peripheral" (motor) processes. The central processes specific to writing are: long-term orthographic memory (lexical-orthographic), phoneme-grapheme conversion and orthographic working memory. The peripheral processes of writing perform the motor actions for the production of written words in a variety of formats, such as spelling, manuscript, typing and others[7].

There is a relationship between reading comprehension, language and cognitive skills of working memory and executive functions[14]. Working memory is the cognitive system responsible for temporary retention and information processing during the performance of complex cognitive activities, consisting of the phonological loop, the episodic buffer and the visuospatial outline[18]. In the linguistic context, working memory is responsible for the coherence of discourse and the understanding of the context, for junctions of information that activate this memory and the acquisition of semantic knowledge for reading[19,20].

Visuospatial skills are involved in the motor actions of writing production. In general terms, they concern the storage and/or processing of visual and spatial information about the environment, in addition to the creation, maintenance and manipulation of mental images. Among the visuospatial skills can be cited visual organization, visuoconstruction and spatial orientation[18,21].

Although other factors influence the acquisition of written language such as socio-economic level, general intelligence, parents' education and the stimulation they offer their children at home; such factors are less accessible to intervention than cognitive factors, such as phonological ones. Metaphonological and phonic skills for the acquisition of competent reading and writing are of utmost importance. Metaphonological and phonic skills for the acquisition of competent reading and writing are of utmost importance[22].

Understanding the writing acquisition process involves an intricate network of interrelationships in which not only neurobiological and developmental factors are involved, but also environmental (family and school), social and emotional ones, thus, the writing acquisition process is not the same for every child.

In this sense, in addition to aspects related to child development, in this study, the cognitive skills involved in writing processing, working memory and visuospatial skills stand out. It is assumed that the child's neuropsychomotor and cognitive development history, associated with environmental factors of stimulation, is related to the level of written elaboration in children in the first years of literacy.

Considering the great cultural and social importance of acquiring written skills for the individual's functionality, it is important to identify risk factors for their development in order to prevent possible changes and disorders as well as to establish solid knowledge with a view to health promotion, prevention and rehabilitation programs. Thus, the objective of this study was to analyze whether the cognitive skills of executive and visuospatial control are related to impaired performance in the writing of elementary school children with school complaints (behavioral or learning).

METHOD

This is a retrospective observational study. This study was approved by the Ethics and Research Committee of Universidade Paulista - UNIP, under Nº 3.023.032, CAAE 01785518.5.0000.5512.

The present study was carried out from 2013 to 2018 with the purpose of analyzing medical records of 6 to 10 years old children who had been through language speech therapy assessment and neuropsychological assessment. All children were accompanied by a

multidisciplinary team from a tertiary-level hospital outpatient clinic whose proposal was to assess children with complaints of learning and/or behavior.

Specific data related to the children's speech and neuropsychological assessment were collected. The following inclusion criteria were considered: (a) children with cognitive assessment whose intellectual estimate was found, by standardized instrument, above score 70; (b) children with previously diagnostic of genetic syndrome. The exclusion criteria included: (a) children who are not literate; (b) children under six and over 11; (c) children who have not performed all the tests necessary for this work; (d) children with hearing loss of some kind or degree.

Two groups of the children who met the inclusion criteria were selected from their written production, more precisely from the level of classification of the coherence of the written narratives, according to the protocol of Spinillo and Martins (1997) 17: G1 - children with difficulties in maintaining consistency in their written narratives (classification of coherence levels I or II); G2 - children with good ability to write coherent texts (classification of coherence levels III or IV).

After approval by the Research Ethics Committee, the following data were collected from the children's electronic medical record: characterization (age, gender and education), parental education, neuropsychomotor and language development, past history of postnatal complications (convulsive crises, trauma), recurrent ear infections), previous interventions in psychology/psychopedagogy and speech therapy.

Subsequently, data were collected from specific instruments applied to speech therapy (level of coherence of written elaboration) and neuropsychological (WISC IV and Rey Complex Figure). The Wechsler Intelligence Scale for Children - WISC IV23 is a neuropsychological assessment tool which aims to assess cognitive performance and the problem-solving process in children aged 6 to 16 years and 11 months. It consists of 15 subtests, 5 of which were supplementarily used as a means of substituting the main subtests or obtaining additional clinical information. The instrument also quantifies cognitive skills through 4 factor indices, namely: Verbal Understanding (VUI), Perceptual Organization (POI), Operational Memory (OMI) and Processing Speed (PSI).

In this study, the Perceptual Organization Index (POI) was analyzed through the joint analysis of the examinee's performance in the Cubes, Figurative Concepts and Matrix Reasoning subtests, as well as the Operational Memory Index (OMI), through the performance composition in the Digits and Sequence of Numbers and Letters subtests; since these indexes evaluate visuospatial skills and executive functions, respectively.

The data collected in the report were the child's scores for each task previously described and the classification by age. According to the rules of the instrument, the scores for each of the indexes are classified as: within the expected average for age (average and upper average ratings); above the expected average (higher and much higher ratings); at the lower limit of the mean (lower mean classification), suggesting difficulty in the assessed function; below average (borderline or extremely low ratings), suggesting deficit.

Rey Complex Figure Test was also used[24]. This test, devised by André Rey in 1942, assesses the perceptual ability, visuospatial planning and visual memory, verifying the way in which the examinee perceives the perceptual data presented to him (this phase of the activity is called copy) and what has been preserved spontaneously through memory (this phase of activity being the reproduction of memory).

In this study, only the "copy" phase was analyzed and it presents a measure of visuospatial processing. According to the rules of the instrument, the scores are organized in percentiles' classified as: within the expected average for age (average and upper average ratings); above the expected average (higher classification); at the lower limit of the mean

(lower mean classification), suggesting difficulty in the assessed function; below average (classification below average), suggesting deficit.

Another instrument used was the Coherence Level of the written narratives[17]. It is an instrument used to assess the coherence of both oral and written narratives. This instrument allows the classification of the child's narrative into four levels, with level I encompassing children with greater difficulties in maintaining coherence and level IV encompassing children with ease in this task.

For the classification of each level, the maintenance of the character during the story (P), the maintenance of the theme (T = topic), the main event and the outcome of the story were analyzed. At each level, the following characteristics were expected: (a) Level I - the stories occur without a main event or defined topics, which are always changed and not related to the outcome, which is done abruptly. Characters may be present; (b) Level II - there is a predisposition to define and maintain the same topic throughout the narrative and there are also several events that may or may not be linked together, one not being defined as the main one. They can relate slightly to the outcome even if there is no such relationship to the narrative. Characters can be present; (c) Level III: - the characters are present from the beginning to the end of the narrative[17].

And, just as at the previous level, events can be linked together as they cannot, without the definition of a principal. There can also be only one, well-defined, and maintained throughout the narrative, the differential of this level. The outcome is not yet in line with the plot, causing a slight compromise in the intelligibility of the message; (d) Level IV - the main character is maintained throughout the story and resumed at the end, being present in the topic and in the main event, very well defined. The latter, in turn, are in line with the outcome, which will involve the entire plot for a narrative[17].

For data analysis, descriptive statistics were used to characterize the results. In statistical inference, the machine learning technique (logistic regression with LASSO) was used to assess which cognitive skills are related to obtaining a better level of coherence in written narratives.

RESULTS

At first, 70 medical records were considered, but only 40 children were included (considering the inclusion and exclusion criteria), 26 were male (65%) and 14 female (35%). In the group of male children, ages ranged between 7 years and 10 months and 10 years and 9 months (average of 9 years and 4 months) and among female children the age range was between 7 years and 4 months and 10 years and 9 months (average of 9 years and 6 months). The school year in which the children were inserted varied between the 2nd year and the 5th year of elementary school, with the majority of the children being enrolled in the 4th year.

Regarding the developmental history, 10 cases (25%) of clinical complications were observed, namely: prematurity; iron deficiency anemia; tympanic perforation, no hearing loss complaint; asthma; epilepsy; maternal anemia during pregnancy; already corrected post-foramen cleft palate; physical aggressions to the mother during pregnancy and various respiratory infections. Six male children (15%) had delayed language acquisition and 3 male children (7.5%) had a delay in neuropsychomotor development. As for follow-up or intervention data, 5 (12.5%) children reported a history of psychotherapy and 4 (10%) of speech therapy due to learning and/or behavior problems.

Regarding the classification of written elaboration consistency, there was a balance: 19 children (47.7%) showed difficulty in maintaining the consistency of their written elaboration and were classified in levels I and II. They comprised the G1 group. The remainder, 21 children (52.5%) had a good ability to write coherent texts (G2).

Regarding visuospatial skills, the Perceptual Organization Index (POI) of the WISC IV instrument and the “copy” phase of the Rey Complex Figure instrument were used. The group

with difficulties in writing consistency (G1) reached 19 children of whom 79% were classified in the middle range for the skills of perceptual organization and visuospatial processing while 21% denoted difficulties or deficits (classified as lower or borderline average). As to the group without difficulties in written coherence (G2), considering 21 children in total, the percentages from 86% classified in the middle range were observed, to 14.2% classified as having difficulties in the assessed skills.

In both groups, the children's performance suggests resources in terms of visuospatial skills presented predominantly by children of the group without difficulties (G2). This predominance can still be observed since G1 has a higher percentage of scores suggesting difficulty/deficit (lower and borderline average classifications).

From the test referring to the copy of the Rey Complex Figure, it was found that, of the total of 19 children in G1, 37% were classified in the middle range, while 63.3% obtained a performance as lower and lower than average. For the 21 children in G2, we see that 14% of children achieved an average performance, for 86% with impaired performance, that is, classified as lower or lower than average.

It can be seen that for both groups, the ability of visuospatial processing was shown to be predominantly compromised, with a worse performance in the group without difficulty in writing consistency (G2). The G2 group also showed a lower percentage of performances in the middle range, which suggests an apparent lack of relationship between the linguistic ability of textual coherence and the visuospatial ability.

Regarding the executive control ability (executive functions, assessed by the OMI of the WISC IV instrument), 63% of 19 children with difficulty in writing consistency (G1) achieved performance within the middle range, while 37% achieved an impaired performance (classified in the lower middle, borderline and extremely low ranges). Twenty-one children in G2, 67% were classified in the middle range and 33% obtained ratings suggesting difficulties or deficits. It was possible to observe a balance between groups G1 and G2, but a marked predominance of executive dysfunction in both groups.

Table 1 shows which variables have influenced the child's ability to elaborate written texts in a coherent way, according to statistical analysis. The “weight” (positive - protective factor; negative - risk factor) specifies the association between the variable “change in written coherence” and the independent variable considered. Thus, negative "weight" indicates that the independent variable is configured as a risk factor for good written coherence, while positive "weight" suggests an association between the variable and good written coherence. The “weight” was calculated using the statistical model.

Table 1 shows that the variables female gender and the child's highest school year (4th and 5th grade) are positively related to an adequate level of written coherence, being considered as protective factors for the child's ability to write coherent texts. On the other hand, history of language delay and reading difficulties were considered risk factors for the development of coherent text writing skills.

Also, the lower classification at the Rey Complex Figure test (copy phase) was associated as a protective factor for written coherence which suggests that children with a deficit in visuospatial processing skills, when considering it a proof of graphic praxis, will be likely to present a more coherent written narrative (Table 1).

Table 1. Statistical model significant variables. Ribeirão Preto, 2013 to 2018.

Variable	Statistical weight
Sex (feminine)	Positive
School year	Positive
History of language delay	Negative
Reading difficulty	Negative
“Lower” classification in the Rey Complex Figure test - Copy phase	Positive

DISCUSSION

In the analysis of risk and protection factors that may be associated with performance in writing by children with school and/or behavioral complaints, five main factors were identified: sex, school year, language delay, reading difficulties and performance at Rey Complex Figure test - copy phase.

Regarding the developmental history, it was possible to observe that only male children had a history of delay in language acquisition and neuropsychomotor development (15% and 7.5% of the sample, respectively). In addition, being female was a protective factor, that is, girls are more likely to produce a text with adequate coherence. Studies[25,26] proved that the difficulty in written language is significantly greater in boys, in addition to low academic performance and a higher incidence of speech/language/learning problems. This data is convergent with the result of the statistical analysis. When comparing the groups with (G1) and without difficulties in the elaboration of coherent written texts (G2), there was a predominance of language delay and neuropsychomotor development in the first group, especially with regard to language acquisition. Also, data resulting from the statistical analysis suggest language delay variables as well as reading difficulty were shown to be risk factors in the acquisition of written coherence. Such data is consistent with the knowledge about the processing of written language as it depends, among other factors, on oral or reading comprehension[7,27], deficits underlying oral language impair written ability.

In this study, it was observed that the highest school year (4th and 5th year) is a variable that positively interferes with the level of written coherence, which corroborates with the study proposals[28,29], for which the various skills involved in the writing process improve over the school years as well as the passing of years in schooling level favors the production of cohesive and coherent texts.

In the Rey Complex Figure test, the "lower" classification was understood as a protective factor in terms of written coherence. It is considered that this association does not reflect reality, but it is a bias resulting from a sample already constituted with cognitive changes in this skill (90% of the cases obtained a "lower" classification in this test), since the population that seeks the service in which the research was carried out, presents some type of difficulty in the learning process and, therefore possibly in the acquisition of reading and writing.

There is a need, however, to work with children without similar cognitive changes in order to observe whether the data found here can also be replicated to children with typical learning development and without behavioral issues.

However, such a result denotes that coherence as a linguistic skill, can work independently of visuospatial skills, since it is a linguistic process[7] and, therefore, central to the processing of writing in a different way from the so-called peripheral writing processes which are responsible for carrying out the necessary motor actions for the production of written words, dependant on a range of non-linguistic cognitive skills (spatial orientation, construction skills and visuospatial discrimination).

Although executive functions, assessed by the WISC IV (IMO) working memory index, have not been shown in this study as a variable that interferes with the development of coherent writing skills, it was possible to observe, by comparative data between G1 and G2, a considerable predominance of executive dysfunction in both groups.

As one of the cognitive functions involved in the processing of writing, working (or working) memory is mainly related to the prefrontal lobes of the brain[18]. Changes in these systems are part of conditions involving learning problems, such as neurodevelopmental disorders, such as ADHD[30,31] or disruptive childhood disorders.

The population of this study were children with school complaints (behavioral and/or school performance), including children with diagnoses of ADHD, anxiety disorder, specific learning disorders, conduct disorder and motor coordination disorder. It is possible that this

fact has contributed to the emergence of a large percentage of children with performance suggesting executive dysfunction from both groups.

CONCLUSION

The present study highlighted that among the several variables hereby analyzed, those that were shown to be protective factors to a better performance in terms of consistency in written narratives, in a sample of children with some type of school complaint (behavioral and/or school performance) were: female gender, more advanced school year and impaired performance in the Rey Complex Figure test (copy phase). Those that proved to be risk factors were: a history of language delay and reading difficulties.

There was a positive relationship between linguistic variables (history of language integrity and reading development) and the coherent construction of the written narrative. It was noticed that the school experience is an important factor in the process of improving the level of written coherence. However, the non-linguistic variable (visuospatial ability) was not directly associated with the processing of writing. The neuropsychological function of working memory, which is related to performance and reading and writing difficulties, was also impaired in both groups (with and without difficulty in writing consistency).

As limitations of this study, it is considered that the sample, in terms of size and composition, may have hindered a consistent conclusion regarding the association between cognitive variables (executive functions and visual motor skills) and the development of written coherence. It was possible to identify the need for a control group devoid of school complaints and, in this sense, disconnected from a health service, as was the context of the sample constituted here, in order to allow more accurate results.

It is considered that the findings of this study evidenced some of the variables related to a good performance in narratives writing coherence in addition to having contributed to the expansion of the field of research involving this theme in order to assist in the elaboration of stimulation program for children considered at risk of developing written skill, as well as in the evaluation and intervention of cases where difficulties are already installed.

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CONTRIBUTIONS
Ângela Cristina Pontes Fernandes has contributed to the conception, design, writing and proofreading. **Marielle Martins Santos** has participated in data analysis and interpretation and writing. **Patrícia Aparecida Zuanetti** e **Ana Paula Andrade Hamad** have helped with proofreading.

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