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Artículos

Working memory in school children with dyslexia. A relational analysis

Memoria de trabajo en escolares con dislexia. Un análisis relacional

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Abstract

Working memory (WM) is an essential cognitive process for the acquisition of learning in reading, writing and arithmetic, allowing for the proper processing of environmental stimuli; people with dyslexia (DLX) have alterations in this neurocognitive process, mainly in handling verbal information. The objective of this study is to analyse the link between MT, verbal memory, visual/verbal memory, consciousness level, mind control and semantic memory in a sample of 130 schoolchildren diagnosed with DLX. In order to identify the link between the aforementioned variables, a structural equation model (SEM) was constructed in RCran 4.0.4 software, using the results obtained in the psychometric tests applied; WISC-IV, Visual/Verbal Memory, Verbal Memory and Wechsler Memory Curve. This paper concludes that people with DLX have deficiencies in several memory domains, the neuropsychological stimulation of this process is fundamental to guarantee the scholastic progress of the population with this neurodevelopmental disorder.

Keywords: Memory; learning processes; learning disabilities; dyslexia; reading difficulties; metacognition.

Resumen

La memoria de trabajo (MT) es un proceso cognoscitivo esencial para la adquisición de aprendizajes en lectura, escritura y cálculo, permite el adecuado procesamiento de los estímulos del medio; las personas con dislexia (DLX) presentan alteraciones en este proceso neurocognitivo, principalmente en la manipulación de información verbal. The objective of this study is to analyse the link between MT, verbal memory, visual/verbal memory, consciousness level, mind control and semantic memory in a sample of 130 schoolchildren diagnosed with DLX. Para identificar la relación entre las variables mencionadas, se construyó un modelo de ecuaciones estructurales (MEE) en el software RCran 4.0.4, haciendo uso de los resultados obtenidos en las pruebas psicométricas aplicadas; WISC-IV, Memoria viso/verbal, Memoria verbal y Curva de Memoria de Wechsler. It is concluded that people with DLX have deficits in several memory domains, and neuropsychological stimulation of this process is essential to ensure the school progress of the population with this neurodevelopmental disorder.

Palabras clave: trastornos del aprendizaje; dislexia; dificultades en la lectura; metacognición; Memoria; procesos de aprendizaje.

INTRODUCTION

According to the Diagnostic and Statistical Manual of Mental Disorders [DSM-V] (2013) neurodevelopmental disorders (2013), they are early-onset clinical disturbances, which break out before school age and affect the educational, social and family sphere; they have a negative impact on academic learning, executive functions, social skills and intelligence. (American Psychological Association [APA], 2013; Bausela-Herreras et al., 2019). Specific learning disorder falls within this group of clinical entities, characterised by impairment in the acquisition of academic skills in reading, writing or arithmetic (Pham, 2015). It has been referred to as dyscalculia (problems in learning mathematical skills), dysgraphia (impaired writing expression) and DLX (difficulties in learning to read). (Rodrigues et al., 2014; Batista & Pestun, 2019). There is a higher prevalence of DLX in the school population, reported to be between 5% and 15% (De-La-Peña & Bernabéu, 2018; Carballal-Mariño et al., 2018). People diagnosed therewith show inaccuracy in reading words, poor lightness, poor understanding of texts, and poor reading comprehension, problems in pronunciation and visual processing (Lawton, 2016). Profiling studies indicate that DLX is associated with neurocognitive impairments. (Bajre & Khan, 2019; Soares et al., 2020; Masoura et al., 2020). WM is essential to acquire reading, writing and mathematical learning (Dawes et al., 2015; Gutiérrez-Sánchez, M., & Vidal-Valenzuela, 2019; Albano et al., 2016). There is low performance on neuropsychological tests assessing verbal WM in people with DLX, research findings have reported significant alterations in this neurocognitive process (Wiseheart & Altmann, 2017; Canet-Juric et al., 2018). WM allows for the proper manipulation of the medium's information through encoding, processing and immediate recall (Artuso et al., 2020; Irak et al., 2019; Rouselle & Abadie, 2021). Baddeley's approach has been a significant clinical and scientific benchmark for theorising WM (central executive), made up of by the articulatory loop and the visuospatial agenda (Maehler et al., 2019; Delage & Durrleman, 2018). The visuospatial agenda is committed to the performance and sustainment of visual/spatial information; the articulatory loop is the verbal memory responsible for receiving information from the environment and the linguistic cognitive system, and maintaining the phonological codes for a short period of time (Martins et al., 2020; Toffalini et al., 2018; Gray et al., 2019). Research has concluded that WM deficits in patients diagnosed with DLX are found in verbal memory, associated with problems in level of awareness, mind control, slow speed in naming verbal and visual symbols affecting the processing and storage of phonological material (Yang et al., 2017; De la Peña-Álvarez, 2014; Lazzaro et al., 2021). Semantic memory is involved in spontaneously acquired knowledge about the environment, it directly influences the functionality of WM, in the pedagogical context it allows the manipulation of linguistic codes for the acquisition of literacy skills. (Campos-Millán, 2019; Cruz-Rodrigues et al., 2014).

There is a wide range of research indicating that people with DLX have impairments in memory components, mainly in WM (Brooks et al., 2011, Männel et al., 2015; Maehler et al., 2019), but there is little scientific evidence analysing the relationship between these components; these findings motivate the following research question: What is the link between WM, verbal memory, visual/verbal memory, consciousness level, mind control and semantic memory in schoolchildren with DLX? Deficits in this neurocognitive component should be addressed clinically, fostering this population's educational progress (Stošljević et al., 2012).

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Based on the above, the aim of this research was to analyse the link between WM, verbal memory, visual/verbal memory, consciousness level, mind control and semantic memory in schoolchildren with DLX. The following relational research hypotheses were formulated: H1. In people with DLX, the lower the WM functionality, the greater the impairment of verbal memory, H2. In people with DLX, the lower the WM functionality, the greater the deficits in visual/verbal memory, H3. The greater the alterations in consciousness level, the lower the functionality of mind control and H4. The lower mind control, the greater the deficiencies in semantic memory. It was concluded that in DLX, WM is affected and is directly related to the clinical manifestations of this neurodevelopmental disorder.

METHOD

Participants

From a population of 156 patients with neurodevelopmental disorders, patients (*N*=130) diagnosed with DLX were included in the sample. The 26 who were excluded had sensory deficits or intellectual disabilities. The sample under analyses was made up of primary/secondary school children, ranging in age from 7 to 15 years. 82 males (M_{age}=9.30, SD_{age}=2.18, *right*-handed=75, left-handed= 7, ambidextrous= 0) and 48 females (M_{age}=9.27, SD_{age}=2.23, right-handed= 42, left-handed= 5, ambidextrous= 1). The medical records of each patient were analysed to identify the presence/absence of neurological risk, family history of DLX or deficiencies in successive developmental milestones (17 patients with neurological risk and delays in successive developmental milestones, 26 patients with neurological risk and no delays in successive developmental milestones, 23 patients with neurological risk and no neurological risk, 64 patients with no neurological risk and no delays in successive developmental milestones).

Design

The study had a quantitative approach, the level was relational, non-experimental, cross-sectional design (Sánchez-Gómez et al., 2018).

Instruments

Wechsler Intelligence Scale -Wechsler- (WISC-IV) (Wechsler, 2005). It makes a comprehensive assessment of cognitive/intellectual functioning and is administered among individuals aged between 6 and 16. It is made up of 10 primary tests and 5 supplementary tests. For this research, the tests measuring the WM index; letter/number succession-digit retention, which assesses recording and data retention skills, were applied. Letter/number succession, estimates storage and combination capabilities of various types of information; the test taker is read a set of letters and numbers, then asked to output the letters in the order of the alphabet and the numbers in an ascending arrangement. The maximum score of this cognitive activity is 30; it includes 10 items each made up of 3 items, and the test is terminated when the test taker has 3 scores of zero on the same item. Digit retention, examines sequential skills, organisation, alertness and cognitive flexibility of WM. It includes two activities; digits in direct arrangement (the test taker repeats the numbers in the same arrangement as presented by the tester), digits in reverse arrangement (the test taker repeats the numbers in the opposite arrangement as presented by the tester). It is made up of 8 items, each with two items; a score of zero on both items of an item is a fail. Each test's score involves the conversion of direct scores into scalar scores. The reliability of the scale was tested through test-retest, it has content validity (Romero-González et al., 2021; Gráf et al., 2020).

Wechsler Memory Scale- (Wechsler, 1945). Administered individually, this test allows for the assessment of the fundamental aspects of memory (information, orientation, mind control, logical memory and associated pairs) in different age groups. The information and orientation test assess the level of awareness through very simple questions about personal elements, basic general culture, location in space and time. Mind Control, made up of three activities, aimed at assessing automated and controlled processing (counting backwards from twenty to one, repeating the alphabet and counting from 3 to 3 starting from 4 up to 40). Logical memory, made up of two stories that are read to the person being tested for immediate recall. Associated pairs, consists on introducing the patient to a pair of words to be memorised, and then telling him to remember the second word while the first word is presented. The version validated by Ardila and Roselli, (1994) for Colombian children and adolescents was applied to the sample. The test has appropriate construct and content validity.

Verbal Memory Curve (Ardila & Rosselli, 2007). The test taker is given 10 words sequentially and must recall the words he remembers immediately after each presentation. Up to 10 verbalisations and evocations of the words are allowed, aiming a certain maximum volume. The score obtained from the initial volume indicates the number of items that the person tested remembers after the first exposure. The maximum volume refers to the number of items that can be evoked after up to 10 training sessions. The test has adequate validity and reliability.

The Visual/Verbal Memory Scale (Ardila et al., 1994). A template with 10 drawings is presented for the person tested to say the name of each drawing, then the visual template is removed so that they can immediately recall the ones they remember, the test allows for up to 10 trials. Initial volume, assesses the number of words evoked after the first trial; peak volume, assesses the maximum number of words evoked after up to 10 trials. The test has adequate validity and reliability.

Procedure

This study was approved by the Research Ethics Committee of Universidad Católica Luis Amigó under file number 62542. At the Neuropser Neuropsychology Specialised Care Centre (Medellín-Colombia), the sample of primary and secondary school children between the ages of 7 and 15 years with a diagnosis of DLX was assessed. The supervisors of the population assessed agreed to sign the appropriate informed consent form for the minors to participate in the research project. The application, scoring and interpretation of the test protocol provided was carried out by a team of professionals specialised in neuropsychology; the assessment of each participant was carried out individually, with an average of two hours. This research was financed by the Universidad Católica Luis Amigó under code 0502029969 of the Cost Centre.

Data analysis

The sample descriptives and SEM were performed within the RCran 4.0.4 environment for statistical computing. Covariance was analysed between the latent variables; WM verbal memory, visual/verbal memory, consciousness level, mind control and semantic memory of the tests provided. SEMs allow the validation of hypothesised constructs between latent variables from observable variables, they are a class of multivariate structures (Fogel et al., 2021). These models determine the dependence or independence relationship by integrating linear equations, combining factor analysis with linear regression to calculate the data fit. Goodness-of-fit tests were performed; Chi-Square, the Comparative Fit Index (CFI), the Tucker Lewis Index and the p-value of indicators.

RESULTS

Table 1 presents the summary of descriptive statistics for the characterisation of the patients under analysis. It shows that there are more men than women (82>48), age was similar for both sexes. Participants in the sample were aged between 7 and 15 years. Most patients were right-handed, the number of left-handed patients was the same in both sexes (7 patients), only one female patient was ambidextrous. The patients' level of education ranged from first grade of primary school to ninth grade of high school. 32% of patients were at neurological risk and 68% were not. 30% of the patients under analysis lagged behind in the successive evolution of the developmental areas. Neurological risk represents adverse factors in the pregnancy/delivery process and family history of DLX; deficiencies in developmental areas present divergences between chronological age and expected developmental milestones (Vericat & Orden, 2017; Velasteguí-Egüez et al., 2018; Medina-Alva et al., 2015).

Table 1. ***Descriptive statistics***

Gender	No.	Age		RN	RAD	Laterality		
		$\bar{x}$	σ^2			D	Z	AD
Man	82	9.30	2.18	Yes= 27 No=55	Yes= 20 No=62	75	7	0
Woman	48	9.27	2.23	Yes=15 No=33	Yes=19 No=29	42	5	1
Total	130			Yes=42 No=88	Yes=39 No= 91	117	12	1

Note. $\bar{x}$= average age, σ^2=standard deviation, RN= neurological risk, RAD= developmental deficiencies, D= right-handed, Z=left-handed, AD=ambidextrous

The LAVAAN library was used to build the SEM, the model converged after 95 iterations. The number of degrees of freedom of the SEM was 30, the Chi-square statistic was greater than 503, defining an adequate model. The Comparative Fit Index CFI=0.856 > 0.5, as well as the Tucker Lewis Index TLI=0.737 > 0.5, indicate the relevance of the SEM. The p-value of the indicators suggests significance, the model developed is valid[i]. All the values of the covariances analysed were positive, accepting the hypotheses put forward. Table 2 presents the results of the SEM.

Table 2. ***Relational hypotheses***

Assumption	Covariance	Criterion	P(>|z|)
H1. In people with DLX, the lower the WM functionality,the greater the impairment of verbal memory	0.72	Accepts	0,000
H2. In people with DLX, the lower the WM functionality,the greater the deficits in visual/ verbal memory	0.51	Accepts	0,000
H3. The greater the alterations in consciousness level,the lower the functionality of mind control.	0.55	Accepts	0,000
H4. The lower mind control, the greater thedeficiencies in semantic memory	0.55	Accepts	0,000

Figure 1 presents the diagram of the developed SEM. The numerical value above the two-way arrows indicates the value of the covariance. Variables between rectangles indicate observed variables, variables between ovals indicate latent variables.

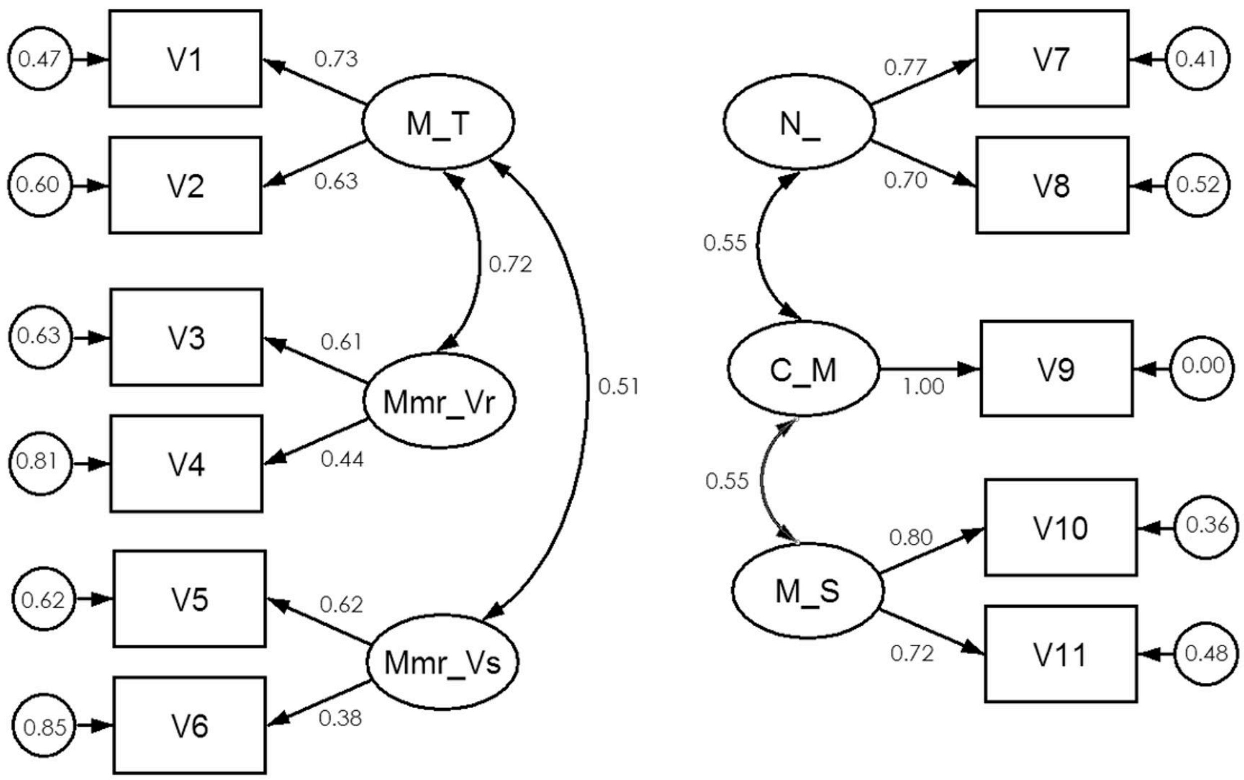

Figure 1. ***Structural Equation Model***

Note. Verbal Memory (Mmr Vr), Visual and Verbal Memory (Mmr Vs), Consciousness Level (N) and Mind Control (C_M), Semantic Memory (M_S)

DISCUSSION

According to epidemiological data, DLX is more prevalent in men (Arnett et al., 2017). The sample analysed in this research was mainly made up of men. Some predisposing factors for DLX have been identified that are not determinant; neurological risk, hereditary background and delay in developmental areas (Wert, 2019). In the sample analysed, 62% had predisposing factors, which shows that not all people diagnosed with DLX have neurological risk or deficiencies in developmental areas.

From the results of the SEM in the DLX there is a deficit in WM, which directly affects verbal memory. This finding is consistent with the results of some research that suggests that DLX generates abnormalities in verbal memory, affecting the functioning of the phonological component of WM, manifesting in perceptual and linguistic difficulties (Wang et al., 2015; Giorgetti & Lorusso, 2018; Varvara et al., 2014). It was evidenced that people with DLX present alterations in the processing of visual/verbal information, implying impairments in visual memory, a slowing down in the processing of data captured from the environment; attention operates in an articulated manner with WM for the automated processing of stimuli. From the scientific background review, little research validates this claim, and it was found that DLX generates deficits in visual processing, negatively impacting the performance of tasks that assess WM (Ortiz et al., 2014; Acha, 2016; Tamayo-Lorenzo, 2017).

Schoolchildren with DLX show failures in tasks that measure mind control, they have a lower ability to focus attention, they do not have adequate competences to regulate the information they receive from the environment due to inhibitory control failures (Aguilar-Mediavilla et al., 2021). This research finding is consistent with hypothesis H3 stated in this research. Attention and WM are fundamental for mind control, cognitive processes that facilitate the learning of pedagogical competences. (Kapa & Plante, 2015; Medina & Guimarães, 2021). The impairment in mental control linked to DLX has an impact on semantic memory functionality (Jiménez et al., 2014). Jalali-Moghadam y Kormi-Nouri (2017) argue that deficiencies in WM and its link with verbal and visual memory and mental control lead to a decrease in semantic storage, with reduced orthographic processing, especially in the early stages of school, adversely impacting academic learning. Studies show that DLX is due to an impaired pattern of recall (episodic/semantic), has been attributed mainly to impaired phonological processing, suggests a conceptual link between reading difficulties and phonological and orthographic integration deficits. Early intervention for language deficits reduces the risk of WM limitations, a key component of good reading and writing performance. (Kibby et al., 2014; Lah & Smith, 2014; González-Valenzuela et al., 2016).

It is concluded that WM is impaired in patients diagnosed with DLX mainly at the level of verbal memory (articulatory loop) and mental control. In this clinical condition there are deficits in explicit memory affecting semantic memory and visual and verbal memory. The SEM developed allowed us to identify that in people with DLX the deficiencies in WM are related to verbal, visual and controlled processing alterations, generating and maintaining some of the symptoms associated with this clinical condition (slow learning, difficulties in morpheme formation, problems in the storage and evocation of phonemes). Studies assessing visual and verbal memory in people with DLX are suggested, the scientific evidence is not conclusive. The results of this research are limited to Spanish-speaking people with DLX. It is important that psychology and neuropsychology continue to explore the link between WM and DLX in order to foster specialised intervention processes for this population.

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Notes

[i] The results of the SEM adjustment are available online at the following URL: https://github.com/victorgil777/MEE/blob/35eb9934ff4e2d2956aa2c3ca9bef4f06e5637f0/MT