© International Journal of Clinical and Health Psychology

ISSN 1697-2600 print
ISSN 2174-0852 online
2012, Vol. 12, Nº 1, pp. 69-80

Neuropsychological analysis of the difficulties in dyslexia through sensory fusion[1]

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ABSTRACT. The aim of this *ex post facto* study was to describe differences in errors of reading mechanics (corrections, substitutions, rotations, omissions, repetitions, hesitations and additions), reading processes (visual and phonological), ocular motility errors (tracking and saccades), and selective attention in two groups of children with dyslexia or reading delay. By means of an *ex post facto* design, we compared the two groups, one with altered sensory fusion measured by the optical Worth test (n = 76 students, and the other without altered sensory fusion (n = 123). Results showed that dyslexic students with impaired sensory fusion had more problems in reading mechanics and significantly in inversion errors. However, few differences were found in reading processes, selective attention, and ocular motility, without differences among the groups analyzed. In short, the diagnosis of dyslexia may be affected by alternative measures that should be examined and that would influence the approach to preventive and specialized intervention of dyslexia.

KEYWORDS. Learning disabilities. Reading. Sensory fusion. Attention. *Ex post facto* study.

RESUMEN. El objetivo de este estudio fue *ex post facto* describir las diferencias en errores de la mecánica de la lectura (rectificaciones, sustituciones, rotaciones, omisiones, repeticiones, vacilaciones y adiciones) y en los procesos lectores (visual y fonológica)

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por un lado, y errores de motilidad ocular (seguimiento y sacádico) y atención selectiva por otro, en una muestra de dos grupos de niños con retraso lector o dislexia. Mediante un diseño *ex post facto* se compararon esos dos grupos, uno con fusión sensorial alterada medida a través de la prueba óptica del Worth, compuesto por 76 alumnos (34 niños y 42 niñas), y un grupo sin fusión sensorial alterada formado por 123 alumnos (59 niños y 64 niñas). Se ha comprobado que los alumnos disléxicos con fusión sensorial alterada tuvieron mayores problemas en la mecánica de la lectura y de forma significativa en las inversiones. Sin embargo, se encontraron escasas diferencias en relación a los procesos lectores, la atención selectiva y la motilidad ocular, no diferenciándose los grupos analizados. En definitiva, parece que el diagnóstico de la dislexia pueda estar afectado por medidas alternativas que sería necesario contrastar, que influirían en la forma de enfocar la labor preventiva y de intervención especializada del problema.

PALABRAS CLAVE. Dificultades de aprendizaje. Lectura. Fusión sensorial. Atención. *Estudio ex post facto*.

Dyslexia is classified as a specific learning disability and defined as a neurological deficit that provokes unexpected difficulties in the development of reading, with a 5-10% prevalence in the population school (American Psychiatric Association, 2000; Nicolson, Fawcett, Brookes, and Needle, 2010). The prevalence of these reading difficulties (hereafter, RD) is usually higher in men than in women, both in studies based on specific samples of RD diagnoses, and in those based on general samples to be subsequently identified. Moreover, the proportion of men to women is higher in samples of subjects with greater reading problems. These reading difficulties are frequently displayed during and after the process of reading acquisition, and are considered evolutional or developmental dyslexia, which is different from acquired dyslexia, which affects subjects who, after completing the process of reading acquisition, for various reasons, cease to read (Hawke, Olson, Willcut, Wadsworth, and DeFries, 2009).

Reading is a complex process in which diverse associated variables confer. Some of them involve the capacity of discrimination, conditioned both by visual skills of control and stimulus recognition. Moreover, with the double controversy of the concept of the reading process on the one hand and, on the other, of more recent conceptualizations of learning difficulties or dyslexia-from diverse approaches and perspectives-which consider dyslexia a complex disorder with a multifactor genesis, which takes on diverse forms (Ziegler *et al.,* 2008). The concept of the reading process has been addressed from a modular and holistic perspective of integrated language, with two main components, decoding and comprehension. Currently, models of processes have emerged that can be used not only to appraise these components, but also to investigate other processes, such as the effects of morphology, semantics, or emotional aspects (Perry, Ziegler, and Zorzi, 2010).

In the conceptualization of learning disabilities, sociocultural and neuropsychological aspects are notable. The former one considers difficulties identifying words, not as a deficit or an organic dysfunction but as a consequence of the subject-context interaction

(Gindis, 2003). Dyslexia is sometimes also characterized as a mild phonological impairment linked with the experience of inadequate reading (Good, Baker, and Peyton, 2009). Few investigations have been able to provide a comprehensive theory of dyslexia, as it is a very heterogeneous problem. However, some attempts have been made to describe dyslexic symptoms that differentiate subgroups of reading problems, as in this study (Pammer and Vidyasagar, 2005).

The neuropsychological conceptualization, supported by Frith (2002) among others, establishes that the diagnosable symptoms of language delay are generated in word identification and they stem from some organic dysfunction with many manifestations, centered on a specific or a general deficit. The specific deficit suggests that the difficulty manifests in phonological processing and in processing speed. The general deficit involves a primary deficit, linked to a sensory, motor, or sensorimotor deficiency. According to Stein's (2003) magnocellular theory, sensory deficiencies affect visual or auditive processing speed and the deficit in cross-modal temporal processing. Brain deficiencies affect motor skills such as balance, writing control (graphism), articulation (phonological awareness), or automation and they generate inadequate word recognition, which affects reading and writing mechanics (Nicolson and Fawcett, 2006). Lastly, the viewpoint of the sensorimotor deficit combines both theories and considers that the dysfunction is structural in origin (Ferretti, Mazzotti, and Brizzolara, 2008). This last set of difficulties presents some contradictions (Pammer and Vidyasagar, 2005), which we explore in this investigation, analyzing the possibilities of sensory fusion by means of the Worth test, which has been extensively applied in clinical and optometric practice.

Some research studies suggest that dyslexic readers are less sensitive to stimuli visual, due to the fact that the brain network involved is interactive and dynamic, synthesizing the signals from different brain areas. Reading requires the sophisticated integration and implementation of the network component. However, despite the suggestion that visual sensitivity and sensory fusion may be essential for normal acquisition of reading skills, no measures of these aspects and their influence have been proposed or specified (Kevan and Pammer, 2008). Hence, the contradictory results in the preceding studies may be due to the possibility that only one subgroup of dyslexic readers has a magnocellular deficit, or because this theory needs more development to describe the exact nature of the visual deficit (Pammer and Vidyasagar, 2005).

In previous investigations (Álvarez, González-Castro, Álvarez, and Bernardo, 2008), it has been shown that there are skills prior to the reading process, which are the origin of different kinds of errors that are typical of subjects with very slow stimulus recognition (neuropsychological deficit). Visual control and recognition skills (fixation and sensory fusion) could be affected, producing a below-normal reading performance and persistent errors that, strangely enough, are also habitual in Braille reading.

Another essential aspect of the comparative studies of reading and sensory sensitivity is attention. Some studies have concluded that deficient attentional processes can lead to a decrease of sensitivity in sensory processing tasks. This aspect is important due to the high incidence of comorbidity of dyslexia and attentional problems (Hulslander *et al.,* 2004). Specifically, diverse investigations have considered that ocular motility skills (tracking, saccades) and selective attention may be very important for reading mechanics. In a comparison of child and adult readers, these movements were observed to be significantly shorter in children than in adults and the fixations were longer (Juhasz, Liversedge, White, and Rayner, 2006). Children's results were poorer in fixation time, saccade length, and regression frequency, and their fixation disparity was greater than that of the adults (Blythe *et al.,* 2006).

Using magnetic resonance and post-mortem analysis of brains, Galaburda and Livingstone (1993) detected a 30% decrease in the size of dyslexic subjects' magnocellular cells, disorderly distributed in the lateral geniculate body. As a consequence of this deterioration of the paths that transport information in movement, stimulus recognition is slow and there are difficulties associated with basic orthography (Kevan and Pammer, 2008), because it is assumed that sensitivity to movement is related to the level of visual-orthographic reader skill. However, upon analyzing magnocellular sensitivity and the number of fixations on pseudowords, more recent investigations reach contradictory results (Hutzler, Kronbichler, Jacobs, and Wimmer, 2006). According to Stein (2003), only 25% of the variance is explained by the low sensitivity of the magnocellular paths in poor readers (some good readers have poor magnocellular sensitivity and vice versa). However, for Hutzler *et al.* (2006), there are significant differences between good and poor readers in pseudoword reading, fixations and times, but not in consonant reading.

These divergent conclusions have allowed the defenders of the strictly phonological models to discuss the lack of relation between reading errors and the skills of control and stimulus recognition. Although when good and poor readers are compared, the close relation between these skills and spelling errors, the number of regressions, and fixation length are difficult to explain. This is because the processes of stimulus transportation, although essential for reading, do not explain it sufficiently, and may also need support from binocular fixation (Álvarez *et al.,* 2008).

Summing up, from this perspective, cognitive neuroscience provides tools to identify in each one of these children a profile of their learning skills, and now, it is time to develop and use them (Hulslander *et al.,* 2004). In this study, with an *ex post facto* design, we propose to determine and describe the differences in errors in reading mechanics and reading processes on the one hand, and errors of ocular motility (tracking and saccades) and selective attention on the other, in two groups of children with reading delay or dyslexia: a group that presents altered sensory fusion (RD+worth), measured by means of the worth test and a group without altered sensory fusion (RD).

The initial hypothesis is that there are basic differences between the two groups, and we expect the subjects with reading delay and altered sensory fusion to present a higher number of errors in reading mechanics and more problems in reading processes (word and pseudoword reading). In addition, they will present tracking (skipping lines) and saccadic errors (number of errors), and more selective attention problems than the participants from the group with reading delay but no altered sensory fusion.

Method

Participants

Sample selection was stratified and random with proportional affixation. The stratification variable was type of center (public, subsidized) and the affixation was proportional to the size of the population of each layer. Thus, 28 schools from the Princedom of Asturias (Spain) were selected, 17 public schools and 11 subsidized schools. We contacted the selected centers and requested their participation in the investigation, and 95% accepted. All the students who theoretically suffered from RD were identified by the orientation departments in the participant schools. Out of the possible students with RD identified by the orientation team and teachers of the respective schools, the presence of dyslexia or RD was considered on the basis of the following criteria (Jiménez, Rodríguez, and Ramírez, 2009): a) low performance in a reading test in standardized Spanish; b) low academic performance in reading, based on the academic report of the corresponding teacher, and average performance in other academic areas (for example, arithmetic); and c) a score higher than 80 in an intelligence test, discarding subjects with scores over 130 and below 80. However, as the discrepancy between reading performance and intelligence quotient has been questioned (Jiménez, 2010) as a relevant criterion for RD diagnosis, in this investigation, it was not taken into account. Subsequently, we requested the informed consent of the parents to participate in this study, ensuring them of meeting the deontological codes as well as the anonymity and confidentiality in the treatment of the data obtained.

According to these criteria, the final sample of students with RD, with a mean of reading delay in months = 20.15 (*SD* = 1.64) was classified into two groups, depending on whether or not they presented altered sensory fusion (RD+worth and RD, respectively). The RD+worth group comprised 76 students (34 boys and 42 girls), with a mean age of 87.37 months (*SD* = 10.49), a mean IQ of 98.53 (*SD* = 7.81), and a reading delay of 19.76 months (SD = 1.54). The RD group comprised 123 students (59 boys and 64 girls), mean age 86.68 months (*SD* = 10.51), a mean IQ of 97.86 (*SD* = 8.07), and a reading delay of 20.38 months (*SD* = 1.65). No age differences were observed in the groups as a function of reading delay in months; the RD group had 66.15 months delay (*SD* = 11.17) and the RD+worth group had 67.61 months (*SD* = 10.83), so the groups were homogeneous, $F_{(1, 197)} = .811$, $p = .369$, $\eta^2 = .004$. Lastly, there were no significant differences in the distribution of the participants as a function of gender ($p = .659$), age in months ($p = .655$), or in IQ ($p = .569$).

Instruments

– WORTH (Worth, 1903) is a test to assess central fixation and ocular dominance. The test has 4 images: two green crosses, a red rhombus, and a white circle. These images are presented together, and a red filter is placed on the right eye and a green filter on the left eye of the participant. Next, participants are asked what they see, and interpretation depends on whether they see a white, a green, or a red circle, or the colors are mixed. The mixture indicates difficulties in stimulus recognition or sensory fusion.

- *Prueba de Evaluación del Retraso en Lectura* (PEREL; Maldonado, Sebastián, and Soto, 1992) is a test to assess reading delay in students from first to third grade of primary education by means of reading 100 words that have a pre-established difficulty index. It classifies the levels of performance by comparing the standardized results by school trimesters.
- Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 1974) is a psychometric test to assess verbal and manipulative general intelligence (IQ).
- *Test de Aprendizaje de la Lecto-escritura* (TALE; Toro and Cervera, 1995) is a performance test that attempts to determine the general levels and specific characteristics of reading and writing of any student at a certain moment of their schooling. In this study, the reading errors, quantified as the number of corrections, substitutions, rotations, omissions, repetitions, hesitations, and additions, were taken into account.
- *Test de los Procesos de la Lectura* (PROLEC; Cuetos, Rodríguez, and Ruano, 1996). This test for the assessment of reading processes includes various reading subtests. Only the word reading (indicating the use of the direct visual or lexical route in reading) and pseudoword word reading (indicating the use of the phonological route) subtests were administered. The authors report an alpha coefficient of .92.
- Ocular Motility (Álvarez *et al.,* 2008). This is the subject's skill to combine two types of ocular movements: tracking and saccades. We used tracking (skipping lines) and saccades (the number of errors) as dependent variables.
  * Tracking. This is a capacity related to gross eye movements that consist of the independence of extra-ocular and parallel eye movements. We used a flashlight or a ball, which we moved in front of the subject, at eye level, from left to right, from top to bottom, and in the form of a cross and in circles around the subject. We observed whether the subjects moved the entire body or the head. In this research, tracking was logged through skipping lines in a reading task.
  * Saccades. These are rapid eye movements between fixation points. The Developmental Eye Movement (DEM) test and Wolff wands were used to measure them. The DEM test is made up of columns of letters, and the wands are two small sticks with a ball at one end, and the test consists of changing the fixations from one wand to the other when so instructed, by moving the wands through space. Speed, accuracy, and fixation quality are assessed. In this study number of errors were logged in DEM test.
- Perception of Differences Test (Thurstone and Yela, 1979). This test assesses perceptive aptitudes and attention during a 3-minute collective administration. It assesses the aptitudes required to quickly perceive similarities and differences with partially ordered stimulus patterns. The stability of the scores and the internal consistency were confirmed with correlation coefficients higher than .96, significant at a 99% confidence level (Crespo-Eguílaz, Narbona, Peralta, and Reparaz, 2006).

Design

This descriptive *ex post facto* study used a two-group design: RD+worth and RD. As dependent measures, we used the partial measures of the TALE (corrections, substitutions, rotations, omissions, repetitions, hesitations, and additions), the PROLEC (the percentiles of the tests of visual and phonological route), selective attention (percentiles obtained in the Test of Perception of Differences) and Ocular Motility (tracking-skipping lines-and saccade-number of errors). The tests were administered in three sessions on different days by the authors of the study, with the groups distributed according to the selection criteria of the sample.

Results

The analyses of data were performed with the statistical package SPSS 17.0. The dependent measures were analyzed with multivariate analysis of covariance (MANCOVA), introducing as covariates age, sex, and IQ. This process was carried out separately, depending on the provenance of the dependent variables, and is described in four sections: the TALE (reading analysis), the PROLEC (reading processes), the Test of Perception of Differences (selective attention), and Ocular Motility (tracking and saccades).

TALE

To control for group differences, we performed MANCOVAs, which revealed differences as a function of the presence or absence of altered sensory fusion in the TALE measures, $\lambda = 0.73$, $F_{(8, 187)} = 296.966$, $p = .000$, $\eta^2 = .927$, with a large effect size. As covariate, we entered sex, $\lambda = .982$, $F_{(8, 187)} = .425$, $p = .905$, $\eta^2 = .018$; and IQ, $\lambda = .953$, $F_{(8, 187)} = 1.161$, $p = .325$, $\eta^2 = .047$, but no differences emerged as a function of this variable. However, upon entering age as a covariate, $\lambda = .890$, $F_{(8, 187)} = 2.903$, $p = .004$, $\eta^2 = .110$, there was a small effect size. These differences show some influence of age on the groups, especially if the Group x Age interaction is taken into account ($p = .000$, $\eta^2 = .602$). Table 1 shows the means and standard deviations of the diverse errors made in the TALE, as well as the group differences in these eight dependent variables.

TABLE 1. Means, standard deviations, and group differences in reading errors as measured by the TALE in the RD and RD+worth groups.

	RD (N=123)		*RD+worth (N=76)*			
Variables	*Mean*	*SD*	*Mean*	*SD*	*F (1, 194)*	η^2
Inversions	0.02	.15	4.91	1.213	1982.90**	.911
Corrections	3.60	.80	4.39	1.008	36.18**	.157
Substitutions	3.41	.79	4.36	1.042	56.52**	.226
Rotations	4.14	.75	4.08	1.197	.09	.001
Omissions	4.21	.87	4.12	1.265	.28	.001
Repetitions	3.98	.67	4.25	1.338	3.37*	.017
Hesitations	4.50	.90	3.83	1.012	23.32**	.107
Additions	3.74	.80	3.99	1.125	3.53*	.018

Note. RD+worth = group with dyslexia and altered sensory fusion; RD = group with dyslexia. ** $p \leqslant .001$;* $p \leqslant .01$.

Notable among these errors, as indicators of failures in reading mechanics, are the number of inversions performed by the RD+worth group, much higher than the RD group, and hence, the error that best differentiates the participants of this group. Although with fewer differences, other errors, such as corrections and substitutions, as well as repetitions and additions, showed the same tendency. Contra-intuitively, in the number of hesitations, the results of the RD group were significantly worse than those of the RD+worth group. With regard to rotations and omissions, the RD group also showed this same tendency, although non significantly.

PROLEC

As with the measures from the TALE, we verified the group differences of the two groups (RD and RD+worth) in two general measures of the PROLEC, specifically the word reading (visual or lexical route) and pseudoword reading (phonological route) subtests. Multivariate analyses of variance yielded no statistically significant group differences, $\lambda = .996$, $F_{(1, 193)} = 0.402$, $p = .670$, with the RD+worth group obtaining a mean percentile of 15.74 ($SD = 8.60$) in the visual route and 12.57 ($SD = 6.95$) in the phonological route, whereas the RD group obtained a mean percentile of 15.34 ($SD = 8.06$) in the visual route and 13.46 ($SD = 7.52$) in the phonological route. With sex, age, and IQ as covariates, we only obtained an age effect, although with a small effect size, $\lambda = .935$, $F_{(1, 193)} = 6.656$, $p = .002$, $\eta^2 = .065$; when analyzing the Age *x* Group interaction, this effect disappeared ($p = .555$), so its influence was lower than in the TALE measures, for example.

Test of Perception of Differences (Faces)

With regard to the measure of selective attention, the ANCOVA revealed statistically significant differences as a function of altered sensory fusion, $F_{(1, 194)} = 8.028$, $p = .005$, $\eta^2 = .040$, although with a small effect size; the RD+worth group obtained a percentile of 27.37 ($SD = 8.22$), whereas the RD group obtained a percentile of 24.27 ($SD = 6.30$); the results of the RD+worth group were slightly better. None of the three covariates-sex, age, and IQ-yielded statistically significant differences ($p = .502$, $p = .060$, and $p = .786$, respectively)

Ocular Motility (tracking and saccades)

With regard to the measures of tracking and saccades, the MANCOVA revealed statistically significant differences as a function of altered sensory fusion, $\lambda = .847$, $F_{(1, 193)} = 17.370$, $p = .000$, $\eta^2 = .153$. The results of tracking were statistically significant ($p = .000$, $\eta^2 = .120$), and the RD+worth group, with a mean of 3.62 ($SD = 1.10$), committed fewer errors of this type than the RD group, which obtained a mean of 4.34 ($SD = 0.90$). There were fewer saccade differences ($p = .049$, $\eta^2 = .020$) and, strange to say, in the opposite direction, as the RD+worth group committed more errors, with a mean of 13.38 ($SD = 5.79$), than the RD group, which obtained a mean of 12.93 ($SD = 5.95$).

Two of the covariates directly affected the variability, for example, age, λ =.199, $F_{(1, 193)}$ = 388.049, p = .000, η^2 = .801, which particularly affected saccades, $F_{(1, 194)}$ = 779.727, p = .000, η^2 = .801, but also tracking, $F_{(1, 194)}$ = 17.596, p = .000, η^2 = .083. There was a smaller effect for IQ, λ =.964, $F_{(1, 193)}$ = 3.589, p = .029, η^2 = .036, and sex had no influence.

Discussion and conclusions

The difficulty of determining the best definition of dyslexia has contributed to the heterogeneity of its problems, with implications for its diagnosis, prevalence, and rehabilitation. Moreover, an imprecise diagnosis in the research samples and some incoherence about the perceptive, sensory, and motor problems of dyslexia affect the reproducibility and generalization of the results (Cotton, Crewther, Crewther, 2005). In this study, we wished to differentiate in general two dyslexic subtypes as a function of the sensory measured with the Worth test (Pammer and Vidyasagar, 2005).

Previous studies (Álvarez *et al.,* 2008) anticipated basic differences in subjects with RD, with those who had altered sensory fusion presenting a greater number of errors in reading mechanics. This hypothesis is partially confirmed for a measure of reading mechanics such as inversions. It seems that letter inversions when reading is a problem closely linked to altered sensory fusion, as the RD group did not have much trouble with this. Therefore, this measure is an indicator of attentional problems in the case of dyslexia. There is also a significant effect of age on this variable, which should be taken into account in the clinical diagnosis (Facoetti *et al.,* 2010).

The RD+worth group is also prone to errors of correction, substitution, and repetition of letters, although to a lesser degree than inversions. We highlight that the RD group had more trouble with hesitations, and this error may be a characteristic of this group. Lastly, a common characteristic of both groups, rotations and omissions, affected both groups equally (Olson, 2002). Preceding studies suggest that any relation between visual processing and reading is more general than specific. Current data show that, after controlling for IQ, individual differences in the thresholds of sensory transformation do not usually have high and significant correlations with reading, in contrast to various oral skills (Cotton *et al.,* 2005). Some studies have concluded that reading difficulties are associated with sensory deficits in processing certain visual stimuli, with statistically significant relations between reading performance and sensory processing tasks in schoolchildren. However, there are some contradictory results about the specificity of the magnocellular visual deficit. Sensitivity to dynamic stimuli has been identified as an essential parameter, instead of the detection of static stimuli for a limited time (Hulslander *et al.,* 2004).

With regard to reading processes, the results obtained present low percentiles in both groups, with no differences in either route. Therefore, these measures of processes seem independent from altered sensory fusion and they do not present the same distinct profile as the mechanical measures of reading, therefore they lack the capacity to discriminate between groups (Ziegler *et al.,* 2008).

In this study, it was logical to assume that the group with sensory fusion would obtain worse results in selective attention; however, there were no group differences, and the group with sensory fusion obtained even higher measures (Álvarez *et al.,* 2008). Despite the anatomical differences in dyslexic readers, performance differences have been particularly revealed in their sensitivity to dynamic visual stimuli, and not so much to static stimuli, as may be in this case (Pammer and Vidyasagar, 2005). Moreover, following current clinical investigations, traditional research of selective attention usually adopts a mechanicist viewpoint, focusing on theories of filter, automatisms, or limited resources (González-Castro *et al.,* 2010; Levi, 2008). However, we need to understand the visual mechanisms underlying reading in order to develop integral assessments to identify the cognitive skills needed for competent reading, which is crucial for the development of rehabilitation programs (Kevan and Pammer, 2008).

In a similar vein, the relation of sensory fusion with the measures of tracking and saccades is inconsistent, producing contradictory results. Although the RD+worth group presented a few more errors in saccades, their results in tracking were better than those of the RD group. We underline that some authors consider that attention in reading skills is independent from the classification or the subtypes we identified in dyslexia (Facoetti *et al.,* 2010).

The limitations of this study are mainly due to its descriptive nature and that of the groups assessed, as there is no control group. More detailed studies should be carried out, incorporating a group of young readers as a control group with a quasi-experimental design, or even incorporating some measure of dynamic attention (Pammer and Vidyasagar, 2005). This would lead to more exhaustive and precise conclusions, controlling, for example, the effect of the variable age, which interacts significantly with the variables under study (Jiménez *et al.,* 2009). On the other hand, more research is needed along the current lines of research of diagnosis of dyslexia as a response to intervention (Grigorenko, 2009), taking into account that the model of discrepancy as a method of diagnosis of learning disabilities is being questioned, and the model of response to intervention is proposed as an alternative (Jiménez, 2010).

The future of this experimental measure will depend on extensive epidemiological and intervention studies, taking into account that the visual deficit occurs before initiation of reading, although the debate about the causes and consequences of this deficit in dyslexia remains open. No doubt, the results obtained in this investigation, in accordance with other previous ones, cannot conclude that the visual deficit leads to the consequence of not learning how to read. However, future research should explore whether this deficit, in the case of sensory fusion, plays a causal role in the development of reading, or whether it represents a biological marker that is associated with more general cognitive alterations (Kevan and Pammer, 2008).

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Received April 17, 2011
Accepted October 24, 2011