



HAL
open science

“Same, same but different”: The optimal viewing position effect in developmental dyslexia, developmental coordination disorder and comorbid disorders

Stéphanie Bellocchi, Stéphanie Ducrot

► To cite this version:

Stéphanie Bellocchi, Stéphanie Ducrot. “Same, same but different”: The optimal viewing position effect in developmental dyslexia, developmental coordination disorder and comorbid disorders. *Dyslexia*, 2021, 27 (3), pp.294-311. 10.1002/dys.1688 . hal-03366867

HAL Id: hal-03366867

<https://hal.science/hal-03366867>

Submitted on 4 Jan 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 SHORT RUNNING TITLE: OVP IN DYSLEXIA, DCD AND COMORBID
2 DISORDERS

3
4 *“Same, same but different”:*

5 **The OVP effect in developmental dyslexia, developmental coordination disorder**
6 **and comorbid disorders**

7
8 **Abstract**

9 The Optimal Viewing Position (OVP) effect indicates that words are identified most
10 quickly when the eyes fixate near the word centre in alphabetic languages. In two studies, we
11 tested OVP in typically developing readers and children with developmental dyslexia (DD),
12 developmental coordination disorder (DCD) and with both disorders (DD+DCD), using a
13 variable-viewing-position technique. Study 1 showed that typically developing readers had
14 developed highly automatized procedures of left-to-right attentional scanning resulting in an
15 inverted *J*-shape VP curve comparable to what is observed in adult readers and that dyslexics
16 showed non-prototypical one. In Study 2 we observed more typical procedures of left-to-right
17 attentional scanning in children with DCD, isolated or comorbid, compared to DD. Moreover,
18 given the absence of significant group differences between children with DD+DCD and
19 children with isolated DD or DCD, our results reinforce the idea that the comorbid condition
20 does not add to the severity of OVP anomalies. We then concluded that OVP atypicalities are
21 specific to children with DD. Finally, we discussed the usefulness of the OVP effect as a
22 clinical tool to identify possible OVP atypicalities that could be specific of some
23 neurodevelopmental disorders (i.e., DD, DCD or DCD+DD).

24 **Keywords:** developmental dyslexia, developmental coordination disorder,
25 comorbidity, optimal viewing position, reading

26 **INTRODUCTION**

27 Learning to read naturally requires the development of a number of strictly linguistic
28 skills (e.g., phonological awareness, phonological short-term memory, lexical knowledge,
29 etc.) (e.g. Goswami & Bryant, 1990). However, processing written language also requires a
30 visual analysis that enables the precise decoding of the words. That is, in addition to linguistic
31 skills, children also need to develop good eye-movement control and visual-perceptual skills
32 to learn to read: their visual system has to learn to correctly land the eyes on words, extract
33 the information that is being fixated, program a saccade to the next word position, etc. These
34 visuo-attentional processes must be automatized in order to develop good reading skills (e.g.
35 Bellocchi, Massendari, Grainger, & Ducrot, 2019; Ducrot, Pynte, Ghio, & Lété, 2013;
36 Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Grainger, Dufau, & Ziegler, 2016;
37 Joseph, Liversedge, Blythe, White, & Rayner, 2009; Vernet, Bellocchi, Leibnitz, Chaix, &
38 Ducrot, 2021). In other words, to be able to match letters and groups of letters to the
39 phonological representations contained in memory, it is necessary that the child learns to
40 perceive the words. It follows that the efficiency and the rapidity of written word-recognition
41 procedures depend on the quality of perceptual processing. When it comes to reading
42 disabilities, an increasing number of studies shows today that associated visual and
43 oculomotor deficits are present in several neurodevelopmental disorders (e.g., Bellocchi et al.,
44 2019; Gori & Facoetti, 2015; Martelli et al., 2009; see Bellocchi, Muneaux, Bastien-Toniazzo,
45 & Ducrot, 2013b and Goswami, 2015, for reviews). Children with developmental dyslexia
46 may show, for example, visual selective attention deficits in automatic orienting and focusing
47 of spatial attention, visuo-attentional span deficits which seem to be independent from a
48 phonological deficit (e.g., Facoetti, Turatto, Lorusso, & Mascetti, 2001; Valdois, Bosse, &
49 Tainturier, 2004). Moreover, atypical eye movement patterns during reading have been
50 showed to characterize dyslexics as a manifestation of an impaired cognitive processing (e.g.,

51 Bellocchi et al., 2019; Gagl, Hawelka, & Hutzler, 2014; Hawelka, Gagl, & Wimmer, 2010).
52 Yet the visual aspects of reading acquisition, however fundamental, remain a neglected field
53 of research.

54 In the current paper, we will focus on the very earliest stages of visual word
55 recognition in both beginning and disabled readers, from the uptake of visual information to
56 sublexical orthographic processing. Visual and attentional factors are thought to have their
57 main impact on reading at this first level of orthographic processing. We examine the
58 importance of these processes for learning to read, and how they can improve our
59 understanding of the difficulties encountered by children showing a specific reading disorder,
60 i.e. those with *developmental dyslexia (DD)*¹. In addition, we investigated children with
61 *developmental coordination disorder*² (DCD), and those with both neurodevelopmental
62 disorders (DD+DCD or comorbid children) in order to explore the impact of comorbidity on
63 these visuo-attentional processes linked to word recognition. Indeed, despite the fact that the
64 association between DD and DCD is a very common condition in neurodevelopmental
65 disorders (Iversen, Berg, Ellertsen, & Tønnessen, 2005; Kaplan, Dewey, Crawford, Wilson,
66 2001), very few researches have been developed considering it.

67

¹ *Developmental dyslexia* is a neurodevelopmental disorder that is diagnosed when no sensory and intellectual deficits can explain reading and/or writing disorders and when adequate instruction and socio-cultural opportunities are available but fail to result in an adequate level of performance [DSM-5, American Psychiatric Association (APA), 2013; W.H.O., 1992].

² *Developmental Coordination Disorder* is a neurodevelopmental disorder characterized by significant difficulties with the acquisition and execution of motor skill [DSM-5, American Psychiatric Association (APA), 2013]. Individuals with DCD demonstrate a level of motor skill out of keeping with their age and intellectual ability.

68 *Viewing position effects and word recognition in children.*

69 Word recognition involves a reading-specific visual processing mode that relies on the
70 ability to process - simultaneously and in parallel - all the letters of a word in their correct
71 positions. Therefore, the beginning reader's first task consists of developing this ability by
72 mobilizing increasingly rapid, automatic, and irrepensible cognitive processes (Lagerbe &
73 Samuels, 1974). One factor known to have a major impact on word reading efficiency in
74 adults is the position of eye fixation in the word (when there is only one fixation). When
75 participants are forced by an experimental manipulation to fixate a word at a specific position,
76 the probability of recognizing it is the highest when the fixation point is to the left of the
77 word's midpoint (for languages read from left-to-right), and it decreases as the eye moves
78 away from this so-called "optimal position" (e.g., O'Regan & Jacobs, 1992; O'Regan, Levy-
79 Schoen, Pynte, & Brugallière, 1984, see Brysbaert & Nazir, 2005, for a review). This typical
80 pattern of results is the *Optimal Viewing Position (OVP)* effect, which is characterized not
81 only by the fact that performance is better when the centre of a word is fixated rather than its
82 edges, but also by an asymmetry to the left in the resulting inverted *J*-shape VP function (with
83 a better performance for left-sided than for right sided fixations, i.e., word-beginning
84 superiority effect, Lavidor & Walsh, 2004).

85 The OVP effect arises from the rapid drop-off of visual acuity with retinal eccentricity
86 and the fact that more letters from a word can be extracted when the eyes are near the word's
87 center (Brysbaert & Nazir, 2005; McConkie, Kerr, Reddix, Zola, & Jacobs, 1989; Nazir,
88 O'Regan, & Jacobs, 1991; Nazir, Jacobs, & O'Regan, 1998; but see also Lavidor & Walsh,
89 2004 for a theoretical account). It may derive, in addition, from orthographic and
90 lexical/morphological constraints associated with word identification (Clark & O'Regan,
91 1999; O'Regan et al., 1984; Stevens & Grainger, 2003). Given that the most informative letter
92 of words in languages such as English and French is the first letter (see, Grainger, 2017), it

93 follows that the OVP emerges at the landing site that maximizes letter perceptibility and
94 minimizes lexical ambiguity. For Brysbaert and colleagues (1996), fixations to the left of the
95 word's centre are less damaging than fixations to the right, because attention can be allocated
96 more rapidly and effectively to the right than to the left in people trained to read in that
97 direction (see also Nazir, Ben-Boutayab, Decoppet, Deutsch, & Frost, 2004 and Ducrot &
98 Grainger, 2007). In the same vein, Nazir (2000; 2003) proposed that perceptual biases may
99 arise from perceptual learning, with frequently fixated positions becoming optimal for word
100 recognition. According to this report, optimal word recognition is obtained with eye fixation
101 on the location in the word where the eyes prefer to land (i.e. between the beginning and the
102 middle of the word) (Ducrot & Pynte, 2002; Rayner, 1979). In this line of reasoning, it is
103 important to note that the OVP is dependent on reading habits (right of centre for languages
104 read from right to left; Deutsch & Rayner, 1999; Farid & Grainger, 1996). Note also that
105 lexical constraints exerted by the perceived letters on word recognition can affect the shape of
106 the VP curve. For example, low-frequency words are less effectively processed at fixation
107 points away from the OVP (O'Regan & Jacobs, 1992). Here we argue that the OVP effect can
108 be used to assess the visual processing mode of words being read.

109 In learning to read, the OVP appears early, even at the end of the first year of reading
110 exposure (Aghababian & Nazir, 2000; Ducrot et al., 2013), thus suggesting that children
111 extract visual information from print in much the same way as proficient readers do. Given
112 that extraction of visual information is a key component of the OVP effect, then variations in
113 the way visual information is extracted from the input may lead to different VP curves.
114 Following this point of view, Aghababian and Nazir (2000) pointed out that a closer analysis
115 of the VP function might help identify deviant reading behaviours. Accordingly, various
116 “non-prototypical” VP curves are reported in pathological cases: a flat curve in a deaf
117 beginning reader (Aghababian, Nazir, Lançon, & Tardy, 2001) and a reverted asymmetry in a

118 pure alexic patient (Montant, Nazir, & Poncet, 1998). Ducrot and colleagues (2003) also
119 found differences in dyslexics' VP curve: even though dyslexic children exhibited, as normal
120 readers do, a systematic variation in reading performance when their eyes were fixating
121 different locations in the word (with best recognition performance when the initial fixation
122 was imposed to the left of the word centre), they also showed a symmetrical VP curve. The
123 absence of left-right asymmetry in the VP curve suggests abnormal processing of information
124 outside of foveal vision for dyslexics, as Geiger and colleagues (1992) found, and could thus
125 reflect a deficit in visuo-attentional processing. We found two other reports of such inverted
126 *J*-shaped VP curves in the literature. Dubois et al. (2007) described the case of a young
127 surface dyslexic boy with an atypical VP curve lacking asymmetry and Aghababian and Nazir
128 (2000) reported similar VP patterns in "poor" beginning readers. The variety of VP shapes
129 reported in reading disabilities highlights the need for a better understanding of their visual
130 processing of printed words. However, to our knowledge, there is no well-described in-depth
131 investigation of VP abnormalities in neurodevelopmental disorders. The present paper is a
132 first step in this direction, with a comparison of VP curves in DD, DCD and DD+DCD.

133

134 *Dyslexia and co-occurring DCD: What is the impact on visuo-attentional processes*
135 *linked to reading?*

136 Although it's not systematic, co-occurrence between dyslexia and other
137 neurodevelopmental disorders is very common. In particular, epidemiological studies
138 demonstrate a rate of comorbid diagnosis of DCD in 16% (Kaplan et al., 2001) to 70%
139 (Iversen et al., 2005) of children with dyslexia. Similarly, Chaix and colleagues (2007) found
140 an high percentage of DCD diagnosis in a group of 58 dyslexics, i.e. 40% scored below -2
141 standard deviations (SDs) on the Lincoln-Oseretsky Motor Development Scale (Rogé, 1984),
142 and 17.2% scored between -1 and -2 SDs. Furthermore, dyslexics proved less successful than

143 their peers at carrying on motor tasks (for a review, see Jover, Ducrot, Huau, Bellocchi, Brun-
144 Hénin, & Mancini, 2013). For instance, participants with dyslexia demonstrated poor
145 performance on the Movement Assessment Battery for Children (M-ABC; Iversen et al.,
146 2005), pegboard tasks (Nicolson & Fawcett, 1994), bead threading (Fawcett & Nicolson,
147 1995), pointing (Velay, Daffaure, Giraud, & Habib, 2002), and motor-learning tasks (Bennett,
148 Romano, Howard, & Howard, 2008). In addition, more relevant for our study is that reading
149 difficulties have been observed in 29% to 70% of children diagnosed with DCD (O'Hare &
150 Khalid, 2002).

151 Unfortunately, despite the evidence of a frequent association between DD and motor
152 disorders, this co-occurrence is often neglected in the scientific studies exploring reading
153 disabilities and the related cognitive disorders. Furthermore, despite the presence of reading
154 deficits in DCD, to the best of our knowledge, no studies have been published on the role of
155 visuo-attentional processes in reading in children with DCD. In particular, this is even true for
156 studies exploring the landing position patterns, such as the OVP effect. Nevertheless, note that
157 a few studies have explored visuo-attentional processes in DCD. Tsai (2009) observed that
158 DCD children performed worse than typical developing children in an endogenous Posner
159 task measuring visuo-spatial attention. This result is consistent with the huge literature
160 highlighting deficits in the visuospatial information processing in DCD (e.g., Tsai & Wu,
161 2008; Wilson & McKenzie, 1998). However, the majority of these studies used visuo-spatial
162 tasks that didn't directly and precisely measure visuo-spatial attention. In other words, the
163 tasks used belonged to clinical neuropsychology batteries of tests and not to experimental
164 paradigms. The analysis of the literature clearly shows the need to better understand the
165 impact of the co-occurring DCD on the visuo-attentional processes involved in reading by
166 using experimental paradigms (Bellocchi, Muneaux, Huau, Lévêque, Jover, & Ducrot, 2017).

167

168 **The present study**

169 The present study focused on the ability of children to recognize briefly displayed
170 single words, while the eyes are fixating a predetermined position within the word.
171 Abnormalities in the developing reading system—although not necessarily “visual” in
172 nature—may nevertheless be apparent in the visual behaviour of the child. Impairments of
173 word recognition performance can differently affect the early stages of visual word
174 processing. The OVP paradigm provides an interesting way to describe the visuo-attentional
175 strategies involved in word recognition by children who have a learning disability and to
176 detect qualitative and quantitative differences in the VP curve of these children. The shape of
177 the VP curve allows to determine the position(s) at which relatively good word processing
178 performance is obtained (maximum of the curve) and at which word processing performance
179 declines (minimum of the curve). The height of the curve allows to evaluate the quality of the
180 lexical competence and the size of the stored lexical knowledge.

181 The originality of this study resides also on the exploration of the OVP atypicalities in
182 DD and DCD taking into account the co-occurring condition. To the best of our knowledge,
183 this is the first study focusing on that purpose.

184 First of all, to better understand the specificity of any OVP anomalies within DD, two
185 typically developing comparison groups were recruited, the first matched to children with DD
186 by chronological age (hereafter ‘CA’ group), and the second matched to the DD group by
187 reading level (hereafter ‘RL’ group). We hypothesized that if DD children show deficits in
188 OVP effect, we should expect that they revealed more marked atypical VP curve (in terms of
189 height and shape) than the CA and RL group; however, if DD children show a delay in OVP
190 effect, we should expect that they underperform only the CA group. These questions will be
191 specifically explored in Study 1.

192 Secondly, in order to explore the impact of co-occurrence, we compared children with
193 DD and DCD (DD+DCD) to children with isolated disorders (DD or DCD). Consistent with a
194 cumulative hypothesis (e.g. Pitcher, Piek, & Barrett, 2002), if co-morbid condition add to the
195 severity of the cognitive deficit, children with DD and DCD should revealed more marked
196 atypical VP curve (in terms of height and shape) than children with isolated disorders.
197 Moreover, the comparison between co-morbid children (DD+DCD) and children with isolated
198 disorders (DD or DCD) can provide evidences about the specificity of the OVP atypicalities
199 to reading or motor impairments. In other words, if OVP anomalies are specifically linked to
200 reading deficits, we should find them in children with specific reading disorder (isolated DD
201 and DD+DCD). However, if OVP anomalies are specifically linked to a motor disorder, we
202 should find them only in DCD children (isolated DCD and DD+DCD). Last but not least, the
203 present study will provide new data on visuo-attentional processing linked to reading in DCD.
204 These questions will be addressed in Study 2.

205 Finally, even if this was not an objective per se, we aimed at discuss the usefulness of
206 the OVP effect as a clinical tool to identify possible OVP atypicalities that could be specific
207 of some neurodevelopmental disorders (i.e., DD, DCD or DCD+DD). This could constitute an
208 important source of information for practitioners to differentiate cognitive profiles of children
209 with neurodevelopmental disabilities, based upon performance on the OVP.

210 This research received the agreement of the National Board of Education (project
211 ADIVA). This work was conducted in accordance with the Declaration of Helsinki (WHO,
212 2008), approved by the local Ethics Committee Review Board (Comité de Protection des
213 Personnes pour la recherche biomédicale, CNRS, France). The children's parents gave their
214 written consent for participation.

215

216

217

STUDY 1

218

Comparisons between dyslexics and typical developing readers

219

In the first study we aimed at exploring the OVP effect in children with DD, as

220

compared to typically developing children matched on chronological age or reading level.

221

222

Method

223

Participants. A total of 72 children participated in the experiment. They were divided

224

into three groups: one of 24 dyslexics (DD) (mean age in months = 126.95; SD= 15.17) and

225

two control groups each composed of 24 typical developing readers, the first of which was

226

matched on chronological age (CA) (mean age in months = 129.66; SD= 6.74) and the second

227

of which was matched on reading level (RL) (mean age in months = 95; SD= 4.47).

228

Children with DD were recruited and diagnosed in different hospitals or clinical

229

centres based in France: La Timone University Hospital in Marseille, Kremlin-Bicêtre

230

Hospital in Paris and the clinical centre “Les Lavandes” in Orpierre. They all underwent a

231

complete medical, psychological and cognitive assessment. All participants were native

232

speakers of French with normal or corrected-to-normal vision. Children whose oral language

233

skills were in the pathological range or who were diagnosed with ADHD were excluded from

234

the study. Criteria for inclusion were manifest reading deficits (at least 1.5 SDs below the

235

normal level) on the “Alouette Test-R” (Lefavrais, 2005), on IQ measured on the WISC-IV

236

(French version by ECPA, 2005) within the normal limits set by the diagnosis unit (IQ > 85)

237

and no deficits in vision or hearing. More importantly, we selected children without a DCD.

238

As we noted by post-hoc analyses, the mean reading level of the dyslexic children

239

(mean=87.37 months; SD=4.94 months) was significantly below the mean reading level of the

240

chronological age matched group (mean=118.58 months; SD=15.12 months; $p < .001$). As

241

expected, the mean reading level of the dyslexic children was comparable from that of the

242 reading-level matched children (mean=89.54 months; SD=8.25; $p = ns$) (ANOVA; group
243 effect: $F(2,71) = 68.07$; $p < .001$).

244 The participants in the two control groups (CA and RL) were recruited from an
245 elementary school (Grade 1 through 5) in a city in southern France, according to their reading
246 level (Grade 1 or 2) and chronological age (Grade 4 or 5) of the dyslexic children. None
247 suffered from any neurological, psychiatric, or emotional disorders or was educationally
248 disadvantaged. The inclusion criteria were a normal reading level and no visual or hearing
249 deficits. We did not include children who were considered by their teachers as having either a
250 specific learning deficit or cognitive and behavioural problems.

251

252 **Material, task, and stimuli.** A pool of 60 words was selected from Manulex (Lété,
253 Sprenger-Charolles, & Colé, 2004). The stimuli were selected from the first-grade lemma
254 lexicon. Half of the words had a low frequency (LF) – that is, a mean printed frequency of 16
255 occurrences per million – and the other half were high frequency (HF), with a mean printed
256 frequency of 419 occurrences per million. In each frequency set, 93% of the words were
257 nouns, 4% were verbs, and 3% were adjectives. All words were 5 or 6 letters long. The words
258 used in this work were a subset of the stimuli used in the Ducrot et al.’s previous study
259 (2013). Stimulus presentation was on a Dell Latitude D600 laptop running the DMDX
260 software package (Forster & Forster, 2001, version 2.9.01). The target words were displayed
261 in white lowercase letters against a black background in 24-point Courier New font, using a
262 14-inch color monitor, at a resolution of 1024×768. Participants were seated 60 cm from the
263 screen. At this distance, one letter subtended a visual angle of 0.5°. Each word was divided
264 into five equally-wide zones (i.e., 1 letter wide for five-letter words and 1.2 letters wide for
265 six-letter words). Words were presented in such a way that subjects initially fixated the centre
266 of each zone (hereafter called positions P1, P2, P3, P4, and P5). Across all participants, each

267 word was seen from all five-fixation positions, using different experimental lists. The stimuli
268 were presented in one block with 60 trials. A chin-and-forehead rest was used to minimize
269 head movements. Exposure time for the target was determined individually for each
270 participant, depending on his/her correct identification score on a training session (in which
271 we looked for the presentation duration that produced scores ranging between 50-75% correct
272 four-letter word identification³, i.e., about 100 ms for CA children, 175 ms for RL children
273 and 250 ms for DD). Each trial consisted of the following sequence of events. Participants
274 were first instructed to look at a fixation point at the beginning of each trial, and not to move
275 their eyes. After 500 ms, the fixation point was replaced by a target word that was displayed
276 on the screen for the duration previously determined for that particular child. The word was
277 displaced laterally with respect to the fixation point according to its position condition. Then
278 the word was replaced by a backward mask that consisted of a string of hashes. The task was
279 to identify (name) the target word. If not possible, participants were asked to report as many
280 letters as they could in the correct position. The experimenter manually recorded each
281 participant's response. The mask remained on the screen until the experimenter pressed the
282 spaced bar to trigger the next trial.

283

284 **Procedure.** All children were tested individually: children with neurodevelopmental
285 disorders were tested at the hospital and normal readers in their schools. The session lasted
286 about 15 minutes.

287

288 **Data analysis**

³ In the training session, we used 20 words which were not the same words used in the following test session in order to avoid learning effect.

289 Analysis of variance was run on the proportion of correct word identifications
290 transformed in arcsine using a 2 Frequency x 5 Positions x 3 groups (dyslexics, chronological-
291 age matched group –CA, and reading-age matched group –RA)⁴. All factors, except Group,
292 were within-participant factors. Effect sizes are reported as eta-square (η^2 , Bakeman, 2005).

293 In order to test the left-right asymmetry of the VP curves we compared performance of
294 word identifications in P1 (left-sided fixation position) vs. P4 and P5 (right-sided positions)⁵,
295 as suggested by other studies (e.g., Ducrot et al., 2013; Stenneken, van Eimeren, Keller,
296 Jacobs, & Kerkhoff, 2008; Wong & Hsiao, 2012). Then, pairwise comparisons were run in
297 order to test the specific hypotheses we defined *a priori*.

298 Statistical analyses were conducted using the SPSS ® program, version 20.0.

299

300 **Results**

301 The mean percentage of correct word identifications was calculated for all
302 participants. Table 1 shows descriptive statistics of accuracy as a function of group, frequency
303 of words and letter position.

304

305

306 Table 1. Means and standard deviations of accuracy (percentage of correct responses) as a
307 function of group (DD= dyslexics; CA= chronological age control; RL = reading level
308 control), frequency of words (HF= High-frequency words; LF= Low-frequency words), and
309 five fixation positions (P1, P2, P3, P, and P5).

310

311

⁴ The assumption of homogeneity of variance was not violated, all $p > .05$ (Levene's test).

⁵ Note that P4 and P5 were averaged.

		DD	CA	RL
		mean (SD)	mean (SD)	mean (SD)
	P1	77.78 (16.04)	90.97 (12.02)	86.10 (14.47)
	P2	89.58 (15.40)	94.44 (10.62)	93.05 (9.73)
HF	P3	84.71 (13.82)	95.14 (10.40)	88.88 (10.62)
	P4	75.00 (23.04)	92.36 (12.98)	83.55 (14.51)
	P5	79.87 (20.83)	77.77 (19.45)	79.16 (18.55)
	P1	38.90 (22.35)	75.69 (17.00)	57.62 (20.73)
	P2	50.69 (25.29)	82.64 (17.35)	60.10 (25.41)
LF	P3	50.70 (28.85)	75.70 (17.00)	54.19 (24.35)
	P4	42.36 (26.91)	67.35 (22.78)	47.89 (20.03)
	P5	29.86 (22.50)	60.40 (25.45)	37.00 (18.79)

312

313

Insert Table 1 about here

314

315

The analyses of variance showed that the effect of initial-fixation position on word

316

recognition was consistently significant for all groups [$F(4,276) = 23.84; p < .001; \eta^2 = .25$].

317

As can be seen in Figure 1a, the location in the words where the recognition curves grew to

318

their maximums was to the left of the target's centre. There was also a significant main effect

319

of frequency [$F(1,69) = 439.70; p < .0001; \eta^2 = .84$], with a higher recognition probability

320

for HF-words (86%) than for LF-words (55%). Note that the size of the frequency effect was

321

different for the three groups, as suggested by the interaction between frequency and group [F

322

$(2, 69) = 7.92; p = .001; \eta^2 = .03$]: the frequency effect was attenuated with the increase of

323

reading skills [38.9% for dyslexics, 32.1% for RL children, and 17.7% for CA children].

324 The interaction between stimulus location and groups was not significant [$F(8, 276) =$
325 $1.65; p = \text{n.s.}$]. However, interestingly, the ANOVA revealed a significant fixation position \times
326 frequency \times group interaction [$F(8, 276) = 2.14; p = .033; \eta^2 = .06$]. This three-way
327 interaction is illustrated in Figure 1a. In order to examine the effects of frequency and fixation
328 position in more detail, separate analyses were conducted for each group.

329 **RL-group.** The ANOVA revealed a large (32.1%) frequency effect [$F(1, 23) =$
330 $176.90; p < .001; \eta^2 = .88$], reflecting the fact that letter identification was better for the HF
331 ($M = 86.2\%$) than for the LF ($M = 54.1\%$) words. A significant effect of fixation position was
332 also found [$F(4, 92) = 7.86; p < .001; \eta^2 = .25$]. There were more correct identifications when
333 the VP corresponded to the middle of the word (74.3% in P2 and P3) than to the beginning
334 (71.9% in P1) or the end (65.7% and 58.1% in P4 and P5, respectively). There was no
335 significant interaction between frequency and fixation position, $F < 1$.

336 **CA-group.** In the CA-group, the ANOVA revealed a significant effect of lexical
337 frequency, [$F(1, 23) = 61.54; p < .001; \eta^2 = .73$], with 90.1 % identification for HF-words and
338 72.4% for LF-words. As for the RL children, there was a main effect of fixation position
339 [$F(4, 92) = 11.353; p < .001; \eta^2 = .33$], with better performance for positions P2-P3 (87%) than
340 for the word-initial (83.3%) and word-final positions (79.9% and 69.1%, for P4 and P5,
341 respectively). No interaction was found between the two factors, [$F(4, 92) = 1.56; p = \text{ns.}$].

342 **Dyslexics.** As beginning readers (RL children), the dyslexic children also exhibited a
343 large main effect of lexical frequency [$F(1, 23) = 290.48; p < .001; \eta^2 = .93$], with 81.4%
344 identification for HF words and 42.5% for LF words. Dyslexic children identified 70.1% and
345 67.7% of the words at P2 and P3, respectively, vs. 58.3% at P1 and 56.8% at P4-P5, [$F(4,$
346 $92) = 7.17; p < .0001; \eta^2 = .24$]. Interestingly, there was a significant frequency by fixation
347 position interaction [$F(4, 92) = 2.98; p = .02; \eta^2 = .11$], indicating that the frequency effect
348 was larger at unfavourable positions.

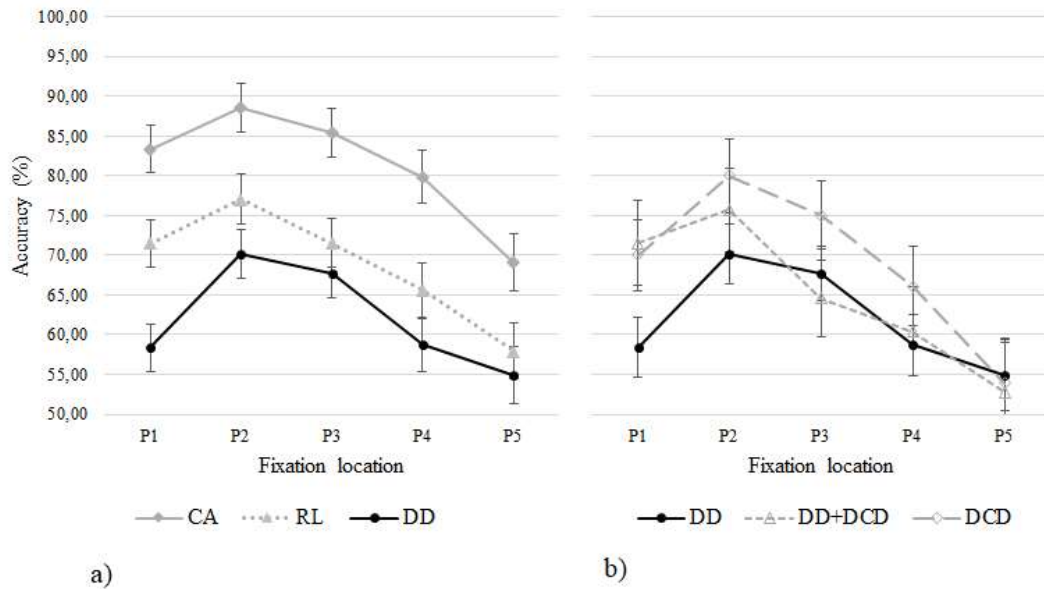
349 As can be seen in Figure 1a, the results revealed systematic differences in the height
350 and shape of the normal readers' and dyslexic children's VP curves [$F(2, 69) = 14.94; p$
351 $<.001; \eta^2 = .30$]. With respect to height, the mean percentage of correct word identifications
352 was much lower for the dyslexics (61.9%) and for the beginning readers (RL) (68.8%) than
353 for the skilled readers (CA) (81.2%). Pairwise comparisons revealed that the group effect
354 could be entirely explained by the fact that there was a difference between children with
355 impaired or emerging reading skills (dyslexics and RL children, respectively) and skilled
356 readers (CA children) [$F(1, 69) = 9.15; p < .001; \eta^2 = .21$], and no difference between
357 dyslexics and RL group [$F(1, 69) = 1.3; p = \text{n.s.}$]. With respect to shape, dyslexics showed a
358 weaker difference between fixating the beginning (P1) and the end of the word (P4-P5)
359 compared with the other groups (1.6%, 10.0%, and 8.9%, for dyslexics, RL and CA children,
360 respectively)⁶. Moreover, this effect was more pronounced for LF words in all groups (2.7%,
361 15.1%, and 14.9%, for dyslexics, RL and CA children, respectively). Pairwise comparisons
362 revealed that the difference between RL and CA groups was non-significant [$F < 1$] and that
363 the interaction between the left-right asymmetry and the groups could be entirely explained by
364 the overt opposition between normal readers (CA and RL) and dyslexic children [$F(1,$
365 $69) = 3.39; p < .05; \eta^2 = .07$, and $F(1, 69) = 4.76; p < .01; \eta^2 = .03$, for low-frequency words
366 only].

367

368 Figure 1(a,b). Accuracy (mean percentage of correct word identifications) as a function of
369 group (DD= dyslexics; CA= chronological age control; RL = reading level control;
370 DD+DCD= children with dyslexia and DCD; DCD = children with DCD only) and five
371 fixation positions (P1, P2, P3, P4, and P5). Errors bars represent standard errors.

⁶ The values are reported by averaging word frequency.

372
373



374
375
376
377

Insert Figure 1(a,b) about here

378 STUDY 2

379 Comparisons between dyslexics, children with developmental coordination 380 disorder and comorbid children

381 In this second study, we tested the OVP effect of a group of children with DD, a group
382 with DCD, and a group with both developmental disorders. Our goal was to explore the
383 impact of co-occurring condition (DD+DCD) on OVP atypicalities.

384

385 Method

386 **Participants.** Three groups with neurodevelopmental disorders participated in this
387 study, one composed of 24 children with developmental dyslexia (DD) (mean age in months

388 = 126.95; SD= 15.17)⁷, the other composed of 15 children with developmental coordination
389 disorder (DCD) (mean age in months = 128.91; SD= 14.37) and the last one composed of 12
390 children with developmental dyslexia and developmental coordination disorder (DD+DCD)
391 (mean age in months = 126.77; SD= 11.55). They were all recruited and diagnosed in
392 different hospitals or clinical centres based in France: La Timone University Hospital in
393 Marseille, Kremlin-Bicêtre Hospital in Paris and the clinical centre “Les Lavandes” in
394 Orpierre. They all underwent a complete medical, psychological and cognitive assessment.
395 All participants were native speakers of French with normal or corrected-to-normal vision.
396 Children whose oral language skills were in the pathological range or who were diagnosed
397 with ADHD were excluded from the study.

398 Concerning children with DD and DCD, criteria for inclusion were manifest reading
399 deficits [at least 1.5 SDs below the normal level on the “Alouette Test-R” (Lefavrais, 2005)]
400 and IQ within the normal limits set by the diagnosis unit ($IQ > 85$), and no vision or hearing
401 deficits. ANOVA analyses showed that the mean reading level of the dyslexic children
402 (mean= 88; SD= 5.9; months) were significantly lower than the DCD’s mean reading level
403 (mean= 118.4; SD= 23.5; months) ($p < .001$) but were not significantly lower than that of the
404 DD + DCD children (mean= 89.6; SD= 4.4; months) ($p = n.s.$). DD + DCD’s mean reading
405 level was significantly lower than that of the DCD children ($p < .001$) (ANOVA; Group
406 effect— $F(2,22) = 53.28; p < .001$). Similarly, the dyslexic children’s mean percentile on
407 motor performance was significantly higher than those of the DCD and the DD+DCD
408 children (mean=35.15; SD=23.15; $p < .001$). The difference between DCD (mean=1,71;
409 SD=1.31) and DD+DCD children (mean=3.57; SD=2.50) was not significant ($p=n.s.$)
410 (ANOVA; Group effect: $F(2,18) = 29.735; p < .001$).

⁷ This was the same group of dyslexics who participated in Study 1.

411 Moreover, children were identified as displaying DCD if they had a score below the
412 15th percentile on the French version of the M-ABC (Soppelsa & Albaret, 2004). Finally,
413 with regard to the DCD only group, we selected children who were diagnosed as DCD on the
414 basis of the criteria listed above, i.e., score on the M-ABC below the 15th percentile, an IQ
415 within the normal limits set by the diagnosis unit ($IQ > 85$), and no vision or hearing deficits.
416 For this last group, we excluded children with DD or reading difficulties.

417

418 **Material, task, stimuli and procedure.** The same used in the Study 1. Exposure time
419 for the target was about 150 ms for DCD children and 250 ms for DD and DD+DCD children.

420

421 **Data analysis**

422 In order to compare comorbid group to children with isolated disorders, we integrated
423 in the analysis the group of dyslexic children of the Study 1. That is, the comparison has been
424 made between three groups. Analysis of variance was thus run on the proportion of correct
425 word identifications transformed in arcsine using a 2 Frequency x 5 Positions x 3 groups
426 (dyslexics, children with developmental coordination disorder, and a group with both
427 neurodevelopmental disorders)⁸. All factors, except Group, were within-participant factors.
428 Effect sizes are reported as eta-square (η^2 , Bakeman, 2005).

429 The left-right asymmetry of the VP curves was measured and tested as in Study 1.

430 Statistical analyses were conducted using the SPSS ® program, version 20.0.

431

432 **Results**

⁸ The assumption of homogeneity of variance was not violated, all $p > .05$ (Levene's test).

433 The mean percentage of correct word identifications was calculated for all
 434 participants. Table 2 shows descriptive statistics of accuracy as a function of group, frequency
 435 of words and letter position.

436

437 Table 2. Means and standard deviations of accuracy (percentage of correct responses) as a
 438 function of group (DD+DCD= children with dyslexia; DCD; DCD = children with DCD only;
 439 DD= dyslexics), frequency of words (HF= High-frequency words; LF= Low-frequency
 440 words), and five fixation positions (P1, P2, P3, P, and P5).

	DD+DCD	DCD	DD
	mean (<i>SD</i>)	mean (<i>SD</i>)	mean (<i>SD</i>)
P1	83.33 (22.47)	82.23 (17.20)	77.78 (16.04)
P2	88.88 (19.26)	90.01 (15.16)	89.58 (15.40)
HF P3	80.55 (22.29)	87.78 (13.31)	84.71 (13.82)
P4	80.55 (19.89)	87.78 (17.21)	75.00 (23.04)
P5	72.22 (24.95)	68.89 (26.62)	79.87 (20.83)
P1	59.73 (25.09)	57.77 (20.76)	38.90 (22.35)
P2	62.48 (23.70)	70.00 (23.74)	50.69 (25.29)
LF P3	48.63 (19.42)	62.21 (20.38)	50.70 (28.85)
P4	40.29 (19.40)	44.43 (27.21)	42.36 (26.91)
P5	33.33 (22.48)	38.89 (34.88)	29.86 (22.50)

441

442

Insert Table 2 about here

443

444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467

Results showed a frequency effect [$F(1, 48) = 422.01; p < .001; \eta^2 = .89$], meaning that accuracy was significantly higher for high-frequency words (81.9 %) than for low-frequency words (47.6 %), but this factor was not modulated by group [$F(2, 48) = 1.675; p = \text{n.s.}$], nor position [$F < 1$]. In addition, there was a main effect of fixation position [$F(4, 192) = 18.63; p < .001; \eta^2 = .26$], thus reflecting the fact that word identification was better in the middle of the word (71.3% in P2 and P3) than in the beginning (64.9% in P1) or the end (61.3% and 54.9% in P4 and P5, respectively). It also emerged a significant group by fixation-position interaction [$F(8, 192) = 2.14, p = .03; \eta^2 = .06$]. As can be seen in Figure 1b, the results revealed systematic differences in the shape of the dyslexic children and other neurodevelopmental disorders' VP curves. As in Study 1, the asymmetry between the beginning (P1) and the end of the word (P4-P5) was less pronounced for dyslexics (1.5%) compared with the other groups, (10.0%, 14.5%, for DCD and DD+DCD, respectively)⁹. Pairwise comparisons revealed that the difference between DCD and DD+DCD groups was non-significant [$F < 1$] and that the interaction between the left-right asymmetry and the groups could be entirely explained by the difference between children with a motor deficit (DCD and DD+DCD) and dyslexic children [$F(1, 48) = 3.976, p = 0.03, \eta^2 = 0.07$].

DISCUSSION

The present study explored early stages of visual word recognition in disabled and typically developing readers, using a fixation-contingent display. The first aim was to better understand the specificity of any OVP anomalies within DD by comparing dyslexics with two groups of typical developing readers, the first of which matched on chronological age (CA) and the second matched on reading level (RL).

⁹ We reported here percentage by averaging word frequency.

468 Results of Study 1 showed that the initial eye position on a word strongly affects the
469 within-word behaviour for all groups. Firstly, as previously reported for adult readers
470 (McConkie et al., 1989; O'Regan & Jacobs, 1992; O'Regan et al., 1984), the likelihood of
471 identifying a word was greater when the eyes initially fixate near the middle of words. This
472 left-half advantage reflects right visual field (RVF) superiority, a finding previously obtained
473 in languages written from left to right (see also, Aghababian & Nazir, 2000; Ducrot et al.,
474 2003; 2013; Dubois et al., 2007, for similar results). Like beginning readers, DD children
475 exhibited a systematic variation in reading performance according to where their eyes were
476 fixating in the word, suggesting that the system that supports normal reading was at least
477 partly functioning. However, if we look separately at the height and shape of the dyslexics'
478 and typical developing readers' VP curves we can observe some differences.

479 With respect to height, analyses showed that word recognition performance was
480 significant lower for the DD group (61.9 %) than CA group (81.2 %); the same trend was
481 observable between RL (68.8 %) and CA groups. Here, the absence of significant differences
482 between dyslexics and RL suggested that activation of lexical knowledge is not impaired in
483 dyslexics, but at least weak, with poor lexicon for these two groups (Ducrot et al., 2003).
484 Moreover, a word frequency effect emerged, modulated by the group. Particularly, results
485 showed that the frequency effect was attenuated with the increase of reading skills. That is,
486 the differences between high- and low-frequency words was larger for DD and beginning
487 readers (here represented by the RL-control group) than for skilled readers (CA group)
488 (38.9% for dyslexics, 32.1% for RL children, and 17.7% for CA children). Accordingly, a
489 more pronounced frequency effect has been already found in dyslexics compared to normal
490 readers (e.g., Dubois et al., 2007; Durrwachter et al., 2010).

491 With respect to shape, the VP curve was affected by reading level, with a weaker P1
492 vs. P4-P5 asymmetry for DD compared to the other groups (see Dubois et al., 2007; Ducrot et

493 al., 2003, for similar results). Moreover, the VP curve was also modulated by word frequency,
494 this effect being more pronounced for LF words, thus suggesting a perceptual recognition
495 probability curve explanation (McConkie et al., 1989). Accordingly, O'Regan and Jacobs
496 (1992) previously showed that the cost of not fixating the OVP of words can be greater for LF
497 words than for HF words. Note that unlike dyslexics, no interaction was found between
498 fixation position and frequency for normal readers, were visuo-attentional and lexical factors
499 were additive, in that frequency increased height equally for all viewing positions (e.g.,
500 McConkie et al., 1989; O'Regan & Jacobs, 1992; Vitu, 1991). It can thus be argued that the
501 frequency effect and its interactions with other variables increase as the quality of the
502 presentation conditions, stimulus attributes, and/or participants' skills become poorer (see
503 Ducrot et al., 2013 for similar results with beginning readers and Slattery & Rayner, 2010, for
504 a similar effect with text degradation). This interpretation is strengthened by the interaction
505 between frequency and group described above, suggesting an attenuated frequency effect
506 linked to an increase of reading skills.

507 Concerning the lack of left-right asymmetry in DD group, since the difference
508 between RL and CA groups was non-significant, the interaction between the left-right
509 asymmetry and the groups could be entirely explained by the overt opposition between
510 normal readers (CA and RL) and dyslexic children. As stated in the Introduction section, the
511 asymmetric inverted *J*-shape curve is linked to visuo-attentional processing in word
512 recognition. In particular, it has been proposed that when the stimulus is discrete (like a
513 word), the participant takes the direction of attentional scanning (left-to-right) into account,
514 which results in asymmetrical landing-position pattern (Ducrot & Pynte, 2002). Indeed, this
515 suggest that reading habits have an influence on the shape and the asymmetry of VP curves
516 (Nazir, Ben-Boutayab, Decoppet, Deutsch, & Frost, 2004). Note that this left-half advantage
517 also suggests that word beginning may play an important role in the word-identification OVP

518 effect. Previous studies have demonstrated that the initial letter of a word provides a great
519 deal of information, and knowledge of the initial letter is more effective than knowledge of
520 the final letter for word identification (Brysbaert & Nazir, 2005; Grainger, 2017; Stevens &
521 Grainger, 2003; White, 2008; Yan, Tian, Bai, & Rayner, 2006). In our study, both the CA-
522 control group and the RL-control group showed asymmetrical curve suggesting that an adult-
523 like pattern is acquired very rapidly while learning to read, even after 1 year of exposure to
524 reading (e.g., Aghababian & Nazir, 2000; Bellocchi, Mancini, Jover, Huau, Ghio, André &
525 Ducrot, 2013a; Bellocchi et al., 2019; Ducrot, Pynte, Ghio, & Lété, 2013). Particularly,
526 beginning readers (here represented by the RL-control group) can extract visual information
527 from words as proficient readers do. On the contrary, we found that DD children showed less
528 asymmetry between P1 and P4-P5 compared to typically developing readers. In other words,
529 in line with other data, DD showed a symmetrical curve (i.e., Aghababian et al., 2001; Ducrot
530 et al., 2003; Montant et al., 1998). Dubois and colleagues (2007), as well as Aghababian and
531 Nazir (2000) have already observed the same pattern of VP inverted *V*-shape curves for a
532 single case surface dyslexic and poor beginning readers. According to the attentional scanning
533 (left-to-right) hypothesis, the absence of left-right asymmetry in the VP curve suggests
534 atypical processing of information outside of foveal vision for dyslexics, as Geiger and
535 colleagues (1992) found, and could thus reflect a deficit in visuo-attentional processing. In
536 that sense, Brannan and Williams (1987) showed that good readers and adults were
537 significantly more accurate when the target appeared on the right side of a fixation point
538 (RVF enhancement), but poor readers were equally accurate on the two sides. The absence of
539 a left-right asymmetry in DD group comes very likely from the fact that dyslexics are not
540 penalized when they see all the letters of a word (-1 letter) in their LVF, unlike normal
541 readers, with their attentional window directed to the RVF, which are thus more penalized in
542 this case. It seems however that DD do as well as other readers when all the letters of the

543 word (-1 letter) are in their RVF, as ever noticed by Bellocchi and colleagues (2019).
544 Therefore, our data reinforced the idea that dyslexics' initial fixation position in word
545 recognition is not "optimal" which can produce more frequent positioning errors, leading to
546 more refixations than normal readers (Hawelka et al., 2010). Differences with RL group
547 suggested non-optimal visuo-attentional strategies, given the left-to-right directionally and the
548 asymmetric word structure of French.

549

550 In the second study, our goals were (1) to examine the visuo-attentional processing in
551 children with DCD and (2) to explore the impact of co-occurring condition (DD+DCD) on
552 OVP atypicalities. As observed in Study 1, results showed that for all groups, the probability
553 of identifying the target word increased when the initial fixation was imposed on the left of
554 the word centre (71.3% in P2 and P3) rather than to the word beginning/ending (64.9% ,
555 61.3% and 54.9% in P1, P4 and P5, respectively). However, it is important to analyse the
556 pattern of results taking into account the height and the shape of OVP curves, separately.

557 Concerning the height, analyses showed no significant differences between groups in
558 word recognition performance. The mean percentage of correct word identification was
559 61.9%, 65.0%, and 69.0%, for DD, DD+DCD and DCD, respectively. The mental lexicon
560 seemed to be used in the same way by the three groups of children in word recognition¹⁰. As

¹⁰ Alexis, Ducrot and Lété (2006) have ever noticed the fact that the height of the VP-
curves was not greatly affected by the presence/absence of reading difficulties in DCD (60%
and 57% of correct identifications for DCD and DD+DCD, respectively), thus suggesting that
activation of lexical knowledge is not impaired in DD or in DD+DCD. It must be noted,
however, that the exposure time used for the target display was significantly shorter for DCD
children (150 ms vs. 250 ms for DD and DD+DCD children).

561 in Study 1, robust effects of word frequency were obtained for all groups, confirming greater
562 sensitivity to word frequency and poor lexical orthographic knowledge in children with
563 learning disorders (see Dubois et al., 2007; Durrwachter et al., 2010; Hawelka et al., 2010).
564 Note that this factor was not modulated by group, nor by VP. The frequency of occurrence of
565 words changed the total height of the VP curves without affecting its shape, with the curves
566 for HF words being above that for LF words (e.g., McConkie et al., 1989; O'Regan & Jacobs,
567 1992; Vitu, 1991).

568 With respect to shape of VP curves, the manipulation of initial VP revealed
569 differences between our three groups of children with neurodevelopmental disorders. In
570 particular, the asymmetry between the beginning (P1) and the end of the word (P4-P5) was
571 less pronounced for DD (1.5%) compared with the other groups, (10%, 14.5%, for DCD and
572 DD+DCD, respectively). In other words, contrary to what it is observed in DD group, DCD
573 and DD+DCD groups showed typical left-right asymmetry in the VP curve. We observed
574 better recognition performance when these children fixated regions in the word where the
575 greatest number of letters could be recognized and where most words could be guessed, that
576 is, left of centre. Visual-field asymmetries comparable to those observed in normal readers
577 were evident for these two groups of children (DCD and DD+DCD), suggesting typical
578 processing of information outside of foveal vision. Contrary to the expectation that the visuo-
579 spatial deficits observed in DCD could lead to OVP atypicalities, our results suggest that
580 visuo-attentional processing in word recognition seems to be not impaired in children with
581 DCD, isolated or comorbid. Note that this is the first evidence of typical OVP effect (in terms
582 of shape of the curve) in children with DCD or DD+DCD.

583 Looking at the impact of comorbidity, we did not find any additional effect on visuo-
584 attentional abilities associated with a dual diagnosis. Therefore, these data do not support the
585 cumulative hypothesis according to which if co-morbid condition add to the severity of the

586 cognitive deficit, children with DD and DCD should revealed more marked atypical VP curve
587 than children with isolated DD (e.g., Pitcher et al., 2002). These results are in line with a
588 bunch of recent studies suggesting that the comorbid condition does not systematically add to
589 the severity of associated cognitive disorders (e.g., Bellocchi, Ducrot, Tallet, Jucla, & Jover,
590 2021; Bellocchi et al., 2017; Biotteau, Albaret, Lelong, & Chaix, 2017; Kaplan et al., 2006;
591 Maziero, Tallet, Bellocchi, Jover, Chaix, & Jucla, 2020). Conversely, our results showed that
592 the comorbid DCD disorder seemed to balance the OVP atypicalities linked to reading
593 deficits. Indeed, only children with isolated DD showed an inverted *V*-shape VP curve
594 qualitatively different from the one showed by typically developing readers suggesting a
595 specific profile in visuo-attentional processing linked to reading deficit in this
596 neurodevelopmental disorder. One possible explanation is that this deficit results from
597 particular scanning strategies linked to a lack of reading exposure, leading to difficulty to
598 control the distribution of attention (Bellocchi et al., 2019; Brannan & Williams, 1987; Ducrot
599 et al., 2003; Facoetti, Turatto, Lorusso, & Mascetti, 2001 ; Geiger et al. 1992; see Bellocchi et
600 al., 2013b and Goswami, 2015 for reviews).

601 Finally, if we look at the VP curves (Figure 1b), we can notice that comorbid children
602 seem to perform partially at an intermediate level between DD and DCD children. Indeed, the
603 comorbid group's VP curve begun at the level of DCD's one (which had typical reading
604 abilities) and then joined the DD's curve. This result supports that co-morbid condition does
605 not add to the severity of the cognitive deficit. Additionally, it corroborates the hypothesis on
606 the impact of the amount of visual attention resources available for processing and the
607 quantity of print exposure on the very earliest stages of visual word recognition.

608

609 Last but not least, our work allows us to bring out some interesting elements on
610 clinical practice regarding both diagnosis and remediation of DD. Agreement is rising that

611 reading difficulties can be due to impairments in different stages of the reading process, either
612 in the visual or in the linguistic system. However, as Bellocchi et al. (2017) previously
613 highlighted, at present, most of the tools available to professionals are designed for the
614 assessment and remediation of child language problems. Furthermore, very few standardized
615 tools today focus on the assessment of fine-grained visuo-attentional processes following
616 experimental paradigms used in the scientific literature (but see, Ducrot et al., 2008; Leibnitz,
617 Ducrot, Grainger, & Muneaux, 2014; Valdois, Guinet, & Embs, 2014). Accordingly, our
618 paper demonstrated that the OVP paradigm provides an interesting way to better understand
619 the nature of the visuo-attentional strategies involved in word recognition by children who
620 have a learning disability. This paradigm allows detecting quantitative and qualitative
621 differences in the VP curve of these children by a fine-grained analysis of the height and the
622 shape of their VP curves.

623 Regarding the height and the quality of lexical processing, these results obtained on
624 disabled readers indicate that activation of lexical knowledge was poorer in children with
625 neurodevelopmental disorders compared to typically developing children. They also
626 confirmed that reading difficulties are more likely to either increase frequency effects
627 themselves or to increase frequency effects under particularly non-optimal conditions of
628 presentation. When it comes to the shape, there was a drop in performance when the fixation
629 point was shifted horizontally from the centre of the word for all groups. However, if typically
630 developing readers have already developed highly automatized procedures of left-to-right
631 attentional scanning which results in asymmetrical landing-position pattern (and a left-half
632 advantage), the drop was not asymmetric for our DD. We argue that the inverted *V*-shape
633 curve obtained in this group is a clinical marker of visuo-attentional difficulties in DD, likely
634 linked to a limited experience with written language (see Bellocchi et al., 2019 for additional
635 data supporting this hypothesis). Contrary to the expectation that the visuo-spatial deficits

636 observed in DCD could lead to OVP atypicalities, our results suggest that visuo-attentional
637 processing in word recognition is not impaired in children with DCD, isolated or comorbid, at
638 least with respect to the left-to-right attentional scanning procedure (i.e., they showed typical
639 *J*-shape curve). This last result suggests that the OVP paradigm could be used as a clinical
640 tool to identify possible OVP atypicalities that could be specific of some neurodevelopmental
641 disorders (i.e., DD vs. DCD and DD+DCD). Again, this could constitute an important source
642 of information for practitioners to differentiate cognitive profiles of children with DD,
643 compared to children with DCD and DD+DCD disorders. The possibility of describing
644 specific cognitive profiles in these populations is fundamental in view of establishing
645 thorough and accurate assessment procedures and proposing an ad hoc remediation and
646 intervention program that take into account the particular processes affected.

647

648 Summing up, our study showed that firstly, typically developing readers had already
649 developed highly automatized procedures of left-to-right attentional scanning which results in
650 asymmetrical landing-position pattern. Here, dyslexics showed a non-prototypical inverted *V*-
651 shape VP curve, which might reflect visuo-attentional difficulties linked to reading difficulties
652 and/or a lack of experience with written language. Secondly, contrary to the expectation that
653 the visuo-spatial deficits observed in DCD could lead to OVP atypicalities, our results suggest
654 that visuo-attentional processing in word recognition is not impaired in children with DCD,
655 isolated or comorbid. Finally, given the absence of significant group differences between
656 children with DD and DCD and children with isolated disorders (DD or DCD), our results
657 reinforce the idea that the comorbid condition does not add to the severity of OVP anomalies.

658

659 **References**

- 660 Aghababian, V., & Nazir, T. A. (2000). Developing normal reading skills: Aspects of visual
661 processes underlying word recognition. *Journal of Experimental Child Psychology*, 76,
662 123–150.
- 663 Aghababian, V., Nazir, T. A., Lançon, C., & Tardy, M. (2001). From "Logographic"
664 to Normal Reading: The Case Of a Deaf Beginning Reader. *Brain and Language*,
665 78, 212-223.
- 666 Alexis, C., Ducrot, S., & Lété, B. (2006). La perception du mot écrit chez l'enfant
667 dyspraxique. *ANAE. Approche neuropsychologique des apprentissages chez l'enfant*, 88-
668 89, 207-213.
- 669 American Psychiatric Association (2013). *Diagnostic and statistical manual of mental*
670 *disorders (5th ed.)*. Washington, DC: Author.
- 671 Bakeman, R. (2005). Recommended effect size statistics for repeated measures
672 designs. *Behavior Research Methods*, 37(3), 379-384.
- 673 Bellocchi, S., Ducrot, S., Tallet, J., Jucla, M. & Jover, M. (2021). Effect of comorbid
674 developmental dyslexia on oculomotor behavior in children with developmental
675 coordination disorder: A study with the Developmental Eye Movement test. *Human*
676 *Movement Science*, 76, 102764. [doi: 10.1016/j.humov.2021.102764](https://doi.org/10.1016/j.humov.2021.102764)
- 677 Bellocchi, S., Mancini, J., Jover, M., Huau, A., Ghio, A., André, C., & Ducrot. S. (August-
678 September 2013a). *Dyslexic readers and saccade computation: Effects of reading*
679 *exposure and visuo-perceptual constraints*. Poster presented at the XVIIIth ESCoP
680 Conference. Budapest. Hungary.
- 681 Bellocchi, S., Massendari, D., Grainger, J., & Ducrot, S. (2019). Effects of inter-character
682 spacing on saccade programming in beginning readers and dyslexics. *Child*

683 *Neuropsychology. A Journal on Normal and Abnormal Development in Childhood and*
684 *Adolescence, 25(4), 482-506.*

685 Bellocchi, S., Muneaux, M., Bastien-Toniazzo, M., & Ducrot, S., (2013b). I can read it in
686 your eyes: What eye movements tell us about visuo-attentional processes in
687 developmental dyslexia. *Research in Developmental Disabilities, 34, 452-460.*

688 Bellocchi, S., Muneaux, M., Huau, A., Lévêque, Y., Jover, M., & Ducrot, S. (2017).
689 Exploring the Link between Visual Perception, Visual-Motor Integration, and Reading in
690 Normal Developing and Impaired Children using DTVP-2. *Dyslexia. An International*
691 *Journal of Research and Practice, 23(3), 296-315*

692 Bennett, I. J., Romano, J. C., Howard Jr, J. H., & Howard, D. V. (2008). Two forms of
693 implicit learning in young adults with dyslexia. *Annals of the New York Academy of*
694 *Sciences, 1145(1), 184-198.*

695 Biotteau, M., Albaret, J.M., Lelong, S., & Chaix, Y. (2017). Neuropsychological status of
696 French children with developmental dyslexia and/or developmental coordination
697 disorder: Are both necessarily worse than one? *Child Neuropsychology. A Journal on*
698 *Normal and Abnormal Development in Childhood and Adolescence, 23(4), 422-441.*

699 Blythe, H.I. (2014). Developmental changes in eye movements and visual information
700 encoding associated with learning to read. *Current Directions in Psychological Science,*
701 *23(3), 201–207.*

702 Borella, E., Chicherio, C., Re, A. M., Sensini, V., & Cornoldi, C. (2011). Increased
703 intraindividual variability is a marker of ADHD but also of dyslexia: A study on
704 handwriting. *Brain and cognition, 77(1), 33-39.*

705 Bosse, M. L., & Valdois, S. (2009). Influence of the visual attention span on child reading
706 performance: A cross-sectional study. *Journal of Research in Reading, 32(2), 230–253.*

707 Brannan, J. & Williams, M. (1987). Allocation of visual attention in good and poor readers.
708 *Perception & Psychophysics*, 41, 23-28.

709 Brysbaert, M., & Nazir, T. A. (2005). Visual constraints on written word recognition:
710 Evidence from the optimal viewing position effect. *Journal of Research in Reading*,
711 28(3), 216–228.

712 Brysbaert, M., Vitu, F., & Schroyens, W. (1996). The right visual field advantage and the
713 optimal viewing position: On the relation between foveal and parafoveal word
714 recognition. *Neuropsychology*, 18, 385–395.

715 Chaix, Y., Albaret, J.M., Brassard, C., Cheuret, E., de Castelnau, P., Bénesteau, J., Karsenty,
716 C., & Démonet, J.F. (2007). Motor impairment in dyslexia: The influence of attention
717 disorders. *European Journal of Paediatric Neurology*, 11, 368–374.

718 Clark, J. J., & O'Regan, J. K. (1999). Word ambiguity and the optimal viewing position in
719 reading. *Vision Research*, 39(4), 843–857.

720 Clark, J. J., & O'Regan, J. K. (1999). Word ambiguity and the optimal viewing position in
721 reading. *Vision Research*, 39(4), 843–857.

722 Danna, J., Massendari, D., Furnari, B., & Ducrot, S. (2018). The optimal viewing position
723 effect in printed versus cursive words: Evidence of a reading cost for the cursive font.
724 *Acta Psychologica*, 188, 110-121. doi: 10.1016/j.actpsy.2018.06.003

725 Deutsch, A., & Rayner, K. (1999). Initial fixation location effects in reading Hebrew words.
726 *Language & Cognitive Processes*, 14, 393–421.

727 Dubois, M. Lafaye De Micheaux, P., Noël, M. P. & Valdois, S. (2007). Pre-orthographical
728 constraints on visual word recognition: Evidence from a case study of developmental
729 surface dyslexia. *Cognitive Neuropsychology*, 24(6), 623-660.

730 Ducrot, S., & Grainger, J. (2007). Deployment of spatial attention to words in central and
731 peripheral vision. *Perception & Psychophysics*, 69(4), 578–590.

732 Ducrot, S., & Pynte, J. (2002). What determines the eyes' landing position in words?
733 *Perception & Psychophysics*, 64, 1130–1144.

734 Ducrot, S., Ghio, A., Michaël, G., Muneaux, M., Rauzy, S., & Lété, B. (2008). *The ADIVA*
735 *(Aide au Diagnostic des déficits Visuo-Attentionnels chez l'enfant) software package.*
736 Unpublished Technical Report (69 p.), Aix-Marseille University.

737 Ducrot, S., Lété, B., Sprenger-Charolles, L., Pynte, J., & Billard, C. (2003). The optimal
738 viewing position effect in beginning and dyslexic readers. *Current Psychology Letters :*
739 *Behaviour, Brain and Cognition*, 10, 1-10.

740 Ducrot, S., Pynte, J., Ghio, A., & Lété, B. (2013). Visual and Linguistic Determinants of the
741 Eyes' Initial Fixation Position in Reading Development. *Acta Psychologica*, 142, 287-
742 298.

743 Dürrwächter, U., Sokolov, A.N., Reinhard, J., Klosinski, G., & Trauzettel-Klosinski, S.
744 (2010). Word length and word frequency affect eye movements in dyslexic children
745 reading in a regular (German) orthography. *Annals of Dyslexia.*, 60(1), 86-101.

746 Facoetti, A., Turatto, M., Lorusso, M. L., & Mascetti, G. G. (2001). Orienting of visual
747 attention in dyslexia: Evidence for asymmetric hemispheric control of attention.
748 *Experimental Brain Research*, 138, 46–53.

749 Farid, M., & Grainger, J. (1996). How initial fixation position influences visual word
750 recognition: A comparison of French and Arabic. *Brain and Language*, 53, 681–690.

751 Fawcett, A. J., & Nicolson, R. I. (1995). Persistent deficits in motor skill of children with
752 dyslexia. *Journal of Motor Behavior*, 27(3), 235-240.

753 Forster, K. I., & Forster, J. C. (2001). *DMDX version 2.9.01*. Retrieved from internet from
754 <http://www.u.arizona.edu/~jforster/dmdx.htm>.

755 Franceschini, S., Gori, S., Ruffino, M., Pedrolli, K., & Facoetti, A. (2012). A causal link
756 between visual spatial attention and reading acquisition. *Current Biology*, 22, 814-819.

757 Gagl, B., Hawelka, S., & Hutzler, F. (2014). A similar correction mechanism in slow and
758 fluent readers after suboptimal landing positions. *Frontiers in Human Neuroscience*, 8,
759 355.

760 Geiger, G., Lettvin, J. Y., & Zegarra Moran, O. (1992). Task-determined strategies of visual
761 process. *Cognitive Brain Research*, 1, 39-52.

762 Goswami, U. (2015). Sensory theories of developmental dyslexia: Three challenges for
763 research. *Nature Review Neuroscience*, 16, 43–54.

764 Goswami, U. C., & Bryant, P. (1990). *Phonological skills and learning to read*. New-York :
765 Psychology Press.

766 Grainger, J. (2017). Orthographic processing: A “mid-level” vision of reading. *The Quarterly*
767 *Journal of Experimental Psychology*, 71 (2), 1-72.

768 Grainger, J., Dufau, S., & Ziegler, J. C. (2016). A vision of reading. *Trends in Cognitive*
769 *Science*, 20, 171–179.

770 Hawelka, S., Gagl, B., & Wimmer, H. (2010). A dual-route perspective on eye movements of
771 dyslexic readers. *Cognition*, 115, 367–379.

772 Huestegge, L., Radach, R., Corbic, D., & Huestegge, S. (2009). Oculomotor and linguistic
773 determinants of reading development: A longitudinal study. *Vision Research*, 49, 2948–
774 2959.

775 Iversen, S., Berg, K., Ellertsen, B., & Tønnessen, F. E. (2005). Motor coordination difficulties
776 in a municipality group and in a clinical sample of poor readers. *Dyslexia*, 11(3), 217-
777 231.

778 Joseph, H.S.S.L., Liversedge, S.P., Blythe, H.I., White, S.J., & Rayner, K. (2009). Word
779 length and landing position effects during reading in children and adults. *Vision Research*,
780 49, 2078-2086.

781 Jover, M., Ducrot, S., Huau, A., Bellocchi, S., Brun-Hénin, F., & Mancini, J. (2013). Les
782 troubles moteurs chez les enfants dyslexiques : Revue de travaux et perspectives.
783 *Enfance*, 4, 323-347.

784 Kajii, N., & Osaka, N. (2000). Optimal viewing position in vertically and horizontally
785 presented Japanese words. *Perception & Psychophysics*, 62(8), 1634-1644.

786 Kaplan, B. J., Dewey, D. M., Crawford, S. G., & Wilson, B. N. (2001). The term comorbidity
787 is of questionable value in reference to developmental disorders: Data and theory.
788 *Journal of Learning Disabilities*, 34(6), 555-565.

789 Kaplan, B., Crawford, S., Cantell, M., Kooistra, L., & Dewey, D. (2006). Comorbidity, co-
790 occurrence, continuum: What's in a name? *Child: Care, Health and Development*,
791 32(6), 723-731.

792 LaBerge, D., & Samuels, S.J. (1974). Toward a theory of automatic information process in
793 reading. *Cognitive Psychology*, 6, 293-323.

794 Lam, S. S., Au, R. K., Leung, H. W., & Li-Tsang, C. W. (2011). Chinese handwriting
795 performance of primary school children with dyslexia. *Research in Developmental*
796 *Disabilities*, 32(5), 1745-1756.

797 Lavidor, M., & Walsh, V. (2004). The nature of foveal representation. *Nature Reviews*
798 *Neuroscience*, 5, 729–735.

799 Lefavrais, P. (2005). *Test de l'Alouette-R*. Paris : ECPA.

800 Legge, G. E., Ahn, S. J., Klitz, T. S., & Luebker, A. (1997). Psychophysics of reading-XVI.
801 The visual span in normal and low vision. *Vision Research*, 37, 1999–2010.

802 Leibnitz, L., Ducrot, S., Grainger, J., & Muneaux, M. (2014). *Une batterie informatisée de*
803 *dépistage des difficultés visuo-attentionnelles à destination des enfants de maternelle*.
804 Proceedings of the APPREC Conference, Learning Written Language: Diversity of
805 languages, Uniqueness of disorders, December 3–5, Strasbourg, France.

806 Lété, B., Sprenger-Charolles, L., & Colé, P. (2004). Manulex: A grade-level lexical database
807 from French elementary-school readers. *Behavior Research Methods, Instruments, &*
808 *Computers*, 36, 156–166.

809 Li, X., Liu, P., & Rayner, K. (2011). Eye movement guidance in Chinese reading: Is there a
810 preferred viewing location? *Vision Research*, 51, 1146–1156.

811 MacKeben, M., Trauzettel-Klosinski, S., Reinhard, J., Durrwachter, U., Adler, M., &
812 Klosinski, G. (2004). Eye movement control during single-word reading in dyslexics.
813 *Journal of Vision*, 4(5), 388–402.

814 Maziero, S., Tallet, J., Bellocchi, S., Jover, M., Chaix, Y. & Jucla, M. (2020). Influence of
815 Comorbidity on Working Memory Profile in Dyslexia and Developmental Coordination
816 Disorder. *Journal of Clinical and Experimental Neuropsychology*, 42(7), 660-674.

817 McConkie, G. W., Kerr, P. W., Reddix, M. D., Zola, D., & Jacobs, A. M. (1989). Eye
818 movement control during reading: II. Frequency of refixating a word. *Perception &*
819 *Psychophysics*, 46, 245–253.

820 McConkie, G.W., Kerr, P.W., Reddix, M.D., & Zola, D. (1988). Eye movement control
821 during reading: The location of initial eye fixations on words. *Vision Research*, 27, 227-
822 240.

823 Montant, M., Nazir, T. A., & Poncet, M. (1998). Pure alexia and the viewing position effect in
824 printed words. *Neuropsychology*, 15(1-2), 93-140.

825 Nazir, T. A., Jacobs, A. M., O'Regan, J.K. (1998). Letter legibility and visual word
826 recognition. *Memory and Cognition*, 26(4), 810–821.

827 Nazir, T. A. (2000). *Traces of print along the visual pathway*. In A. Kennedy, R. Radach, D.
828 Heller, & J. Pynte (Eds.). *Reading as a perceptual process* (pp. 3–23). Oxford: Elsevier.

829 Nazir, T. A. (2003). On hemispheric specialization and visual field effects in the perception of
830 print: A comment on Jordan, Patching and Thomas. *Cognitive Neuropsychology*, 20, 73–
831 80.

832 Nazir, T. A., Ben-Boutayab, N., Decoppet, N., Deutsch, A., & Frost, R. (2004). Reading
833 habits, perceptual learning, and recognition of printed words. *Brain and Language*, 88,
834 294–311.

835 Nazir, T. A., O'Regan, J. K., & Jacobs, A. M. (1991). On words and their letters. *Bulletin of*
836 *the Psychonomic Society*, 29, 171–174.

837 Nicolson, R. I., & Fawcett, A. J. (1994). Comparison of deficits in cognitive and motor skills
838 among children with dyslexia. *Annals of Dyslexia*, 44(1), 147-164.

839 O'Hare, A., & Khalid, S. (2002). The association of abnormal cerebellar function in children
840 with developmental coordination disorder and reading difficulties. *Dyslexia*, 8(4), 234-
841 248.

842 O'Regan, J. K., & Jacobs, A. M. (1992). Optimal viewing position effect in word recognition:
843 A challenge to current theory. *Journal of Experimental Psychology. Human Perception*
844 *and Performance*, 18, 185–197.

845 O'Regan, J. K., Lévy-Schoen, A., Pynte, J., & Brugailière, B. (1984). Convenient fixation
846 location within isolated words of different length and structure. *Journal of Experimental*
847 *Psychology. Human Perception and Performance*, 10, 250–257.

848 Pitcher, T. M., Piek, J. P., & Barrett, N. C. (2002). Timing and force control in boys with
849 attention deficit hyperactivity disorder: Subtype differences and the effect of comorbid
850 developmental coordination disorder. *Human Movement Science*, 21(5–6), 919–945.

851 Rayner, K. (1979). Eye guidance in reading: Fixation location within words. *Perception*, 8,
852 21-30.

853 Rogé, B. (1984). *Manuel de l'échelle de développement moteur de Lincoln-Oseretsky*. Paris:
854 ECPA.

855 Schroeder, S., Hyönä, J., & Liversedge, S. P. (2015). Developmental eye-tracking research in
856 reading: Introduction to the Special Issue. *Journal of Cognitive Psychology*, 27(5), 500-
857 510.

858 Soppelsa, R., & Albaret, J.-M. (2004). *Manuel de la Batterie d'Evaluation du Mouvement*
859 *chez l'Enfant (MABC)*. Paris: ECPA.

860 Stenneken, P., van Eimeren, L., Keller, I., Jacobs, A. M., & Kerkhoff, G. (2008). Task-
861 dependent modulation of neglect dyslexia? Novel evidence from the viewing position
862 effect. *Brain Research*, 1189, 166–178.

863 Stevens, M., & Grainger, J. (2003). Letter visibility and the viewing position effect in visual
864 word recognition. *Perception & Psychophysics*, 65(1), 133–151.

865 Stevens, M., & Grainger, J. (2003). Letter visibility and the viewing position effect in visual
866 word recognition. *Perception & Psychophysics*, 65(1), 133–151.

867 Tsai, C. L., & Wu, S. K. (2008). Relationship between visual-perceptual deficits and motor
868 impairments in children with developmental coordination disorder. *Perceptual and Motor*
869 *Skills*, 107, 457–472.

870 Tsai, C.L. (2009). The effectiveness of exercise intervention on inhibitory control in children
871 with developmental coordination disorder: using a visuospatial attention paradigm as a
872 model. *Research in Developmental Disabilities*, 30(6), 1268-80.

873 Valdois, S. Guinet, E., & Embs, J. L. (2014). *EVADYS: Outil diagnostique des troubles de*
874 *l'empan VA (EVADYS: a diagnostic tool for VA span assessment)*. Isbergues, France :
875 Ortho-Edition.

- 876 Valdois, S., Bosse, M. L., & Tainturier, M. J. (2004). The cognitive deficits responsible for
877 developmental dyslexia: Review of evidence for a selective visual attentional disorder.
878 *Dyslexia, 10*, 339–363.
- 879 Velay, J. L., Daffaure, V., Giraud, K., & Habib, M. (2002). Interhemispheric sensorimotor
880 integration in pointing movements: A study on dyslexic adults. *Neuropsychologia,*
881 *40(7)*, 827-834.
- 882 Vernet, M., Bellocchi, S., Leibnitz, L., Chaix, Y., & Ducrot, S. (2021). Predicting Future Poor
883 Readers from Pre-reading Visual Skills: A Longitudinal Study. *Applied*
884 *Neuropsychology: Child.*
- 885 Vitu, F. (1991). The existence of a center of gravity effect during reading. *Vision Research,*
886 *31(7/8)*, 1289–1313.
- 887 Vitu, F., O'Regan, J. K., & Mittau, M. (1990). Optimal landing position in reading isolated
888 words and continuous text. *Perception & Psychophysics, 47*, 583–600.
- 889 Vorstius, C., Radach, R., & Lonigan, C.J. (2014). Eye movements in developing readers: A
890 comparison of silent and oral sentence reading. *Visual Cognition, 22(3–4)*, 458–485.
- 891 Wechsler, D. (2005). *Echelle d'Intelligence pour Enfants et Adolescents, 4ème édition*. Paris:
892 ECPA.
- 893 White, S. J. (2008). Eye movement control during reading: Effects of word frequency and
894 orthographic familiarity. *Journal of Experimental Psychology: Human Perception and*
895 *Performance, 34(1)*, 205.
- 896 Wilson, P. H., & McKenzie, B. E. (1998). Information processing deficits associated with
897 developmental coordination disorder: A meta-analysis of research findings. *Journal of*
898 *Child Psychology and Psychiatry, 39*, 829–840.

- 899 Wong, Y.K. & Hsiao, J.H. (2012). *Reading direction is sufficient to account for the optimal*
900 *viewing position in reading: The case of music reading*. Proceedings of the Thirty-Fourth
901 Annual Meeting of the Cognitive Science Society.
- 902 World Health Organisation. (1992). *The ICD-10 classification of mental and behavioural*
903 *disorders. Clinical descriptions and diagnostic guidelines*. Geneva: WHO.
- 904 World Health Organisation. (2008). 59th general assembly. In: Association WM, editor.
905 Seoul, Korea: WHO.
- 906 Yan, G., Tian, H., Bai, X., & Rayner, K. (2006). The effect of word and character frequency
907 on the eye movements of Chinese readers. *British Journal of Psychology*, 97(2), 259-268.