Annals of Dyslexia (2022) 72:552–565
https://doi.org/10.1007/s11881-022-00269-x

Reading performance in children with ADHD: an eye-tracking study

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Received: 8 October 2021 / Accepted: 20 July 2022 / Published online: 3 August 2022

Abstract
Reading disabilities have a profound impact on the academic performance and achievement of children. Although oculomotor pattern abnormalities during reading in children with dyslexia are well known, those in individuals with attention deficit and hyperactive disorders (ADHD) — who also frequently exhibit a reading impairment — remain largely undetermined. The objective of the present study was to evaluate the peculiarities of oculomotor pattern abnormalities during a reading task. An eye-tracker was used to record eye movements in four distinct groups of children with neurodevelopmental disorders: children with dyslexia, children with ADHD with and without comorbid dyslexia, and in a group of typically developing children (TD). Ninety-six children participated in the study (24 children per group, IQ- and age-matched groups). The duration of fixation, the total reading time, and the number of forward and backward saccades were similar in children with dyslexia and ADHD + dyslexia, but were significantly different from those observed in children with ADHD and with TD. Our findings suggest a link between dyslexia and oculomotor reading impairments in both children with dyslexia and children with ADHD + dyslexia, indicating that the oculomotor pattern in children with ADHD without comorbid dyslexia is similar to that observed in TD children. We suggest that an objective eye movement recording during a reading task could help clinicians to better evaluate the possible presence of comorbid dyslexia in children with ADHD. Furthermore, children with ADHD with and without comorbid dyslexia could also have working memory deficiencies. Further studies are needed to confirm this finding.

Keywords ADHD · Children · Dyslexia · Eye movements · Neurodevelopment

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Introduction

Attention deficit hyperactivity disorder (ADHD) is characterized by inattention, hyperactivity, and impulsivity related symptoms. It affects approximately 2–5% of children (American Psychiatric Association APA, 2013). Children with ADHD show frequent adaptive impairment at school, as they display difficulties remaining calm in class or doing their homework (Nigg & Barkley, 2014). Attention deficit is also associated with frequent learning disorders and leads to poor academic performance in these children (Loe & Feldman, 2007) as maintaining one's attention is necessary to ignore distractors and for reading comprehension (Miller et al., 2013).

Dyslexia is among the most frequent learning disorders observed in children with ADHD and co-occurs in 45% of them (DuPaul et al., 2013). Reading disabilities are associated with a negative impact in children with ADHD, leading to underachievement and learning difficulties (Kofler et al., 2019; Rapport et al., 2009; Sexton et al., 2012), with some studies reporting specific impairment in phrase/word decoding and comprehension (Ehm et al., 2016; Greven et al., 2012). Several models have attempted to explain the presence of comorbidity between ADHD and dyslexia (see Willcutt, 2018); the comorbidity of dyslexia and hyperactivity could be due to a distinct heavy disorder characterized by the presence of difficulties several cognitive process as working memory, rapid naming and speed processing (Katz et al., 2011; Rucklidge & Tannock, 2002). Some studies reported a specific relation between inattention and poor reading (Cain & Bignell, 2014; Willcutt & Pennington, 2000) but also between hyperactivity and reading difficulties (Adams & Snowling, 2001).

Even if in the literature it has been reported that the presence of learning disorders in subjects with ADHD has a crucial long-lasting clinical, psychological and social impact (Birnbaum et al., 2005; Quinn et al., 2001), the mechanisms unifying ADHD and dyslexia remain unclear. Pennington (2006) proposed a multiple deficit instead of a single deficit to explain the comorbidity in neurodevelopmental disorders. In other words, this model suggested that there are multiple, probabilistic predictors of developmental disorders and that comorbidity occurs because of risk factors (genetic, neural, cognitive) that are shared by disorders.

To explore further the dyslexia-ADHD comorbidity, Langer et al. (2019) conducted a structural and functional MRI study comparing children with ADHD *vs.* those with ADHD and dyslexia *vs.* those with dyslexia alone *vs.* those with typical development. They reported a decreased cortical thickness in the supplementary motor area, the anterior cingulate cortex, and the inferior frontal gyrus in children with ADHD and/or dyslexia. In the same regions and in the same groups of subjects, they observed functional peculiarities, specifically in the supplementary motor area and the anterior cingulate cortex during an executive function task, and in the inferior frontal gyrus during a reading task. Note that these areas are involved in reading and in executive functions such as attention, inhibition, and switching (Fiske & Holmboe, 2019). Interestingly, only the group of children with ADHD and dyslexia showed a significantly decreased cortical thickness and functional alterations in the middle temporal gyrus, supporting the hypothesis of a shared etiology in ADHD and dyslexia (McGrath & Stoodley, 2019; Willcutt, 2018).

Reading is a higher cognitive process that depends on multiple processes including sensory perception, eye movements, linguistic abilities, and semantic abilities (Rayner et al., 2011). Control of the ocular motor system, in particular saccades, convergence, and fixation, is essential for efficient reading (Levy-Schoen & O'Regan, 1979; Seassau & Bucci, 2013): saccades bring the eyes from left to right to the word, convergence allows the eyes to focus on the word, and fixation offers the time to properly read the word. Oculomotor performances are developmentally mediated, and their realization changes throughout the developmental trajectory until adulthood (McConkie et al., 1991; Rayner, 1986; Seassau & Bucci, 2013). Interestingly, as suggested by Maron et al. (2021), several cortical areas are involved in both oculomotor systems and cognitive activities such as attention, planning, inhibition, and working memory. Given that eye movements are highly stereotyped, a deficient oculomotor pattern could reflect some deficits in cognitive networks.

Oculomotor performances during reading are frequently explored in children with reading disabilities (Bucci et al., 2012; Caldani et al., 2020a; Seassau et al., 2014). Most studies reported atypical eye movement patterns in children with reading difficulties compared to controls from the general population. Specifically, children with dyslexia more often present forward saccades (from left to right) of smaller amplitude, fixations of longer duration, and a high number of backward saccades (from right to left) associated with a slower reading speed. The deficient oculomotor performances in children with reading disabilities are independent of their country or language of origin, and appear robust biomarkers of reading impairment in children (De Luca et al., 1999; Pavlidis, 1981; Rayner, 1985; Trauzettel-Klosinski et al., 2010). Note that even if the presence of a phonological deficit in dyslexia is the most prevalent theory (Brady et al., 1983; Bruck, 1992; Snowling, 1995), many researchers reported abnormal eye movements during reading in dyslexic subjects suggesting that the phonological theory cannot explain all the deficiencies observed in dyslexia (Stein, 2018). Indeed, other researchers showed abnormalities in auditory and visual perception, working memory, and attentional capabilities (Brosnan et al., 2002; Facoetti et al., 2003; Nicolson & Fawcett, 1990; Stein et al., 1988; Tallal, 1980). Furthermore, functional magnetic resonance imaging studies (Demb et al., 1997; Eden et al., 1996) reported abnormal processing of visual motion, particularly in the extrastriate middle temporal brain areas, supporting the hypothesis of an M-cell pathway visual abnormality in subjects with dyslexia (see Stein, 2018). A recent study by our group (Premeti et al., 2022) reviewed the two main hypotheses (phonological and visual-atttentional deficit) in dyslexia, suggesting that they are not necessarily mutually exclusive, and that dyslexia should rather be considered as a multifactorial deficit. Further studies on such issues are needed to better understand the etiology of dyslexia.

In the literature, several oculomotor studies recording saccades and pursuit movements in subjects with ADHD have been performed showing deficient performances in reflex and voluntary saccades, in fixation abilities (see the meta-analyses by Maron et al., 2021), and also in pursuit movements (Caldani et al., 2020b). In contrast, to the best of our knowledge, few studies have explored the oculomotor performances during a reading task in children with ADHD. Thaler et al. (2009) recorded eye movements during reading single words of different lengths and orthographic complexity in a small group of children with dyslexia or with co-occurring ADHD compared to a group of children with ADHD alone, and to a group of controls. They reported a longer fixation duration and a longer time taken to read single words in the children with dyslexia or with co-occurring ADHD compared to the group of children with ADHD, and to the control group. Deans et al. (2010) recorded eye movements in a small group of children with ADHD, a group of children with dyslexia, and a group of control children while reading short sentences. They asked the children to read three sets of words and five short sentences presented on the computer screen. They reported a significant difference in oculomotor pattern during reading between the group of children with ADHD and the group of typically developing children: the fixation duration was longer and the reading time also longer. In contrast, the group of children with ADHD with respect to the dyslexic children group showed a significantly slower reading time. A recent study by Molina et al. (2020), in which eye movements were recorded during the reading of a text standardized according to their reading age, reported a significantly longer duration of fixations, a higher number of backward saccades, and a longer reading time in children with ADHD compared to controls. The discrepant results observed in these studies could be due several factors: for instance, the clinical groups of children were not rigorously selected, the reading task was different, and the precision of the eye trackers used differed, leading to different saccade detection.

Based on this literature, we aimed to gain greater insight into the reading capabilities of children with ADHD and to explore further the relationship between reading impairment and ADHD related symptoms. In the present study, we explored whether children with ADHD and dyslexia exhibited a poorer reading performance compared to that observed in children with dyslexia only.

In this study, we therefore recorded eye movements during a reading task in four groups of children: children with ADHD only, children with ADHD and comorbid dyslexia, children with dyslexia alone, and children with typical development. Eye tracking allowed the oculomotor performance of the children to be monitored during reading. Given that attention plays a critical role in the information processing that is necessary for the implementation of reading, we hypothesized that children with ADHD would display abnormal reading performances and abnormal oculomotor patterns during reading similar to those reported in the literature on dyslexia. We also hypothesized that such deficiencies would be more evident in children with ADHD co-occurring with dyslexia.

Methods

Participants

The investigations were conducted in accordance with the principles of the Declaration of Helsinki and were approved by our Institutional Human Experimentation Committee. Informed consent was obtained from the participants' parents after the nature of the procedure had been explained in detail.

Twenty-four children with ADHD (mean age 10.28 ± 0.39 years); twenty-four IQ-, age-matched children with ADHD with comorbid dyslexia; twenty-four IQ-, age-matched children with dyslexia; and twenty-four IQ-, age-matched children with typical development (TD) were enrolled in the study.

The diagnosis of ADHD according to DSM-5 criteria (American Psychiatric Association APA, 2013) was carried out using the Kiddie-SADS-EP (Goldman et al., 1998). Psychiatric comorbidities were systematically screened during the interview. ADHD symptom severity was assessed using the parental report of the ADHD Rating Scale (ADHD-RS). This scale is based on a large collection of normative data and has demonstrated its reliability and discriminant validity in children and adolescents (Collett et al., 2003; Du Paul et al., 1998). For the group of children with ADHD but without dyslexia, the reading age had to be similar with respect to their chronological age; any reading impairment was excluded in this group of children. For children with ADHD and dyslexia, additional explorations were performed to achieve an extensive examination of their phonological capabilities. For each dyslexic child, the L2MA (Langage Oral Écrit Mémoire Attention) battery by Chevrie-Muller et al. (1997) was used to measure text comprehension and the ability to read words and pseudo-words. Children with ADHD and dyslexia had a score on the L2MA more than two standard deviations below the normal mean. The ADHD-RS total score and the attention hyperactive/impulsive sub-scores were similar in both groups of children (Table 1). For the group of children with dyslexia, we also used the L2MA battery and children in this group were included if they had a score more than two standard deviations below the normal mean.

To be included in our study, children with dyslexia and TD had to have an ADHD-RS total raw score ≤ 10 (Dickson et al., 2011). The global cognitive abilities of the two groups of children with ADHD (ADHD alone and ADHD + DYS) and dyslexia were assessed using the Wechsler scales (Wechsler Intelligence Scale for Children, fourth edition). Intelligence quotient in children with TD was estimated in two subtests of the Weschler scales only, assessing their verbal ability with the similarity subtest and their logic ability with the matrix-reasoning subtest. The scores on these two subtests were not significantly different from those of the other two groups of children with ADHD and/or dyslexia.

For each child enrolled in the study, an orthoptist evaluation was done in order to be sure that the children had normal binocular vision, normal convergence amplitude at near distance, and a visual acuity test in the normal range (neither strabismus nor any oculomotor abnormality were observed); we also assessed the reading age with the ELFE test (www.cognisciences.com, France). All subjects enrolled in the study also underwent a neurological examination. The clinical characteristics of the children and controls are summarized in Table 1.

Reading task

The reading paradigm used consisted of reading a paragraph of four lines containing five short sentences. The paragraph contained 40 words and 174 characters. The size of the text was 29° wide and 6.4° high; mean character width was 0.5°, and the text was written in black "courier" font on a white background. The text was an extract from "Jojo Lapin fait des farces" (Enid Blyton, Hachette), a book for 8-year-old children. In the text, the number of high- and low-frequency words was balanced. The children were asked to read the text silently. The story is about a little disobedient bear that runs away from home. He decides to hide under the window so that no one will be able to see him. After the reading task and the eye movement recording, we asked each child three questions in order to verify text comprehension. All the children had understood the text correctly (3/3 right answers).

Eye movement recordings

Eye movements were recorded using the Mobil EBT®, a CE-marked medical non-contact eye-tracking device (from www.suricog.com). Infrared cameras captured the movements of each eye independently. Recording frequency was 300 Hz. The precision of this system is 0.25°. There is no obstruction of the visual field with this recording system.

Procedure

Each child was seated in a chair in a dark room, their head stabilized by a headrest supporting both the forehead and chin. Viewing was binocular and with a distance of 60 cm. Calibration was done at the beginning of the reading task. During the calibration procedure,

Table 1 Characteristics of the children tested. ADHD: attention deficit and hyperactive disorders, ADHD-RS: attention deficit and hyperactive disorders-rating scale. Footnotes $^{+}$ and $^{\$}$ indicate that values are significantly different ($p < 0.001$) with respect to the group of children with ADHD and children with typical development, respectively. Footnotes * and $^{\#}$ indicate that values are significantly different ($p < 0.001$) with respect to the group of children with ADHD and children with dyslexia and ADHD, respectively

	Children with ADHD	Children with ADHD + dyslexia	Children with dyslexia	Children with typical development
	$n = 24$	$n = 24$	$n = 24$	$n = 24$
Girls/Boys	3/24	4/24	4/24	5/24
Age (years)	10.28 ± 0.39	10.25 ± 0.34	10.10 ± 0.29	10.39 ± 0.33
Reading age (years, by ELFE test)	10 ± 1.9	$8 \pm 2.0^{+,\$}$	$8 \pm 1.9^{+,\$}$	10 ± 2.1
L2MA (**Z** score-mean)				
Oral language		−2.8	−2.9	
Written language		−2.7	−2.6	
Memory		−2.8	−2.7	
ADHD-RS				
ADHD-RS total score	38.2 ± 1.1	39.2 ± 1.2	$5 \pm 1.0^{*,\#}$	$4 \pm 0.8^{*,\#}$
ADHD-RS Inattention sub-score	19.3 ± 0.7	19.9 ± 0.7	$2^{*,\#}$-	$2^{*,\#}$
ADHD-RS Hyperactivity/Impulsivity sub-score	18.5 ± 0.9	19.3 ± 0.9	$3^{*,\#}$	$2^{*,\#}$-
Wechsler scale (WISC-IV) scores				
Verbal comprehension subscale	99.1 ± 3.3	100 ± 4.0	98.5 ± 2.0	-
Perceptual reasoning subscale	93.6 ± 3.5	96.5 ± 2.2	99.2 ± 1.2	-
Working memory subscale	86.6 ± 3.0	84.6 ± 2.0	86.8 ± 3.1	-
Processing speed subscale	90.9 ± 2.7	92.1 ± 3.1	95.6 ± 2.2	-
Similarity test	9.9 ± 0.6	9.7 ± 1.1	9.9 ± 1.2	10.06 ± 0.4
Matrix reasoning test	9.7 ± 0.5	9.8 ± 0.7	9.6 ± 1.0	10.14 ± 0.5

children were asked to fixate a grid of 13 points (diameter 0.5 deg) mapping the screen. Each calibration point required a fixation of 250 ms to be validated. A polynomial function with five parameters was used to fit the calibration data and to determine the visual angles. After the calibration procedure, the reading task was presented to each child.

Data analysis

Calibration factors for each eye were determined from the eye positions during the calibration procedure. MeyeAnalysis® software was used to extract the defining parameters of saccadic eye movements from the data. This software automatically detected both the onset and the offset of each saccade by using a built-in saccade detection algorithm.

The duration of fixations between each saccade, the total task duration, the number, and the amplitude of forward saccades and backward saccades were measured. Note that all these parameters were measured on the total text read. The fixation duration is the time measured during two saccades (forward or backward), and it is calculated on the averaged forward and backward saccades. Oblique saccades made to start a new line were excluded from the analysis.

Statistical analyses

Separate one-way ANOVA was performed using the Statistica software® (12.0, Palo Alto, California, United States) to compare the values from the different tests done for selecting different groups of children (reading age, ADHD rating score, IQ score) and each oculomotor variable (duration fixation time, the total reading time, the number, and amplitude of forward and backward saccades) in the four different groups of children tested (ADHD and dyslexia, those with dyslexia alone, those with ADHD alone, and those with a TD). Bonferroni post hoc comparisons were employed. The effect of a factor was considered significant when the *p*-value was below 0.05. Note that since the subjects were age-matched, we did not explore the impact of age as a covariate.

Results

The total fixation time duration for the four groups of children showed a significant group effect ($F_{(3,92)} = 9.24$, $p < 0.0002$, $\eta = 0.76$) (Fig. 1A). The Bonferroni post hoc analysis reported no significant difference between children with dyslexia *vs.* those with co-occurring ADHD, but an increased fixation time duration in these subjects compared to controls ($p < 0.0009$ and $p < 0.0004$, respectively) compared to children with ADHD only ($p < 0.0080$ and $p < 0.0004$, respectively, see Table 2). A significant group effect was also found for the total reading time ($F_{(3,92)} = 21.46$, $p < 0.0001$, $\eta = 0.51$) (Fig. 1B). The Bonferroni post hoc test showed no significant difference between children with dyslexia with or without ADHD. The total task time duration was longer in these subjects compared to children with typical development (both $p < 0.0001$) compared to children with ADHD only ($p < 0.0003$ and $p < 0.0001$, respectively; see Table 2).

A significant effect of group was found on both forward and backward saccades ($F_{(3,92)} = 12.83$, $p < 0.00001$, $\eta = 0.17$, and $F_{(3,92)} = 12.47$, $p < 0.0001$, $\eta = 0.36$, respectively) (Fig. 2). Post hoc comparisons showed no significant difference between children with dyslexia with or without co-occurring. They exhibited however an increased number of forward

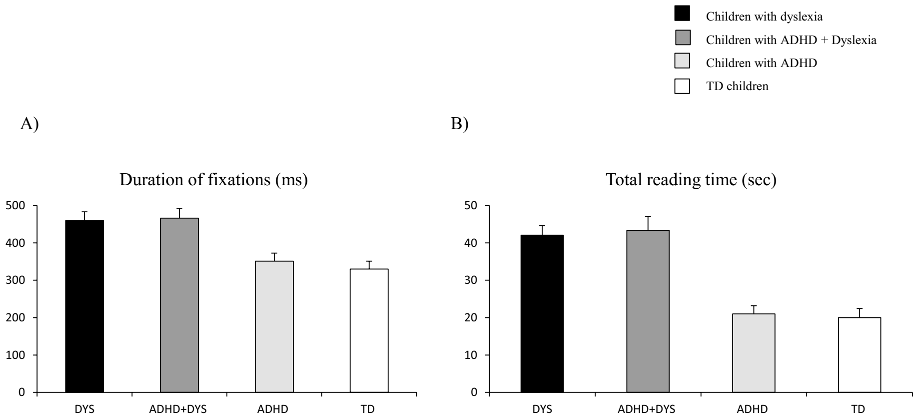

Fig. 1 Mean values (with standard errors) of total fixation time duration, in milliseconds (**A**), and of the total reading time, in seconds (**B**) during the reading task for the four groups of children tested (DYS, ADHD + DYS, ADHD, and TD). Vertical lines indicate the standard error

Table 2 ANOVA results. One-way ANOVA values of the post hoc test between the different groups of children tested for the fixation duration, total reading time, and the number of forward and backward saccades

Groups	Fixation duration (ms) $F_{(3,92)}=9.24$, $p<0.0002$, $\eta=0.76$	Total reading time (s) $F_{(3,92)}=21.46$, $p<0.0001$, $\eta=0.51$	Number of forward saccades $F_{(3,92)}=12.83$, $p<0.00001$, $\eta=0.17$	Number of backward saccades $F_{(3,92)}=12.47$, $p<0.0001$, $\eta=0.36$
ADHD vs ADHD + Dys	$p<0.0004$	$p<0.0001$	$p<0.0010$	$p<0.0001$
ADHD vs Dys	$p<0.0080$	$p<0.0003$	$p<0.0002$	$p<0.0005$
ADHD vs TD	$p=1$	$p=1$	$p=1$	$p=1$
ADHD + Dys vs Dys	$p=1$	$p=1$	$p=1$	$p=1$
ADHD + Dys vs TD	$p<0.0004$	$p<0.0001$	$p<0.0010$	$p<0.0001$
Dys vs TD	$p<0.0009$	$p<0.0001$	$p<0.0003$	$p<0.0004$

and backward saccades compared to children with typical development ($p<0.0003$, and $p<0.001$, respectively, for forward saccades and $p<0.0004$, and $p<0.0001$, respectively, for backward saccades) compared to children with ADHD only ($p<0.0002$, and $p<0.001$, respectively, for forward saccades and $p<0.0005$, and $p<0.0001$, respectively, for backward saccades; see Table 2). Table 3 shows the mean amplitude of saccades reported in children by phenotype. ANOVA failed to show any significant difference in amplitude ($F_{(3,92)}=1.02$, $p=0.3$, $\eta=0.10$, and $F_{(3,92)}=0.56$, $p=0.6$, $\eta=0.09$, respectively, for forward and backward saccades).

Discussion

In the present study, we aimed to further explore the reading abilities of children with ADHD and whether ADHD by itself could impact the reading performance independently from the occurrence of dyslexia or whether the comorbidity of ADHD and dyslexia

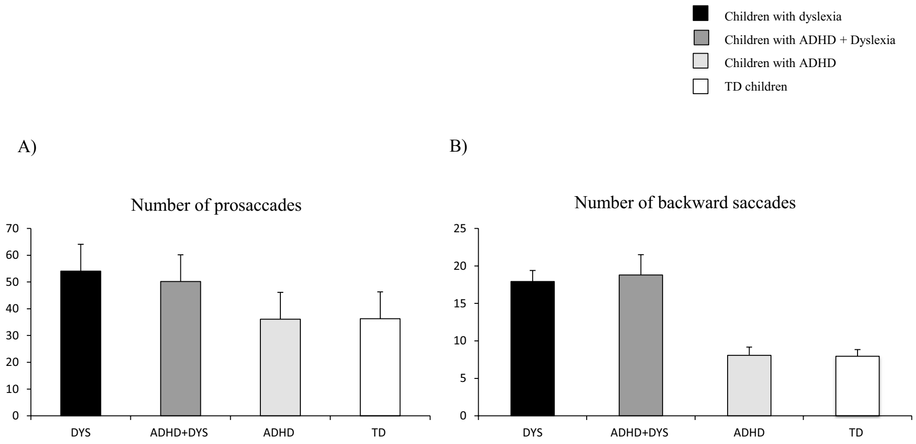

Fig. 2 Mean values of the number of forward saccades (**A**) and backward saccades (**B**) for the four groups of children tested (DYS, ADHD + DYS, ADHD, and TD). Vertical lines indicate the standard error

Table 3 Amplitude of saccades during reading task. Mean and standard error of the amplitude of forward and backward saccades, in degrees, for the four groups of children enrolled in our study

	Children with ADHD	Children with ADHD + dyslexia	Children with dyslexia	Children with typical development
Amplitude of forward saccades (deg)	3.0° ± 0.1°	2.9° ± 0.3°	2.8° ± 0.1°	3.2° ± 0.2°
Amplitude of backward saccades (deg)	3.2° ± 0.3°	2.9° ± 0.3°	2.6° ± 0.1°	3.0° ± 0.3°

impacts reading performance more. Results show the presence of an abnormal oculomotor pattern in the group of children with comorbid ADHD + DYS similar to that observed in a dyslexic group by several studies from our (Bucci et al., 2012; Caldani et al., 2020a; Seassau et al., 2014) and other research groups (De Luca et al., 1999; Pavlidis, 1981; Rayner, 1985; Trauzettel-Klosinski et al., 2010), while children with ADHD performed this task quite well and, most importantly, their oculomotor characteristics during reading were similar to those observed in TD children.

Our findings suggest that dyslexia could affect oculomotor reading behavior and that the use of an objective eye movement recording could be a useful tool to better evaluate the possible presence of comorbid dyslexia in children with ADHD. Children with only ADHD did not display significant abnormal oculomotor performances compared to controls. In this study, we found an increased duration of fixation time and of the total time taken to perform the reading task, associated with a high number of forward and backward saccades, in children with dyslexia only, despite the presence or not of ADHD. Taken together these results suggest the presence of specific oculomotor atypicalities in dyslexia in line with the hypothesis that visual/oculomotor impairments could be, at least, one of the causes of dyslexia (Bucci, 2019). Note, however, that the results reported in our study are in contrast with previous findings (Deans et al., 2010; Molina et al., 2020), in which researchers seemed to identify an abnormal oculomotor pattern in children with ADHD. This discrepancy could be due to the clinical screening and selection of patients included in the studies, since most of them did not control patients with ADHD for the absence of dyslexia.

Dyslexia is a frequent comorbidity associated to ADHD symptoms, and has been reported in approximately 45% of the subjects with ADHD, introducing a significant bias in these studies (Willcutt et al., 2010). However, several authors observed that children with ADHD had reading difficulties even in the absence of a comorbid dyslexia (Frazier et al., 2007; Loe & Feldman, 2007; Miller et al., 2012). These difficulties could be due more to their poor sustained attention in school activities and/or impairment in working memory (Friedman et al., 2017) than to specific reading difficulties. In the present study, we did not test working memory deficiencies in children with ADHD. To assess working memory capabilities in these kinds of children, larger studies are warranted to further explore the complex interplay between behavioral symptoms of ADHD, executive dysfunctions — specifically working memory — and dyslexia. According to works described in the "Introduction," it will be interesting to explore other cognitive capabilities in children with ADHD and combining these tests with imaging studies in order to explain further the comorbidity in neurodevelopmental disorders.

Also, in line with the model proposed by Pennington (2006), developmental disorders could be due by several factors, needing to be examined at the same time. Concerning subjects with ADHD, Roman-Urrestarazu et al. (2016) in an fMRI study suggested that cerebellar dysfunctions could contribute to the memory deficits in children with ADHD. In line with these studies, it can be argued that two distinct mechanisms are involved in the reading disabilities of children with dyslexia and those with ADHD.

Limitations

Further studies with a larger number of children with ADHD alone and with a comorbid dyslexia would make it possible to better evaluate the impact of ADHD symptoms on oculomotor behavior and reading capabilities, given that we failed to show any correlation between clinical tests and oculomotor behavior. The exploration of working memory capacity will also be necessary in order to examine the effect of this function in children with ADHD. Working memory plays a pivotal role during reading processes given its contribution in converting orthographic symbols to phonological sounds (Friedman et al., 2017) and children with ADHD demonstrate poorer performance concerning specifically the phonological and visuospatial storage sub-systems (Kofler et al., 2019).

Moreover, it is important to note that in our study, the reading task comprised a paragraph of four lines only that was similar for all children. In the future, it could be interesting to use a longer text adapted for each reading age of the children in order to better explore the ability of these children to sustain their attention during reading. It would also be interesting to impose experimental constraints on reading time in order to explore whether oculomotor pattern is correlated to time constraints.

Conclusions

Our data, obtained by objectively recording oculomotor behavior peculiarities during a reading task, suggest the presence of reading disabilities in children with ADHD only when comorbid dyslexia is present. Based on these findings, we suggest that an evaluation of reading impairment in children with ADHD could be facilitated and objectified by using an oculomotor recording test for excluding rapidly comorbid dyslexia in ADHD but also in children with neurodevelopmental disorders. This could facilitate the diagnosis but also improve the estimation of the efficiency of the rehabilitation strategies that we use for children with ADHD and learning impairments.

Acknowledgements The authors thank the children who participated in the study as well as the practitioners from the Child and Adolescent Psychiatry Department (Robert Debré Hospital, Paris, France).

Funding MP Bucci was supported by the Académie des Sciences, Institut de France/Fondation NRJ.

Declarations

Conflict of interest The authors declare no competing interests.

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