Revista Latinoamericana de Psicología (2019) 51(2), 166-175 Doi: http://dx.doi.org/10.14349/rlp.2019.v51.n2.4

Revista Latinoamericana
de Psicología

www.editorial.konradlorenz.edu.co/rlp

ORIGINAL

# Profile and neuropsychological differences in adolescent students with and without dyslexia

**Estefanía Ibáñez Azorín[a,*], Pilar Martin- Lobo[a], Esperanza Vergara-Moragues[a,b] y Ana Calvo[a,c]**

[a] *Department of Educational Psychology and Psychobiology, Universidad Internacional de la Rioja (UNIR), Logroño, Spain*
[b] *Department of Psychobiology and Methodology in Behavioral Sciences, Universidad Complutense de Madrid (UCM), Madrid, Spain*
[c] *Faculty of Health Sciences, Universidad Internacional de la Rioja (UNIR), Logroño, Spain*

Received 17 July 2018; accepted 21 November 2018

**KEYWORDS**
Neuropsychology, dyslexia, students, saccadic eye movements, functional laterality, executive functions

**Abstract** Dyslexia is a problem of increasing prevalence in school-age students. The latest experiences in the application of neuropsychology to education are interesting because they allow for the evaluation of different neuropsychological variables to obtain a better understanding of the learning processes of students in this population for specific subsequent interventions. The purpose of this study was to explore the following neuropsychological variables related to reading in adolescent students with and without dyslexia. The sample consisted of 60 students between 13 and 15 years of age, 30 with dyslexia and 30 without. The King Devick test was used to assess the saccadic eye movements, specifically the fast and automated denomination of digits; the Harris laterality test was used to evaluate functional laterality, and the ENFEN test for executive functions. The results revealed significant differences between the two groups. Students with dyslexia scored lower on the three neuropsychological skills assessed. These findings suggest that students with dyslexia may manifest poorer performance in those neuropsychological skills that are key to reader development.



**Perfil y diferencias neuropsicológicas en alumnos adolescentes con y sin dislexia**

**PALABRAS CLAVE**
Neuropsicología, dislexia, estudiantes, movimientos sacádicos oculares, lateralidad funcional, funciones ejecutivas

**Resumen** La dislexia es un problema que cada vez afecta más al alumnado en edad escolar. Las últimas experiencias de aplicación de la neuropsicología al ámbito educativo resultan interesantes porque van a permitir evaluar distintas variables neuropsicológicas con el objeto de comprender mejor los procesos de aprendizaje del alumnado para plantear posteriormente intervenciones específicas en esta población. El propósito de este estudio fue explorar variables neuropsicológicas relacionadas con la lectura y escritura en estudiantes con y sin dislexia. La muestra estuvo compuesta por 60 estudiantes de entre 13 y 15 años, 30 con dislexia y treinta sin dislexia.

* Corresponding author.
*E-mail address:* estefania.ibanez@murciaeduca.es

http://dx.doi.org/10.14349/rlp.2019.v51.n2.4

La prueba King Devick fue utilizada para valorar los movimientos oculares sacádicos, la prueba de la lateralidad de Harris para evaluar la lateralidad y la prueba ENFEN para las funciones ejecutivas. Los resultados revelaron diferencias significativas entre los dos grupos. Los estudiantes con dislexia obtuvieron puntuaciones más bajas en las tres habilidades neuropsicológicas evaluadas. Estos hallazgos sugieren que los niños con dislexia podrían manifestar un peor desempeño en habilidades neuropsicológicas que son clave para el desarrollo lector y escritor.



Dyslexia is related to several risk factors, both genetic and environmental. The neurocognitive impairment is also multifactorial and involves phonological processing deficits, with weaknesses in oral language skills and processing speed (Peterson & Pennington, 2015; Ramus, 2003). According to Paz-Alonso et al. (2018), dyslexia is usually manifested by difficulties with phonological segmentation, slow linguistic processing, poor vocabulary, low verbal fluency and reduced operative memory, short-term verbal memory or speech perception and other symptoms generally associated with dyslexia, although they do not necessarily cause problems. Thus, Power, Colling, Mead, Barnes & Goswami (2016) suggest that alteration in the neural coding of low frequency voice envelopes, related to speech prosody, can support the phonological deficit that causes dyslexia in all languages.

Functional difficulties of people with dyslexia occur in those parts of the brain that process the correct execution of reading and writing. Scientists tend to argue that a problem in the development of certain brain regions could be the cause of the progressive establishment of this specific difficulty in learning to read manifested by dyslexics. Neuroimaging studies have found quantitative differences in the brain areas involved in reading skills, as well as cognitive and behavioural skills (Paz-Alonso et al., 2018; Yitzchak & Pavlakis, 2001). Paulesu et al. (2001) conducted comparative studies of 72 adults with dyslexia problems in France, the United Kingdom and Italy. The researchers used the positron emission tomography technique to observe blood flow and the neurological activity in the brain while the participants read printed material. Brain scans revealed the same reduction in activity in a region of the left hemisphere of the brain of the participants studied in all three countries. Reduced activity of the temporal and left parietal cortex could affect phonological processing; an atypical development was noted in several structures of the neuronal system that serve as support when learning to read. Therefore, most specialists believe that the nuclear dyslexia deficit would correspond to a dysfunction of those neuronal circuits responsible for phonological processing capacity (Ramus et al., 2003, Shaywitz et al., 1998). During the phonological analysis that underlies every reading process, the activation of the posterior cortical regions (Wernicke, angular gyrus and striated cortex) is lower in dyslexic people than in non-dyslexic people, while over-activation of the anterior regions occurs (mainly from the inferior frontal gyrus) (Puente, Jiménez & Ardila, 2009). Likewise, brain imaging research has shown differences in the brains of people with and without dyslexia (Pollack, Luk, & Christodoulou, 2015). These structural and functional anomalies would in turn originate in the mutation of certain genes (Astrom, Wadsworth, Olson, Willcut & DeFries, 2012; Byrne, Finlayson, Flood, Lyons & Willis, 2009; Gibson & Gruen, 2008). Therefore, scientific evidence indicates that dyslexia has a neurobiological origin caused by the abnormal development and dysfunction of certain neuronal circuits (Benítez-Burraco, 2012; Paracchini, Scerri & Monaco, 2007). In synthesis, dyslexia denotes a series of limitations in learning to read caused by brain alterations in the right and left hemisphere, in the subcortical structures and the cerebellum, as well as the expression of certain genes (Rodenas-Cuadrado, Ho & Vernes, 2014; Kraft et al., 2016; Morken, Helland, Hugdahl & Specht, 2017).

While the relevance of phonological awareness deficits should not be minimized, there is substantial evidence that other factors, such as visual deficits and perceptual processing, are involved in dyslexia. Advances until about the 1960s were made by ophthalmologists, such as Morgan, Hinshelwood, or Orton, who coined the term "word blindness" to describe the syndrome (Hinshelwood, 1917). Different authors have noted perceptual-visual problems such as altered orientation in spatial attention, possibly related to dysfunction in the right parietal cortex, slower reaction time to visual stimuli, and a tendency not to focus attention as normal readers would (Heiervang & Hugdahl, 2003). The recent study by Franceschini, Bertoni, Gianesini, Gori & Facoetti (2017) challenges phonological deficit as being the only explanation for dyslexia, suggesting that learning to read would also depend on an efficient right neural network for a global analysis of the visual scene. Likewise, Stein (2018) determines that, in dyslexics, development of the visual magnocellular system is compromised. The development of the magnocellular layers of the lateral geniculate nucleus (LGN) is abnormal in dyslexic people. Therefore, sensitivity to movement is reduced in people with dyslexia, with unstable binocular fixation, giving rise to poor visual location, particularly on the left side (left negligence). Studies conducted by Frostig showed that students require well developed visual perception when learning to read, and above all, skills of constancy of form, position in space, figure-background discrimination or spatial relations, revealing the importance of saccadic eye movements for proper, fluid and precise reading (Lázaro, García & Perales, 2013; Martin Lobo, 2003; Santiuste, Martin Lobo & Ayala Flores, 2006). A good development of the saccadic eye movements enables better reading speed (Leong et al. 2014). Abnormal eye movements are frequently related to reading ability in particular. Studies found that children with dyslexia had inefficient eye movements and their fixation pauses were very high (Bucci, Bremond-Gignac & Kapoula, 2008).

Another aspect that appears to influence the learning of dyslexic students is laterality, understood as asymmetries of bilateral structures or behaviour biases (Wiper, 2017). It is necessary to begin by explaining a series of terms that could otherwise be confusing. Lateralization is the process by which a person's laterality is defined, that is, a predominance of one part of the body over another is produced as a consequence of the hegemony of one of the cerebral hemispheres. Hemispheric dominance refers to the part of the brain charged with performing a given task, while the other part acts as a complement (Ortigosa, 2004). In this regard, the importance and implication that each of the hemispheres has in functional and cognitive processes has been researched. Authors such as Ferré & Irabau (2008) propose to speak of a referent instead of a dominant hemisphere, since the participation of both hemispheres in different linguistic and perceptive-motor activities is always necessary. However, in each hemisphere a preferential cognitive style is developed. The left hemisphere is responsible for linguistic, logical, analytical and sequential processing, and the right hemisphere for visuospatial tasks, as well as the expression and interpretation of emotional information (Dubois et al., 2009). The left hemisphere is usually dominant in linguistic tasks. Nevertheless, in people with dyslexia, it does not appear to happen that way, so the number of messages sent from one hemisphere to another slows down linguistic processing (Dehaene et al., 2010), such as the reading process. Other studies have linked students' learning problems to the lateralization process, i.e. hand, foot, eye, attributing this as a problem to their achieving literacy (Mayolas, Villarroya & Reverter, 2010).

Along with the phonological nuclear deficit that characterizes dyslexia, other studies point to a relationship between reading difficulties with activation of the frontal lobe, considered the centre for attention control and executive functions that acts as a filter and control and helps the processing of information in a determined visual field (Reiter, Tucha & Lange, 2005). The executive functions allow people to autonomously develop self-directed, goal-oriented behaviours through a set of capacities (Rebollo & Montiel, 2006). However, in the case of students with dyslexia, they showed a lower performance in abilities such as mental flexibility, working memory, and the ability to inhibit cognitive, verbal and visual fluency (Reiter et al., 2005) as well as in selective attention (Lima, Pinheiro-Travaini, Salgado-Azoni & Ciasca, 2012), with difficulties in basic executive functions such as attention, planning and working memory (Berninger, Nielsen, Abbott, Wijsman & Raskind, 2008). Other research establishes a relationship between executive functions and scholastic performance. One of the capacities that has received empirical attention is verbal and visual working memory; finding relationships between performance in this executive ability and the learning of different subjects such as language, reading and writing, math and science (Best, Miller & Jones, 2009).

In summary, it appears that dyslexia of neurobiological origin is the result of a combination of multiple-risk factors, including phonological problems, perceptual-visual deficits, as well as motor and executive functioning (Thompson, 2015). Therefore, taking into consideration the results of studies of this neuropsychological construct in the scholastic performance of adolescent students with dyslexia, visual abilities at the perceptual-sensory level, laterality at the neurological level, or the executive functions, will be highly relevant variables for the students' development by playing a highly pertinent role in learning in general and, in particular, in relation to the school environment. Hence, dyslexia is accepted as a disorder of life duration. However, throughout a student's development, the reading trajectories are not homogeneous and the manifestations of cognitive deficits in dyslexic readers can change throughout life (Catts & Kamhi, 2005). Therefore, the novelty of this study lies in the age range of the sample, as well as its mother tongue. Research has focused on young children with dyslexia, but little research has examined the cognitive and other skills that underlie dyslexia in adolescent students, with the majority of studies being restricted to English-speaking dyslexic adolescents. Other contributions from different studies compare the neuropsychological performance of adolescents with dyslexia. This is the case of the study by Chung, Ho, Chan, Tsang & Lee (2010) which evaluated cognitive abilities such as morphological awareness, visual-orthographic knowledge, rapid naming, and verbal working memory in Chinese adolescents with dyslexia. The results showed that these Chinese adolescents were less competent than the control students in all cognitive and literacy measures. The study by Nielsen et al., 2016 evaluated whether dyslexia in adolescents and young adults could be expressed differently phenotypically. To date, we have no evidence that the neuropsychological parameters in adolescents with dyslexia in the Spanish language, such as those included in this study, have been studied.

Therefore, the aim of this study is to analyse and explore the differences in saccadic eye movements, specifically the fast and automated denomination of digits, laterality and executive functions related to reading development in students with and without dyslexia. Based on previous studies, our hypothesis is that adolescents with dyslexia score lower than students without dyslexia in neuropsychological skills such as saccadic eye movements, laterality and executive functions.

## Material and methods

### Participants

A sample of 60 students participated in the study, 30 with dyslexia and 30 without dyslexia, aged between 13 and 15, all enrolled in a Public Secondary School in the Region of Murcia, Spain. On the one hand, the group of students with dyslexia was diagnosed by a team of educational psychologists and a neuropsychologist, following the protocol of the Educational Administration of the Region of Murcia (Spain). This protocol is based on the diagnostic criteria of DSM-IV-TR (2002), the International Dyslexia Association and information collected from family and tutor interviews. The anamnesis, and a battery of neuropsychological and psychological tests, allowed the team of experts to collect data related to linguistic, cognitive and psychomotor development, emotional development, behaviour and health problems, as well as any family history of reading problems. On the other hand, the teachers of those students without dyslexia confirmed they had no history of literacy problems, dyslexia, or other learning difficulties or any childhood psychopathology, nor had they been treated in any special educational services. These students were carefully selected to match the group of students with dyslexia in age. Inclusion criteria for the group of students without dyslexia: (a) Standardized performance in the different areas of the curriculum; (b) Their mother tongue being Spanish; (c) Informed consent of parents or guardians to their participation in the study. The exclusion criteria were: (a) Poor general linguistic competence: difficulties in reading unknown words or pseudowords, low reading speed, poor reading comprehension, difficulty reading with good prosody; (b) Existence of any disability, autism spectrum disorder or diagnosis of learning difficulties. The recruitment of the participants was carried out in an informed way and with the consent of the relatives, in collaboration with the researcher who developed his teaching work in the Guidance Department of the educational centre, to which the whole of this study sample belonged. The students participated voluntarily in the study, without perceiving any form of emolument or compensation of economic or academic nature. The study was carried out according to the Declaration of Helsinki principles and approved by the Department of Neuropsychology and Education of the International University of La Rioja, UNIR.

### Assessment and Measuring Instruments

***The King-Devick Test*** (Devick, 2007). The King-Devick Test was originally designed in the 1970s and has been used as a screening instrument to identify adolescents with learning disabilities and reading fluency concerns caused by changes in saccadic movements (ie., dyslexia) (Leong et al., 2014; Oberlander, Olson & Weidaver, 2017; Rincón, Hernández & Prada, 2017). This clinical test is widely used in Spain to assess the development of saccadic eye movements; specifically, the fast and automated digit denomination (Megino-Elvira, Martín-Lobo & Vergara-Moragues, 2016). To avoid interpretation, saccades are assessed reading numbers. The age of application is between 6 and 14 years of age. It is composed of three subtests. The King-Devick test consists of reading out aloud a series of numbers from left to right, spread over four cards. The first is a test and the remaining three are used for evaluation. The administrator places the demonstration page on the table in front of the child and asks him to say all the numbers on the page as quickly and carefully as possible. Once the student understands the test, the test begins. For the correction of the ocular follow-up evaluation, this proceeds as follows: the administrator must add the reading time of each of the I, II and III cards (the test card is excluded). The time is compared according to age. To determine whether the student passes the test or not, the exact time difference between their reading and the required value for their age is established. There is a margin of error for each age group.

***The Harris Test*** (Harris, 1978). Measures the pattern of lateral dominance of hand, foot and eye. Studies conducted by the author regarding the validity and reliability of the instrument have been conducted on children aged 7-9 years old, although it has also been applied to adults. The test includes brief and entertaining tasks, favouring the application of the test. The students' knowledge of right to left is also measured. Lateral dominance is defined with a result of 8-10; right or left dominance is not clearly defined with a result of 7; and mixed dominance is considered defined with a score lower than 6, on either right or left. In the assessment of lateral eye dominance, right or left dominance is considered defined if the same eye was used in all three tests; unclearly defined right or left dominance if the same eye was used in two of the three tests; and mixed eye dominance in the remaining cases. To assess right-to-left awareness of the right or left eye and spatial orientation, a card with right and left handprints is held in front of the student in varying positions. The student stands with arms crossed and is asked to identify the right or the left print as perceived by the student. If the answers are correct, they have identified right from left correctly.

***The Spanish test for the evaluation of executive functions (ENFEN)*** (Portellano, Martínez-Arias & Zumárraga-Astorqui, 2009). Evaluation of the level of maturity and cognitive performance in activities relating to executive functions. This is composed of four tests:

-*Verbal fluency*. A two-part verbal fluency task: phonological fluency and semantic fluency. It assesses operational working memory where the subject must say as many words as possible out loud in one minute, in response to the examiner's instructions.

-*Trails*. Consists of two parts: a grey trail and a coloured trail. This is to assess cognitive flexibility, grapho-motor and visuospatial skills. In the first part, the subject draws a path linking the numbers 20 to 1, arranged at random on a sheet of paper. In the second part, the colour trail, the subject draws another trail by joining the randomly displayed numbers 1 to 21, but alternating the yellow and pink numbers.

-*Washers*. Measures the student's abstraction and programming ability. This test consists of one training trail and 14 trails where the subject must try to achieve the proposed model in the shortest amount of time with the least possible moves in each trail.

-*Resistance to interference*. This is a task-based test composed of a list of 39 words arranged in three vertical columns of 13 words each. The 39 words are names of colours, but are randomly printed in green, blue, yellow and red. The subject has to call out the colour the word is printed in. This subtest measures the subject's attention control.

In order to create a profile for each student, the punctuation for each of the tests was converted into DECA-types: very high: 9-10; high: 8; average-high: 7; average: 6-5; average-low: 4; low: 3; very low: 2-1.

## Procedures

The evaluation of the sample was carried out by the same researcher, thus avoiding any inter evaluating bias. The researcher in charge of the evaluation is an expert in neuropsychology and education, and therefore, has sufficient knowledge to apply the different tests, as well as the subsequent written collection of the data, and the analysis and rigorous interpretation of the data. The tests were applied in the following order: King-Devick test, Harris laterality test, and the Spanish EFEN test for the evaluation of executive functions. The duration of the evaluations of the entire study sample lasted approximately one month. Two students per day were evaluated. The evaluation of each student was carried out individually for approximately 45 minutes. The sessions were held in a classroom where the researcher develops her educational work. The classroom was always the same and lacked distractors that could affect the normal development of the evaluations, and had adequate lighting conditions. During the administration of the different tests, the researcher made sure that the participants understood the tasks they had to perform. The group of students with dyslexia were tested first, and then the control group.

## Data Analysis

All the analyses were performed using the statistical SPSS programme, version 20.0, for Windows. The socio-demographic characteristics of the two groups were compared using Pearson's Chi-square test for categorical variables, like gender, and the Student t-test for quantitative variables, like age. The differences between the study groups (students with and without dyslexia) were assessed with the parametric Student t-test. Pearson's Chi-square test was performed for categorical variables. The level of bilateral significance for all the statistical tests was set at $\alpha$ = 0.05.

## Results

The mean age of students with dyslexia = 14.10 (SD±0.71) and of students without dyslexia = 14.13 (SD±0.73), $p$=0.85. In relation to the sample gender, 55% of the group with dyslexia were male compared to 45 % in the control group. No significant differences were found between the study groups (group with and without dyslexia) in either age or gender as can be seen in Table 1.

Table 2 shows the neuropsychological and cognitive results from the two study groups. In the evaluation of saccadic and ocular movements of both groups, significant differences were found between the group of students with dyslexia and the group without dyslexia in a number of errors: for the group with dyslexia = 7.90 (SD±3.19) and for the group without dyslexia = 5.36 (SD±3.20), $p$<0.05., as well as in head movements: for the group with dyslexia = 1.00 (SD±0.00) for the group without dyslexia = 1.26 (SD± 0.45), $p$<0.05. With regard to hand, foot and eye lateral dominance, significant differences were established in lateral foot dominance, with 36.6% for the group with dyslexia and 80% for the group without dyslexia, $p$<0.05. Although no significant differences were established in hand and eye dominance, it was noted that hand dominance is undefined at 50% of the group of students with dyslexia, compared with 46.7% of the control group. Significant differences were established between groups in right-left recognition, with 36.6% for the group with dyslexia and 80% for the group without dyslexia, and $p$<0.05, indicating a significantly higher percentage of difficulty in the students with dyslexia. Regarding executive functions, significant differences were established between the two groups in the phonological fluency subtest, which evaluates memory: for the group with dyslexia = 4.20 (SD±1.71), and for the group without dyslexia = 7.86 (SD±1.56), $p$<0.001. In semantic fluency: for the group with dyslexia = 3.93 (SD±1.52), and for the group without dyslexia = 7.30 (SD±1.36), $p$<0.05. In the grey trail, providing data on cognitive flexibility, grapho-motor and visuospatial skills: for the group with dyslexia = 4.00 (SD±1.23), and for the group without dyslexia = 6.63 (SD±1.18), $p$<0.05. In the coloured trail subtest: for the group with dyslexia = 3.66 (SD±1.06), and for the group without dyslexia = 6.23 (SD±1.13), $p$<0.05. In the resistance to interference subtest which analyses attention control: for the group with dyslexia = 3.00 (SD±1.08), and for the group without dyslexia = 5.63 (SD±1.15), $p$<0.05. In the washers subtest which assesses abstraction and programming capacity, for the group with dyslexia = 2.73 (SD±1.25), and for the group without dyslexia = 5.13 (SD±1.30), $p$<0.05.

## Discussion

The purpose of this study was to analyse the existence of differences between adolescent students with and without dyslexia in their saccadic eye movements, laterality and executive functions relating to the reading development of these groups. The results of this study support the hypothesis given that the students with dyslexia had poorer scores in the neuropsychological skills (saccadic eye movements, laterality and executive functions) than the students without dyslexia. The results indicate that the causes of dyslexia are heterogeneous and that there may be a common primary cause in students with dyslexia, such as difficulties with phonological decoding, but it is also plausible that there are other contributing factors that partly exacerbate reading problems.

The current theoretical revision considers dyslexia as a complex disorder of multifactorial genesis, predominantly with difficulties at a phonological level, as well as in other learning processes, among which are the neuropsychological difficulties. In this study, the students with dyslexia presented poor scores in the three neuropsychological skills evaluated in the reading processes; results that are in line with Franceschini et al. (2017), suggesting that the phonological deficit is not the only explanatory deficit for dyslexia. In relation to the neuropsychological sensory skills, results similar to others studies were noted, like those of Singleton & Trotter (2005) who found that abnormal eye movements in dyslexia arise from cognitive difficulties with the text, as well as visual difficulties (Franceschini et al., 2017; Bucci et

Table 1. Descriptive data of participants

| | Group with Dyslexia $n$=30 | Group without Dyslexia $n$=30 | P |
|---|---|---|---|
| Age. Mean (SD) | 14 (0.71) | 14 (0.73) | 0.859 |
| Male N (%) | 17 (56.6) | 16 (53.3) | |
| Female N (%) | 13 (43.3) | 14 (46.6) | |

Note.- Level of bilateral significance for the statistical tests: *$p\leq$ 0.05

Table 2. Neuropsychological processes: saccadic eye movement and lateral dominance and executive functions

| | Group with Dyslexia $n$=30 | Group without Dyslexia $n$=30 | T Student [b] $\chi^2$ test [a] | *P* |
|---|---|---|---|---|
| Saccadic eye movement | | | | |
| Time Mean (SD) | 93.973 (15.37) | 90.143 (13.66) | -1.02 [b] | 0.31 [b] |
| Number of errors Mean (SD) | 7.900 (3.19) | 5.367 (3.20) | -3.06 [b] | 0.00* [b] |
| Eye movement Mean (SD) | 2.000 (0.871) | 2.033 (0.850) | 0.10 [a] | 0.94 [a] |
| **Lateral Dominance** | | | | |
| Lateral dominance: hand | 30(50%) | 30 (73.3%) | 3.89 [a] | 0.27 [a] |
| Lateral dominance: foot | 30 (36.6) | 30 (80%) | 18.94 [a] | 0.00* [a] |
| Lateral dominance: eye | 30 (53.3%) | 30 (63.3%) | 5.53 [a] | 0.23 [a] |
| Right-left recognition | 30 (36.6%) | 30(80%) | 4.80 [a] | 0.02* [a] |
| **Executive Functions** | | | | |
| Phonological fluency Mean (SD) | 4.200 (1.71) | 7.866 (1.56) | -8.65 [b] | 0.00* [b] |
| Executive Functions: Semantic fluency Mean (SD) | 3.933 (1.52) | 7.300 (1.36) | -8.98 [b] | 0.00* [b] |
| Executive Functions: Grey trail Mean (SD) | 4.000 (1.23) | 6.633 (1.18) | -8.42 [b] | 0.00* [b] |
| Executive Functions: Coloured trail Mean(SD) | 3.666 (1.06) | 6.233 (1.13) | -9.04 [b] | 0.00* [b] |
| Executive Functions: Washers Mean (SD) | 3.000 (1.08) | 5.633 (1.15) | -9.09 [b] | 0.00* [b] |
| Executive Functions: Resistance to interference Mean (SD) | 2.733 (1.25) | 5.133 (1.30) | -7.25 [b] | 0.00* [b] |

Note. - Level of bilateral significance for the statistical tests: *$p\leq 0.05$ [a]$\chi^2$ test

al., 2008). It was confirmed that those students who presented some type of visual perception problem manifested learning difficulties and further studies have confirmed the importance of assessing saccadic eye movements for early detection and correction, thus increasing learning potential (Facoetti, Ruffino, Peru, Paganoni & Chelazzi, 2008; Solan, Hansen, Silverman, Larson & Ficarra, 2004). Nevertheless, in the present study, the lower performance of the dyslexic group in the King-Devick test does not confirm a deterioration in saccadic movements per se, but a specific deterioration in the rapid automated denomination of digits (Wolf, Bowers & Biddle, 2000). The speed of naming digits has been shown to be a good predictor of reading in alphabetic languages, based on the speed with which the brain can integrate visual and linguistic processes (Papadopoulos, Georgiou & Kendeou, 2009). A deficit in denomination speed is related to problems in reading fluency. Alterations in the occipital-temporal zone, called the area for the visual form of the word in students with dyslexia, explains the difficulties they have in reading fluency. The results of this study are in line with those of Nilsson-Benfato et al. (2016) whose results suggested that eye movements in reading are predictive of individual reading ability, with eye tracking being an effective means to identify students at risk of suffering long-term reading difficulties.

With respect to evaluating laterality, the following types of lateral dominance were evaluated: manual *hand*, podal *foot* and ocular *eye*, since manual laterality alone is not indicative of hemispherical dominance. The results established significant differences between both groups with respect to foot dominance and right-left spatial orientation. These data suggest that difficulties in spatial-temporal orientation could have an impact on the perceptual processing required in reading. Authors like Siviero, Rysovas, Juliano, Del-Potro & Bertolucci (2002) indicate that students with cross-dominance were the students who exhibited greater difficulty in learning to write, reading comprehension, and also made a greater number of reversals. Following Catalán, Casaprima, Ferré & Mombiela (2006), when laterality is seen to be developing inadequately, this can give rise to difficulties in reading automation (slow, without fluidity, with inversions or substitutions), spatial and temporal disorientation or motor and rhythm clumsiness.

Regarding the executive functions evaluated in the students with and without dyslexia, this data concludes that the students with dyslexia manifested greater difficulty with memory processes, cognitive flexibility visuospatial skills, attention control, and abstraction and planning capacity. Studies like those of Berninger et al. (2008) concluded there was a deficit in basic executive functions, planning and working memory, and learning difficulties where reading and writing processes were involved. Other studies in line with our results, such as that carried out by Best et al. (2009), indicate that, in addition to working memory, there is a relationship between inhibitory control and planning capacity in the mathematical and literacy difficulties manifested by children of ages 6 to 13. Other authors, studying samples of children with reading difficulties, point out the importance of the executive functions of working memory, planning and inhibitory control in tasks that require good comprehension and general reading ability (Cutting, Materek, Cole, Levine & Mahone, 2009). These executive functions have also been shown to be relevant skills in predicting students' academic performance, while some studies indicate that delayed maturational development in preschool courses could be indicative of difficulties in school learning, such as in the area of mathematics (Blair & Razza, 2007; Bull, Espy & Wiebe, 2008). This data is supported by studies like those of Reiter et al. (2005) which established a significant correlation between reading and writing difficulties and activation of the frontal lobe. The connection of the area for visual form to the right frontal cortex in students with dyslexia suggests that they use memory strategies to compensate for their difficulties. However, they fail because, as shown by the data in this study and in line with those mentioned above, students with dyslexia have limited memory capacity, particularly short-term verbal memory, which has been shown to be a basic reading skill (Delfior & Serrano, 2011).

## Educational research and neuropsychological implications

In short, this study indicates that the poorer performance of students with dyslexia in certain neuropsychological skills, such as saccadic eye movements, and a specific deterioration in rapid automated denomination, laterality and executive functions, which maintain a close relationship with the reading processes, has clear educational implications, pointing to the need to carry out early interventions based on neuropsychological programmes in schools. The purpose of the evaluation based on the evidence revealed during adolescence is to plan the educational programming of these students in accordance with any other neuropsychological parameters that may be compromised, along with the phonological deficit (Ibáñez-Azorín, Martín-Lobo, Vergara-Moragues & Calvo, 2018). Therefore, it is recommendable to introduce activities in the classroom that do not merely focus on learning to read in the formal manner, but also on activities that favour the capture of visual attention mechanisms, such as saccadic eye movements, crucial to reading (Gori & Facoetti, 2015). Another aspect, based on the data from our study, points to the possibility of incorporating, in the afore-mentioned neuropsychological programme, performing activities which develop laterality, in order to contribute to the inter-hemispherical connection, thus promoting the development of reading, and reading comprehension of the students with dyslexia (Martin-Lobo, 2006). That is to say, if we consider the motor and perceptual aspects as elements fundamental to the students' neurodevelopment in the early stages, this could help minimize the difficulties of these students (Ferré & Aribau, 2008; Goddard, 2005). On the other hand, stimulation of executive functions in the classroom must always bear in mind that development of the executive functions begins in infancy and is fully developed by adulthood with the maturation of the frontal brain areas (Bausela-Herrera, 2014). As such, education professionals should begin concentrating on aspects such as working memory, inhibitory control or capacity planning, amongst others, early on, to minimize the mathematical and literacy difficulties in the academic development of students with dyslexia (Best, et al. 2009).

Therefore, neuropsychology applied to the educational field can incorporate intervention programmes in classrooms, which not only benefit students with dyslexia, but also enrich the educational processes of other students, providing scientific knowledge and methods to allow a better understanding of the cognition, motivation and the different processes involved in learning (Murphy & Benton, 2010). The success of such neuropsychological programmes will depend on close collaboration between the clinical centres, school psychologists, teachers and parents in order for the neuropsychological processes that are the basis of scholastic performance, as shown by the results of this study and in the publications relating to improvement in scholastic performance, incorporating neuropsychology into the field of education (Martín-Lobo, 2006; 2003). In general, if students do not manifest learning difficulties, conventional teaching will be sufficient to enable them to acquire processes such as reading, writing and other mathematical knowledge or skills adequately. Nevertheless, if a student suffers from dyslexia, it is very likely that, over time, this student will suffer a delay in learning the basic instrumental tasks, and a gap will grow between the student and the rest of the classmates over the years. Therefore, in this study we have used educational neuropsychology to detect and try to find skills to prevent the onset of problems like dyslexia.

## Limitations

It is important that the data in this study be interpreted with caution, based on the following limitations. First, regarding the intelligence quotient (IQ), we only collected the results for the group of students with dyslexia. To determine the diagnosis of students with dyslexia, the criterion of discrepancy between IQ and performance was taken into account together with another set of parameters, not just the student's IQ, since, if reading correlates with IQ, dyslexia would not exist. The exclusive use of this unique criterion for the diagnosis of dyslexia has generated controversy. In the case of students without dyslexia, although it is true that their IQ was not documented, a series of data was collected that determined whether or not the students had a normalized performance in the processes related to reading, as well as aspects that were relevant to the selection of this student body in the present study. Therefore, it should be borne in mind that IQ data between both groups of students are not part of the objective of this study and, in our opinion, would not hinder the interpretation of the study data. Likewise, the study's design is crossed, as we have no evaluation data, so it would be interesting to follow the evolution of these students to verify whether the difficulties experienced in adolescence are maintained or otherwise in adulthood, or whether they have been compensated, in which case, how. Finally, with regard to the measurements of the saccadic eye movements, this could be completed in future studies with another instrument that evaluates with an eye tracker, in addition to the King-Devick test.

Despite the descriptions of the limitations in the present study, this research shows that the persistent reading difficulties of students with dyslexia is caused by a group of cognitive and neuropsychological deficits that are not homogeneous and are changing; therefore, generating different needs throughout school life, adolescence and adulthood. In the future, it would be interesting to carry out a longitudinal study, incorporating advancements in neuroimaging in order to see the needs of these students in adulthood. The prospective that emerges from this study suggests that, in the future, it will be necessary to create specific programmes to foment the development of neuropsychological abilities in order to improve the acquisition of literacy in students with dyslexia. The data that can be provided from such studies in the Spanish population with dyslexia will be especially relevant if we take into account the fact that the majority of scientific research in this field is carried out in English (De-La-Peña & Bernabéu, 2018).

## Acknowledgements

This work is partially funded by UNIR Research (http://research.unir.net), Universidad Internacional de La Rioja (UNIR, http://www.unir.net), under the Research Support Strategy 2 [2015], "Research Group, Grupo de Investigación Neuropsicología aplicada a la Educación (GdI.14-NYE)"

## References

American Psychiatric Association, APA. (2002). *DSM-IV-TR. Diagnostic and statistical manual of mental illnesses*. Rev. Ed. Barcelona: Masson.

Astrom, R.L., Wadsworth, S.J., Olson, R.K., Willcutt, E.G., & DeFries JC. (2012). Genetic and environmental etiologies of reading difficulties: DeFries–Fulker analysis of reading performance data from twin pairs and their non-twin siblings. *Learning and Individual Differences, 22*(3), 365-369. http://dx.doi.org/10.1016/j.lindif.2012.01.011

Bausela-Herreras, E. (2014). Selective attention modulates the processing of information and the implicit memory. *Acción Psicológica, 11*(1), 21-34. http://dx.doi.org/10.5944/ap.11.1.13789

Benítez-Burraco, A. (2012). Aspectos problemáticos del análisis genético de los trastornos específicos del lenguaje, FOXP2 como paradigma [Problematic aspects of the genetic analysis of specific language disorders, FOXP2 as a paradigm]. *Neurología, 27*(4), 225-33. http://dx.doi.org/10.1016/j.nrl.2011.04.008

Berninger, V., Nielsen, K., Abbott, R., Wijsman, E., & Raskind, W. (2008). Writing problems in developmental dyslexia: Under-recognized and under-treated. *Journal of School Psychology, 46*(1), 1-21. http://dx.doi.org/10.1016/j.jsp.2006.11.008

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental review, 29*(3), 18-200. http://dx.doi.org/10.1016/j.dr.2009.05.002

Blair, C., & Peters Razza, R. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*(2), 647-663. http://dx.doi.org/10.1111/j.1467-8624.2007.01019.x

Bucci, M.P., Brémond-Gignac, D., & Kapoula, Z. (2008). Poor binocular coordination of saccades in dyslexic children. *Graefe's Archive for Clinical and Experimental Ophthalmology*, 246(3), 417-428. http://dx.doi.org/10.1007/s00417-007-0723-1

Bull, R., Espy, K.A., & Wiebe, S.A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33*(3), 205-28. http://dx.doi.org/10.1080/87565640801982312

Byrne, M., Finlayson, O., Flood, B., Lyons, O., & Willis, P. (2010). A comparison of the learning approaches of accounting and science students at an Irish university, *Journal of Further and Higher Education, 34*(3), 369-383. http://dx.doi.org/10.1080/0309877X.2010.484055

Catalán, J., Casaprima, V., Ferré, J. & Mombiela, J.V. (2006). *Técnicas de tratamiento de los trastornos de la lateralidad*. Barcelona: Instituto Médico del desarrollo infantil.

Catts H.W., & Kamhi, A.G. (2005). Defining reading disabilities. In: Catts HW & Kamki AG, (Eds.), *Language and Reading Disabilities*. Boston, MA: Allyn & Bacon, pp.50–67.

Chung K. K. H., Ho C. S., Chan D. W., Tsang S. M., & Lee S. H. (2010). Cognitive profiles of Chinese adolescents with dyslexia. *Dyslexia, 16*, 2-23. http://dx.doi.org/10.1007%2Fs11145-010-9227-1

Cutting, L.E., Materek, A., Cole, C.A., Levine, T.M., & Mahone, E.M. (2009). Effects of fluency, oral language, and executive function on reading comprehension performance. *Annals of Dyslexia, 59*(1), 34-54. http://dx.doi.org/10.1007/s11881-009-0022-0

Dehaene, S., Pegado, F., Braga, L.W., Ventura, P., Nunes, G., Jobert, A., Dehaene-Lambertz, G., Kolinsky, R., Morais, J., & Cohen, L. (2010). How learning to read changes the cortical networks for vision and language. *Science, 330* (6009), 1359-64. http://dx.doi.org/10.1126/science.1194140

De La Peña., C. & Bernabéu, E. (2018). Dislexia y discalculia: Una revisión sistemática actual desde la neurogenética [Dyslexia and discalculia: A current systematic review from neurogenetics]. *Universitas Psychologica, 17*(3), 1-11. http://dx.doi.org/10.11144/Javeriana.upsy17-3.ddrs

Defior, S. & Serrano, F. (2011). Procesos fonológicos explícitos e implícitos, lectura y dislexia. *Revista Neuropsicología, Neuropsiquiatría y Neurociencias*, 11(1), 79-94.

Dubois, J., Hertz-Pannier, L., Cachia, A., Mangin, J., Le Bihan, D., & Dehaene-Lambertz, G. (2009). Structural asymmetries in the infant language and sensorimotor networks. *Cerebral Cortex, 19*(2), 414-423. http://dx.doi.org/10.1093/cercor/bhn097

Facoetti, A., Ruffino, M., Peru, A., Paganoni, P., & Chelazzi, L. (2008). Sluggish engagement and disengagement of non-spatial attention in dyslexic children. *Cortex, 44*(9), 1221-1233. http://dx.doi.org/10.1016/j.cortex.2007.10.007

Ferré, J., & Aribau, E. (2008). *The neurofunctional development of the child and its disorders. Vision, learning and other cognitive functions*. Barcelona: Lebón.

Franco-de-Lima, R., Pinheiro-Travaini, P., Salgado-Azoni, C., & Ciasca, S. (2012). Atención sostenida visual y funciones ejecutivas en niños con dislexia de desarrollo [Sustained visual attention and executive functions in children with developing dyslexia]. *Anales de Psicología, 28*(1), 66-70.

Franceschini, S., Bertoni, S., Gianesini, T., Gori, S., & Facoetti, A. (2017). A different vision of dyslexia: Local precedence on global perception. *Scientific Reports, 7*(1), 17462. http://dx.doi.org/10.1038/s41598-017-17626-1

Gibson, C.J., & Gruen, J.R. (2008). The human lexinome: Genes of language and reading. *J Commun Disord, 41*, 409-20. http://dx.doi.org/10.1016%2Fj.jcomdis.2008.03.003

Goddard, S. (2005). *Reflexes, learning and behaviour. An open window to understanding the mind and behaviour of children*. Barcelona, Spain: Vida y Kinesiología.

Gori, S., & Facoetti, A. (2015). How the visual aspects can be crucial in reading acquisition: The intriguing case of crowding and developmental dyslexia. *Journal of vision*, *15*(1), 8-8. http://dx.doi.org/10.1167/15.1.8

Harris, A. (1978). *Lateral Dominance Test*. Madrid: TEA Ediciones.

Heiervang, E., & Hugdahl, K. (2003). Impaired visual in children with dyslexia. Journal of Learning Disabilities, *36*, 68-73. http://dx.doi.org/10.1177/00222194030360010801

Hinshelwood, J. (1917). *Congenital word blindness*. London: Lewis.

Ibáñez-Azorín, E., Martín-Lobo, P., Vergara-Moragues, E., & Calvo, A. (2018). Neuropsychological program of English learning for students with dyslexia. *Electronic Journal of Research in Educational Psychology*, *16*(2), 417-445, http://dx.doi.org/10.25115/ejrep.v16i45.2100

King, A., & Devick, S. (1976). King-Devick Test. Mosby's Medical Dictionary (8th ed.).

Kraft, I., Schreiber, J., Cafiero, R., Metere, R., Schaadt, G., Skeide, M.A;… (2016). Predicting early signs of dyslexia at a preliterate age by combining behavioral assessment with structural MRI. *Neuroimage*, *143*, 378-386. http://dx.doi.org/10.1016/j.neuroimage.2016.09.004

Lázaro, M., García, J., & Perales, F. (2013). Visual and performance anomalies in primary education. A pilot study on the population of Granada. *Revista Interuniversitaria de Formación del Profesorado*, 101-119. Available at http://www.aufop.com/aufop/uploaded_files/articulos/1396630110.pdf. ISSNN 0213-8646

Leong, D. F., Maestro, C.L., Messner, L. V., Pang, Y., Smith, C., & Starling, A. J. (2014). The effect of saccadic training on early reading fluency. *Clinical Pediatric*, *53*(9), 858-64 http://dx.doi.org/10.1177/0009922814532520

Martin-Lobo, P. (2003). *Reading: neuropsychological processes of learning difficulties; intervention programmes and case studies*. Madrid: Lebon.

Martín-Lobo, P. (2006). *The leap to learning. How to achieve success in study and overcome learning difficulties*. Madrid: Palabra.

Mayolas, M., Villarroya, A., & Reverter, J. (2010). Relationship between laterality and school learning. *Apuntes de Educación Física y Deportes*, *101*, 32-42. Available at https://repositori.udl.cat/bitstream/handle/10459.1/46410/015510.pdf?seq. ISSN 1577-4015

Megino-Elvira, L., Martín-Lobo, P., & Vergara-Moragues, E. (2016). Influence of eyes movements, auditory perception and phonemic awareness in the reading process. *Journal of Education Research, 109*(6), 567-573. http://dx.doi.org/10.1080/00220671.2014.994197

Morken, F., Helland, T., Hugdahl, K., & Specht, K. (2017). Reading in dyslexia across literacy development: A longitudinal study of effective connectivity. *Neuroimage*, *144*, 92–100. http://dx.doi.org/10.1016/j.neuroimage.2016.09.060

Murphy, P. K., & Benton, S. L. (2010). The new frontier of educational neuropsychology: Unknown opportunities and unfulfilled hopes. *Contemporary Educational Psychology*, *35*(2), 153-155. http://dx.doi.org/10.1016/j.cedpsych.2010.04.006

Nielsen K., Abbott R., Griffin W., Lott J., Raskind W., & Berninger, V. W. (2016). Evidence-based reading and writing assessment for dyslexia in adolescents and young adults. *Learning Disabilities*, *21*, 38–56. http://dx.doi.org/10.18666%2FLDMJ-2016-V21-I1-6971

Nilsson-Benfatto, M., Öqvist-Seimyr, G., Ygge, J., Pansell, T., Rydberg, A., & Jacobson, C. (2016). Screening for dyslexia using eye tracking during reading. *PLoS One, 11(*12). http://dx.doi.org/10.1371/journal.pone.0165508

Oberlander, T.J., Olson, B.L., & Weidauer, L. (2017). Test-retest of the King-Devick test in an adolescent population. *J Athl Train*, *52*(5), 439-445. http://dx.doi.org/10.4085/1062-6050-52.2.12

Ortigosa, J.M. (2004). *Mi hijo es zurdo*. Madrid: Pirámide.

Papadopoulos, T. C., Georgiou, G. K., & Kendeou, P. (2009). Investigating the double-deficit hypothesis in Greek: Findings from a longitudinal study. *Journal of Learning Disabilities*, *42*(6), 528–547. http://dx.doi.org/10.1177/0022219409338745

Paracchini, S., Scerri, T., & Monaco, A.P. (2007). The genetic lexicon of dyslexia. *Annual Review of Genomics and Human Genetics*, *8*(1), 57-79. http://dx.doi.org/10.1146/annurev.genom.8.080706.092312

Paulesu, E., Démonet, J.F., Fazio, F., McCrory, E., Chanoine, V., Brunswick, N. (2001). Dyslexia: Cultural diversity and biological unity. *Science*, *291*, 2165–2167. http://dx.doi.org/10.1038/71163

Paz-Alonso, P.M., Oliver, M., Lerma-Usabiaga, G., Caballero-Gaudes, C., Quiñones, I., Suárez-Coalla, P., (2018). Neural correlates of phonogical, orthographic and semantic reading processing in dyslexia. *Neuroimage Clinical*, *20*, 433-447. http://dx.doi.org/10.1016/j.nicl.2018.08.018

Peterson, R.L., & Pennington, B.F. (2015). Developmental dyslexia. *Annual Review of Clinical Psychology, 11*,283-307. http://dx.doi.org/10.1146/annurev-clinpsy-032814-112842

Pollack, C., Luk, G., & Christodoulou, J.A. (2015). A meta-analysis of functional reading systems in typically developing and struggling readers across different alphabetic languages. *Front Psychology*, *6*, 191. http://dx.doi.org/10.3389/fpsyg.2015.0019

Portellano, J., Martínez-Arias, R., & Zumárraga-Astorqui, L. (2009). *ENFEN. Neuropsychological Evaluation of Executive Functions in Children*. Madrid: TEA Ediciones.

Power, A.J., Colling, L., Mead, N., Barnes, L., & Goswami, U. (2016). Neural encoding of the speech envelope by children with developmental dyslexia, *Brain Language*, *160*, 1-10. http://dx.doi.org/10.1016/j.bandl.2016.06.006

Puente, A., Jiménez, V., & Ardila, A. (2009). Anormalidades cerebrales en sujetos disléxicos. *Revista Latinoamericana de Psicología*, *41*(1) 27-45.

Ramus, F. (2003). Developmental dyslexia: Specific phonological deficit or general sensoriomotor dysfunction? *Current Opinion in Neurobiology*, *13*(2), 212-218. http://dx.doi.org/10.1016/S0959-4388(03)00035-7

Rebollo, M.A., & Montiel, S. (2006). Atención y funciones ejecutivas [Attention and executive functions]. *Revista de Neurología*, *42*(2), S3-S7.

Reiter, A., Tucha, O., & Lange, K. W. (2005). Executive functions in children with dyslexia. *Dyslexia*, *11*(2), 116-131. http://dx.doi.org/10.1002/dys.289

Rincón, G., Hernández, C., & Prada, R. (2017). Influence of saccades movements on the academic performance of elementary school students in vulnerable situation in the city of Cúcuta. Psicogente, *20*(38), 256-267. http://dx.doi.org/10.17081/psico.20.38.2545

Rodenas-Cuadrado, P., Ho, J., & Vernes, S. (2014). Shining a light on CNTNAP2: Complex functions to complex disorders. *European Journal of Human Genetics*, *22*, 171-1788. http://dx.doi.org/10.1038/ejhg.2013.100

Santiuste-Bermejo, V., Martin-Lobo, P., & Ayala-Flores, C. (2006). *Neuropsychological bases of scholastic failure*. Fugaz Ediciones. Pro-Logos Educación.

Shaywitz, S. E., Shaywitz B. A., Pugh K. R., Fulbright R. K., Constable R. T., Mencl, W. E., & Gore J. C. (1998). Functional disruption in the organization of the brain for reading in dyslexia. *Proceedings of the National Academy of Sciences*, *95*, 2636–2641. http://dx.doi.org/10.1073/pnas.95.5.2636

Singleton, C., & Trotter, S. (2005). Visual stress in adults with and without dyslexia. *Journal of Research in Reading*, *28*(3), 365-378. http://dx.doi.org/10.1111/j.1467-9817.2005.00275.x

Siviero, M. O., Rysovas, E. O., Juliano, Y., Del-Porto, J. A., & Bertolucci, P. H. F. (2002). Eye-hand preference dissociation in obsessive-compulsive disorders and dyslexia. *Arquivos de Neuro-Psiquiatria*, 60 (2-A), 242-245. http://dx.doi.org/10.1590/S0004-282X2002000200011

Solan, H. A.T., Hansen, P. C., Silverman, M. E., Larson, S., & Ficarra, A. (2004). M-cell deficit and reading disability: A preliminary study of the effects of temporal vision-processing therapy. *Optometry*, *75*, 640-650. http://dx.doi.org/10.1016/S1529-1839(04)70211-0

Stein, J.F. (2018). The Magnocellular Theory of Developmental Dyslexia. *Dyslexia*, *7*(1), 12-36. http://dx.doi.org/10.1002/dys.186

Thompson, P.A. (2015). Developmental dyslexia: Predicting individual risk. *Journal of Child Psychology and Psychiatry*, *56*, 976–987. http://dx.doi.org/10.1111/jcpp.12412

Wiper, M.L. (2017) Evolutionary and mechanistic drivers of laterality: A review and new synthesis. *Laterality*, *22* (6), 740-770. http://dx.doi.org/10.1080/1357650X.2017.1291658

Wolf, M., Bowers, P.G., & Biddle, K. (2002). Naming- speed processes, timing and reading: A conceptual review. *Journal of Learning Disabilities*, *33*(4), 387-407. http://dx.doi.org/10.1177/002221940003300409

Yitzchack, F., & Pavlakis, G.S. (2001). Brain imaging in neurobehavioral disorders. *Pediatric Neurology*, *25*(4), 278-287. http://dx.doi.org/10.1016/S0887-8994(01)00282-X