



**HAL**  
open science

## The cognitive deficits responsible for developmental dyslexia: Review of evidence for a visual attentional deficit hypothesis.

Sylviane Valdois, Marie-Line Bosse, Marie-Josèphe Tainturier

### ► To cite this version:

Sylviane Valdois, Marie-Line Bosse, Marie-Josèphe Tainturier. The cognitive deficits responsible for developmental dyslexia: Review of evidence for a visual attentional deficit hypothesis.. *Dyslexia*, 2004, 10, pp.339-363. hal-00826009

**HAL Id: hal-00826009**

**<https://hal.science/hal-00826009>**

Submitted on 25 May 2013

**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.



# ■ The Cognitive Deficits Responsible for Developmental Dyslexia: Review of Evidence for a Selective Visual Attentional Disorder

Sylviane Valdois<sup>1,\*</sup>, Marie-Line Bosse<sup>1</sup> and Marie-Josèphe Tainturier<sup>2</sup>

<sup>1</sup>*Laboratoire de Psychologie et Neuro-Cognition (UMR 5105 CNRS), Université Pierre Mendès France, Grenoble, France*

<sup>2</sup>*School of Psychology, University of Wales, Bangor, UK*

There is strong converging evidence suggesting that developmental dyslexia stems from a phonological processing deficit. However, this hypothesis has been challenged by the widely admitted heterogeneity of the dyslexic population, and by several reports of dyslexic individuals with no apparent phonological deficit. In this paper, we discuss the hypothesis that a phonological deficit may not be the only core deficit in developmental dyslexia and critically examine several alternative proposals. To establish that a given cognitive deficit is causally related to dyslexia, at least two conditions need to be fulfilled. First, the hypothesized deficit needs to be associated with developmental dyslexia independently of additional phonological deficits. Second, the hypothesized deficit must predict reading ability, on both empirical and theoretical grounds. While most current hypotheses fail to fulfil these criteria, we argue that the visual attentional deficit hypothesis does. Recent studies providing evidence for the independence of phonological and visual attentional deficits in developmental dyslexia are reviewed together with empirical data showing that phonological and visual attentional processing skills contribute independently to reading performance. A theoretical model of reading is outlined in support of a causal link between a visual attentional disorder and a

\*Correspondence to: S. Valdois, Laboratoire de Psychologie et Neuro-Cognition, Université Pierre Mendès France, 1251 Ave Centrale BP 47X, 38040 Grenoble Cedex 9, France. E-mail: Sylviane.Valdois@upmf-grenoble.fr

1 failure in reading acquisition. Copyright © 2004 John Wiley &  
2 Sons, Ltd.

## 5 INTRODUCTION

7 **I**n the past four decades, many studies have attempted to identify the nature  
8 of the cognitive disorders associated with and potentially responsible for  
9 developmental dyslexia. The proposal of a phonological deficit as the  
10 cognitive basis of developmental dyslexia is now widely accepted. However, the  
11 view that a phonological deficit is the only core disorder in developmental  
12 dyslexia seems difficult to reconcile with a variety of evidence which highlights  
13 the heterogeneity of the dyslexic population. In particular, dyslexic children with  
14 opposite reading profiles have been reported. Children with surface dyslexia fail  
15 to read exception words despite normal pseudo-word reading; phonological  
16 dyslexic children show the reverse pattern—good exception word reading but  
17 poor pseudo-word reading. In addition, there have been several reports of  
18 dyslexic children who demonstrated no associated phonological deficit.  
19 Researchers who support the view that a phonological deficit is the sole core  
20 deficit in developmental dyslexia have argued that heterogeneity in the surface  
21 manifestations of dyslexia may be explained by varying degrees of severity of the  
22 phonological processing deficit, or that some reading disorders may be seen as  
23 general reading delays rather than developmental dyslexia *per se*. However, this  
24 heterogeneity of the dyslexic population also raises the interesting possibility that  
25 different performance patterns might actually reflect distinct underlying  
26 cognitive impairments. Thus, poor pseudo-word reading and phoneme aware-  
27 ness skills may be the consequence of an underlying phonological processing  
28 deficit, whereas poor exception word reading despite good phonological skills  
29 may follow from a non-phonological core cognitive disorder.

30 Defending such a hypothesis requires providing evidence for the indepen-  
31 dence between the phonological processing deficit and the second hypothesized  
32 cognitive disorder. It further requires demonstrating that the second hypothe-  
33 sized disorder accounts for unique variance in the reading performance of  
34 dyslexic participants beyond that explained by phonological skills. Informing a  
35 causal relationship between a cognitive disorder and specific reading disability  
36 further requires a theoretical framework clearly establishing how a dysfunction  
37 of this cognitive mechanism would hamper reading acquisition. Discussing  
38 current theories on these issues, the present paper gives empirical and theoretical  
39 arguments suggesting that a visual attentional deficit appears as a plausible  
40 second core deficit in developmental dyslexia.

41 This review first includes a brief summary of the well-known phonological  
42 core-deficit literature, emphasising both the strengths and weaknesses of the  
43 phonological hypothesis. Then, we discuss the validity of low-level sensory  
44 deficits, cerebellar deficits and rapid automatised naming disorders as causal  
45 factors in specific reading disability. Evidence for associated visual attentional  
46 disorders in developmental dyslexia is then reviewed before focusing on recent  
47 findings that suggest that visual attentional disorders contribute to reading  
48 acquisition disorders independently of phonological skills. Finally, we finally  
49 outline a theoretical model of reading which accounts for the separable influence

1 of visual attentional processes and phonology on various aspects of skilled  
2 reading and reading acquisition.

3

## 5 THE PHONOLOGICAL DEFICIT HYPOTHESIS

7 The most widely accepted hypothesis with respect to the cognitive origin of  
8 developmental dyslexia is the phonological deficit hypothesis (Frith, 1997;  
9 Snowling, 1981, 2000; Stanovitch, 1986; Stanovitch & Siegel, 1994; Vellutino,  
10 Fletcher, Snowling, & Scanlon, 2004; Wilding, 1989, 1990). Numerous studies  
11 have shown that, compared to normal readers, developmental dyslexic children  
12 are impaired in phonological processing tasks such as non-word repetition  
13 (Elbro, Borstrom, & Petersen, 1998; Snowling, 1981; Snowling, Staskhouse, &  
14 Rack, 1986), phonemic fluency (Frith, Landerl, & Frith, 1995), picture naming  
15 (Snowling, van Wagendonk & Stafford, 1988), phonological learning (Aguar &  
16 Brady, 1991; Wimmer, Mayringer, & Landerl, 1998), phonemic awareness (e.g.  
17 Bradley & Bryant, 1978; Griffiths & Snowling, 2002; Morris *et al.*, 1998) or verbal  
18 short-term memory (Griffiths & Snowling, 2002; Nelson & Warrington, 1980;  
19 Rack, 1985). The persistence of phonological difficulties in well-compensated  
20 dyslexic adults (Bruck, 1992; Campbell & Butterworth, 1985; Fawcett & Nicolson,  
21 1995; Funnell & Davison, 1989; Howard & Best, 1996; Shaywitz *et al.*, 1999)  
22 provides additional support to the phonological hypothesis.

23 Furthermore, studies on normal reading acquisition suggest a causal relation-  
24 ship between phonological processing skills and reading abilities: phonological  
25 awareness is strongly related to reading progress (Goswami & Bryant, 1990, for a  
26 review), children's knowledge of the phonological structure of their language is a  
27 good predictor of early reading ability (Bradley & Bryant, 1983; Elbro, 1997; Elbro  
28 *et al.*, 1998; Stanovich, Cunningham, & Cramer, 1984) and phonemic awareness  
29 training improves learning to read (Bradley & Bryant, 1983; Ehri *et al.*, 2001, for a  
30 meta-analysis; Castles & Coltheart, 2004, for a critical review).

31 These findings provide strong support to the phonological deficit hypothesis,  
32 but there are problematic data as well. First, several cases of developmental  
33 dyslexia and/or dysgraphia with good phonological skills have been reported;  
34 these cases show good pseudo-word reading, phonological awareness and verbal  
35 short term memory, and the majority of the errors they produce are  
36 phonologically plausible (Broom & Doctor, 1995; Castles & Coltheart, 1996;  
37 Coltheart, Masterson, Byng, Prior, & Riddoch, 1983; Goulandris & Snowling,  
38 1991; Hanley & Gard, 1995; Hanley, Hastie, & Kay, 1992; Job, Sartori, Masterson,  
39 & Coltheart, 1984; Romani & Stringer, 1994; Romani, Ward, & Olson, 1999;  
40 Temple, 1984). These case studies indicate that not all developmental dyslexics  
41 have a phonological deficit, a rather unexpected finding within the phonological  
42 hypothesis framework. However, these studies often assessed performance of  
43 teenagers or young adults. Accordingly, one could argue that the phonological  
44 disorder was present earlier in development but was so well compensated as to  
45 become undetectable by the time of testing. In addition, the sensitivity of the  
46 phonological tests used in these studies can sometimes be questioned. However,  
47 two studies, which compared the performance of dyslexic readers of similar age  
48 and reading level on the same phonological tests, provide more convincing  
49 evidence for the existence of developmental dyslexia without phonological

1 processing disorders (Hanley & Gard, 1995; Valdois *et al.*, 2003). Each of these  
2 studies reported two dyslexic cases with opposite reading patterns and  
3 contrasted phonological skills. In each study, one dyslexic participant showed  
4 poor phonological awareness and made only a few phonologically accurate  
5 errors in reading or spelling (phonological dyslexia pattern) while the other  
6 showed good phonological awareness and produced a majority of phonologically  
7 accurate errors (surface dyslexia pattern). Thus, cases of developmental dyslexia  
8 with normal phonological processing have been documented despite using  
9 sensitive enough phonological measures. In other cases however, phonological  
10 and surface dyslexia differ only in the degree of severity of the phonological  
11 disorder and in the cognitive resources available to compensate for this  
12 phonological deficit (Snowling, 2000). Thus, it could be argued that dyslexic  
13 children with good phonological skills are exceptional cases and rare syndromes  
14 of no theoretical significance.

15 Classification studies have also identified subgroups of dyslexic children who  
16 demonstrate distinct, and even opposite patterns of reading disability, relative to  
17 patterns of normal reading performance (Castles & Coltheart, 1993; Castles,  
18 Datta, Gayan, & Olson, 1999; Genard *et al.*, 1998; Manis, Seidenberg, Doi,  
19 McBride-Chang, & Petersen, 1996; Sprenger-Charolles, Colé, Lacert, & Serniclaes,  
20 2000; Stanovich, Siegel, & Gottardo, 1997). These studies consistently found that  
21 around a third of the dyslexic sample was constituted of individuals for whom  
22 only one reading sub skill (pseudo-word or exception word reading) was outside  
23 the range of the performance of chronological age matched control children.  
24 These studies also emphasised that most dyslexic children showed stronger  
25 impairment on one sub skill than the other, thus exhibiting 'soft-signs' of either  
26 phonological or surface dyslexia. These findings clearly document the existence  
27 of individual differences in the reading behaviour of the dyslexic population, but  
28 they provide no insight on the cognitive factors underlying these different  
29 behavioural profiles.

30 Extending the phonological hypothesis, the severity hypothesis (Griffiths &  
31 Snowling, 2002; Snowling, Goulandris, & Stackhouse, 1994) postulates that  
32 differences in the reading profiles of dyslexic children depend on the severity of  
33 the phonological deficit, combined with variations in general processing  
34 resources, reading experience (print exposure) and compensatory strategies.  
35 The severity hypothesis is compatible with data showing that some dyslexic  
36 children specifically impaired on irregular words are also mildly impaired in  
37 phonological processing (Bailey, Manis, Pedersen & Seidenberg, 2004; Castles  
38 *et al.*, 1999; Sprenger-Charolles *et al.*, 2000; Stanovich *et al.*, 1997). However, in  
39 addition to the case studies mentioned above, other data are less consistent with  
40 this account. For example, Manis *et al.* (1996) and Curtin, Manis, and Seidenberg  
41 (2001) found that the phonological dyslexia subgroup had difficulty analysing  
42 the phonemic structure of spoken words or pseudo-words whereas the surface  
43 dyslexia subgroup did not differ from normal readers matched on chronological  
44 age on this task. In addition, Castles *et al.* (1999) showed that their two groups of  
45 surface and phonological dyslexics had comparable low scores on the print  
46 exposure measure they used (see also Manis, Seidenberg, & Doi, 1999). The  
47 authors suggested that low print exposure would result in a phonological  
48 dyslexic pattern in poor readers with a severe phonological deficit but in the  
49 surface dyslexia pattern in children with a milder phonological deficit. However,

1 print exposure is known to primarily affect exception word reading (Griffiths &  
2 Snowling, 2002); on the other hand, phonological deficits primarily affect pseudo-  
3 word reading, although they also prevent the normal acquisition of lexical  
4 orthographic knowledge (Share, 1995, 1999). Accordingly, one would expect that  
5 poor print exposure associated with a severe phonological deficit should result in  
6 poor reading of both exception words and pseudo-words. Finally, reading  
7 theories do not predict that mild phonological impairments should result in  
8 specific difficulties in exception word reading. Indeed, in both dual-route  
9 (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, &  
10 Ziegler, 2001) and PDP connectionist (Harm and Seidenberg, 1999; Plaut,  
11 McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989)  
12 models, phonological deficits have far more impact on pseudo-word reading  
13 than on exception word reading. Harm and Seidenberg (1999) clearly showed in  
14 a simulation that a mild phonological deficit affected pseudo-word reading but  
15 not exception word reading; severe phonological deficits resulted in a mixed  
16 profile, with impairments in both pseudo-word and exception word reading.  
17 Overall, it appears that neither mild phonological deficits alone nor poor print  
18 exposure alone can account for the profile of poorer exception word reading  
19 relative to pseudo-word reading. Therefore, the question remains open as to  
20 whether the inability of surface dyslexic children to encode the orthographic  
21 form of words could be explained by a non-phonological cognitive disorder.

22 However, except for case JAS (Goulandris & Snowling, 1991) whose surface  
23 dyslexia was associated with poor visual memory, most case and group studies  
24 have failed to find any specific cognitive impairment that may be responsible for  
25 a selective disorder in exception word reading. Moreover, the performance of  
26 surface dyslexic readers has consistently been found to be similar to that of  
27 younger reading-age matched controls. Consequently, it has been assumed that  
28 the surface dyslexia profile stems from a general developmental delay in overall  
29 reading ability (Manis *et al.*, 1996; Sprenger-Charolles *et al.*, 2000; Stanovich *et al.*,  
30 1997). Obviously, this interpretation does not apply to those cases who  
31 demonstrate a strict dissociation characterized by poor exception word reading  
32 but normal pseudo-word reading. Moreover, although the similarity between the  
33 reading performance of dyslexic readers and younger controls was clearly  
34 established in terms of accuracy, very few studies have investigated whether  
35 dyslexic children and younger controls produce comparable error patterns. Thus,  
36 contrary to the delay hypothesis, the performance of dyslexic children may be  
37 qualitatively different from that of younger controls. This hypothesis was  
38 supported by Martinet and Valdois (1999) who showed that surface dyslexic  
39 children produced proportionally more phonologically plausible errors than  
40 reading-age matched children, even though their overall scores on exception  
41 word spelling did not differ; as a matter of fact, the proportion of phonologically  
42 accurate errors produced by these children was comparable to that of  
43 chronological age-matched controls (see however Curtin *et al.*, 2001). Moreover,  
44 similarity of performance with younger control children tells us 'nothing about  
45 the causes of developmental dyslexia' (Bryant & Impey, 1986, p. 124) and does  
46 not rule out the possibility that developmental surface dyslexia derives from a  
47 specific underlying deficit. In their simulation of this disorder, Harm and  
48 Seidenberg (1999) showed that the delay characteristic of surface dyslexia could  
49 arise from several causes including a disorder at the level of visual processing

1 (see also, Seidenberg, 1992) or a resource limitation affecting the capacity of the  
2 network to encode dependencies that span an appropriate number of letters.  
3 Although such interpretations are not entirely supported by empirical data  
4 (Valdois *et al.*, 2003), they at least demonstrate that a specific cognitive  
5 impairment affecting the normal visual processing of the entire orthographic  
6 sequence could in principle result in surface dyslexia. This visual processing  
7 deficit hypothesis will be considered in more depth in the following section.

8 In sum, the hypothesis that a specific cognitive deficit affecting phonological  
9 processing results in reading acquisition disorders is well supported on both  
10 empirical and theoretical grounds. However, the present critical review suggests  
11 that the phonological deficit hypothesis cannot account for the surface dyslexia  
12 profile characterized by poor exception word reading relative to pseudo-word  
13 reading. Neither can it explain reported cases of developmental dyslexia without  
14 associated phonological deficits. In addition, the proposal that the surface  
15 dyslexia pattern may be the mere consequence of insufficient reading experience  
16 or of a general reading delay is not entirely supported empirically. It follows that  
17 the surface dyslexia pattern may actually reflect a non-phonological core  
18 disorder. In the next section, we will review other deficits which have been  
19 found to be associated with developmental dyslexia and will examine whether  
20 they could be causally related to reading acquisition disorders.

21

## 23 CURRENT ALTERNATIVE HYPOTHESES

25

### 25 **Low-Level Auditory Deficits**

27 Several alternative hypotheses have been proposed as an attempt to identify the  
28 cognitive or biological bases of specific reading disability. At the cognitive level, a  
29 general non-linguistic auditory temporal deficit was proposed by Tallal and her  
30 colleagues. This hypothesis was supported by studies showing that dyslexics  
31 performed below normal readers on auditory temporal order perception tasks  
32 (Tallal, 1980; Tallal *et al.*, 1996; Tallal, Miller, & Fitch, 1993). However, the  
33 hypothesis of a general non-linguistic auditory deficit is highly debated  
34 (Vellutino *et al.*, 2004, for a review). One potential problem is that the auditory  
35 impairment of dyslexic children seems limited to the perception of speech  
36 sounds (Breier, Fletcher, Foorman, & Gray, 2002; Farmer & Klein, 1995; Merzenich  
37 *et al.*, 1996; Mody, Studdert-Kennedy, & Brady, 1997; Serniclaes, Sprenger-  
38 Charolles, Carré, & Démonet, 2001); this raises the possibility that impairments in  
39 speech perception tasks may be the consequence rather than the cause of a  
40 phonological deficit (Ramus, 2004). In addition, even though poor auditory  
41 processing skills are frequently associated with poor phonological awareness in  
42 dyslexia, this is not always the case; that is, some dyslexic individuals have  
43 phonological deficits without auditory processing deficits (Ramus *et al.*, 2003).  
44 This casts doubts as to whether the auditory processing hypothesis can be seen as  
45 a core deficit responsible for developmental dyslexia independently of the  
46 phonological disorder. Be this as it may, the auditory processing deficit  
47 hypothesis does not seem to be any more suited to account for developmental  
48 surface dyslexia than the phonological deficit hypothesis. Although poor  
49 auditory processing skills affect pseudo-word reading (Witton *et al.*, 1998), they

1 do not seem to contribute to the performance in exception word reading  
(Baldeweg, Richardson, Watkins, Foale, & Gruzelier, 1999).

3

## 5 **Low-Level Visual Deficits**

7 Low-level visual processing deficits have also been reported in developmental  
dyslexia and they have been viewed as potential sources of reading acquisition  
9 disorders. In particular, many studies of developmental dyslexia have reported  
associated deficits in the transient visual system, manifesting themselves by  
11 impaired contrast sensitivity (Livingstone, Rosen, Drislane, & Galaburda, 1991;  
Lovegrove, Garzia, & Nicholson, 1990; Lovegrove, Martin, & Slaghuis, 1986;  
13 Stein, 2003; Stein & Fowler, 1993) and motion perception (Cornelissen,  
Richardson, Mason, Fowler, & Stein, 1995; Demb, Boynton, & Heeger, 1998;  
15 Eden *et al.*, 1996; Talcott, Hansen, Assoku, & Stein, 2000). These visual deficits in  
dyslexia have been linked to functional anomalies in the magnocellular visual  
17 subsystem (Livingstone *et al.*, 1991; Lovegrove *et al.*, 1986; Eden *et al.*, 1996; see  
Skottun, 2000 for a critical review). Several models stress the importance of the  
19 visual magnocellular system in text reading (Breitmeyer, 1980; Chase, 1996;  
Chase, Ashourzadeh, Kelly, Monfette, & Kinsey, 2003; see also Skottun & Parke,  
21 1999, for a critical review). Furthermore, performance on magnocellular low-level  
visual tasks is correlated to pseudo-word reading (Talcott, Hansen, & Stein, 1998;  
23 Witton *et al.*, 1998) and is typically associated to phonological disorders (Slaghuis,  
Lovegrove, & Davidson, 1993; Van Ingelghem, Van Wieringen, Wouters,  
25 Vandebussche, & Onghena, 2001; Witton *et al.*, 1998). To account for the co-  
occurrence of phonological and low-level visual deficits, Stein and collaborators  
27 later proposed a more general amodal version of the magnocellular theory (Stein  
& Walsh, 1997; Stein & Talcott, 1999; Stein, 2001, 2003). This theory postulates that  
29 magnocellular temporal processing deficits result in basic visual and auditory  
processing impairments. The impairment in low level auditory transient  
31 processing would entail problems with phonological analysis which remains  
the proximal source of the reading problem. In sum, although some data suggest  
33 that a visual magnocellular disorder might contribute to poor reading  
performance (Chase *et al.*, 2003; Vidyasagar, 1999), there is no evidence showing  
35 that low-level visual processing problems contribute to the reading outcome of  
dyslexic children, independently of their phonological skills. In addition,  
37 magnocellular deficits have been reported in the context of phonological dyslexia  
but not in surface dyslexia (Borsting *et al.*, 1996; Cestnick, 2001; Cestnick &  
39 Coltheart, 1999; Spinelli *et al.*, 1997), which leaves open the question of the origin  
of reading difficulties in this dyslexia sub-type.

41

## 43 **Cerebellar Deficits**

45 Similarly, the cerebellar theory of dyslexia (Nicolson & Fawcett, 1990; Fawcett &  
Nicolson, 2004; Nicolson, Fawcett, & Dean, 2001) postulates a close link between  
47 phonological disorders and reading acquisition disorders. Given the role of the  
cerebellum in motor control and automatisaion, a cerebellar dysfunction would  
affect speech articulation; this would lead to poor phonological representations  
49 and poor phonological skills which would be directly responsible for reading



1 acquisition disorders. The cerebellar deficit hypothesis is thus presented as a  
2 biological explanation of the co-occurrence of cognitive phonological deficits and  
3 low-level motor impairments in developmental dyslexia. As there is no evidence  
4 for a specific contribution of motor or automatised problems to developmental  
5 dyslexia, the causal nature of the link between cerebellar dysfunctions and  
6 reading disorders is now widely debated (Wimmer, Mayringer, & Landerl, 1998;  
7 Wimmer, Mayringer, & Raberger, 1999; Ramus, Pidgeon, & Frith, 2003).

#### 9 *Rapid automatised naming deficits*

10 Contrary to the hypotheses discussed above, the double-deficit hypothesis  
11 explicitly postulates that a phonological deficit and a deficit in rapid automatised  
12 naming of letters or symbols represent two independent sources of reading  
13 disability (Wolf & Bowers, 1999; Wolf *et al.*, 2002). A growing number of data  
14 point to naming speed deficits in developmental dyslexia (e.g., Denckla & Rudel,  
15 1976; Ho, Chan, Tsang, & Lee, 2002; Wimmer, Mayringer, & Landerl, 2000; Wolf &  
16 Bowers, 1999) and suggest that rapid naming abilities contribute to reading  
17 acquisition even after controlling for phonological skills (Manis, Doi, & Bhadha,  
18 2000; Manis *et al.*, 1999; Ho, Chan, Lee, Tsang, & Luan, 2004; see Wolf & Bowers,  
19 1999, for a review; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997, for a  
20 methodological critique). Moreover, rapid naming appears to be more strongly  
21 related to reading speed and measures of orthographic knowledge than  
22 phonological skills (Manis *et al.*, 1999; Bowers, Sunseth, & Golden, 1999).  
23 However, rapid naming measures and phonological skills measures are  
24 significantly correlated (Bowers, Sunseth, & Newby-Clark, 1998) and, contrary  
25 to the independence hypothesis, dyslexic children tend to exhibit both a  
26 phonological and a naming speed disorder (Wolf *et al.*, 2002). It remains however  
27 that some dyslexic children exhibit a selective deficit in naming speed and that  
28 naming speed makes a specific contribution to reading acquisition disorders,  
29 particularly with respect to the acquisition of lexical orthographic knowledge.  
30 Thus, the rapid naming deficit hypothesis appears as a plausible alternative  
31 candidate to explain cases of developmental dyslexia without associated  
32 phonological disorders and with selective exception word reading (and spelling)  
33 disorders. However, further investigations are required to specify the impaired  
34 mechanism(s) which could underlie both naming speed deficits and reading  
35 acquisition disability. The hypothesis that inadequate temporal integration of  
36 letter identities might be responsible for this co-occurrence of disorders is under  
37 debate (Vellutino *et al.*, 2004) and will be discussed below in relation with the  
38 visual attentional hypothesis.

#### 41 VISUAL ATTENTIONAL DISORDERS IN DEVELOPMENTAL 42 DYSLEXIA

43 Several lines of evidence indicate that visual attentional difficulties are correlated  
44 with developmental dyslexia. First, several studies have shown that dyslexic  
45 children are impaired in tasks in which they have to search for a target among  
46 distracters. More specifically, Marendaz, Valdois, and Walch (1996) showed that  
47 dyslexic children were impaired when the task required serial attentional search  
48

1 but unimpaired in parallel search. Marendaz *et al.* (1996) proposed that this visual  
2 search deficit could result either from a perceptive grouping dysfunction  
3 (reducing the number of items simultaneously processed during serial search)  
4 or from a problem in the shifting of attention. Similar findings were reported by  
5 Iles, Walsh, and Richardson (2000), who were also able to show that the visual  
6 attentional deficit was restricted to a subgroup of dyslexic children with  
7 associated magnocellular visual processing difficulties. Severe serial search  
8 disorders were also reported in a case of surface dyslexia without associated  
9 phonological problems (Valdois, 1996). In addition, several studies have shown  
10 that dyslexic children have a defective spatial orienting of visual attention  
11 (Brannan & Williams, 1981; Facoett *et al.*, 2003; Facoetti & Molteni, 2001; Facoetti,  
12 Turatto, Lorusso, & Mascetti, 2001; Facoetti, Paganoni, & Lorusso, 2000). They  
13 demonstrate an asymmetric distribution of attentional resources across the visual  
14 field, as shown by mild left inattention in cue-target reaction time tasks and  
15 abnormally high sensitivity in the right visual field (Facoetti & Molteni, 2001;  
16 Facoetti & Turatto, 2000; Hari, Renvall, & Tanskanen, 2001). In line with these  
17 findings, Valdois, Gerard, Vanault, and Dugas (1995) described a case of  
18 developmental visual dyslexia who demonstrated a right attentional bias when  
19 processing briefly presented pseudo-words. Geiger, Lettvin, and Zegarra-Moran  
20 (1992) also showed that dyslexic children were abnormally good at processing  
21 eccentrically located letters in the right visual field, suggesting a difficulty in  
22 inhibiting peripheral information (in the direction of reading) and focus attention  
23 in the centre of the gaze (see also, Rayner, Murphy, Henderson, & Pollatsek,  
24 1989). Accordingly, recent data suggest that dyslexic people distribute attentional  
25 resources more diffusely because of difficulties in narrowing their attentional  
26 focus (Facoetti *et al.*, 2000); they display slower capture of attention (Facoetti *et al.*,  
27 2003) but once their attention is engaged it cannot easily disengage (Hari, Valta, &  
28 Utela, 1999). A growing number of data therefore point to a visual attentional  
29 disorder which could contribute to the reading impairment of dyslexic children.  
30 Attentional disorders affecting speed in parallel processing (Yap & van der Leij,  
31 1993) might interfere with letter order encoding, leading to letter sequence errors  
32 and confusions between visually similar words. Indeed, there are case reports of  
33 dyslexic children without phonological deficits who are more prone to such  
34 localisation errors (McCloskey & Rapp, 2000; Romani *et al.*, 1999). The relation  
35 between visual attention and reading acquisition was further explored by Casco,  
36 Tressoldi, and Dellantonio (1998) in non selected children engaged in a  
37 cancellation task. They found that the lowest the performance in the cancellation  
38 task, the slower the reading rate and the higher the number of visual errors. Thus,  
39 children's performance in a search task involving selective attention appears to  
40 be related to their reading performance. However, this relation was established  
41 without controlling for the influence of phonological skills, thus undermining the  
42 specific role of selective attention in reading acquisition. This is all the more  
43 detrimental that other data suggest that the spatial attention deficit in dyslexia is  
44 not restricted to the visual modality but also extends to auditory information  
45 processing (Facoetti *et al.*, 2003; Hari & Kiesilä, 1996). Accordingly, Hari and  
46 Renvall (2001) proposed the 'sluggish attentional shifting' (SAS) theory of  
47 dyslexia according to which sluggish attentional capture and prolonged  
48 attentional dwell time would impair processing of rapid stimulus sequences in  
49 all sensory modalities. According to the SAS theory, visual attentional deficits

1 should typically co-occur with phonological processing and phonological  
2 awareness deficits in developmental dyslexia. Although the nature of the visual  
3 attention deficit highlighted in the previous studies should affect reading  
4 performance, it remains to be shown that this deficit does contribute to the  
5 reading performance of dyslexic children, independently of their phonological  
6 skills.

7

## 9 ARE VISUAL ATTENTIONAL AND PHONOLOGICAL DEFICITS 10 INDEPENDENT PREDICTORS OF READING ACQUISITION 11 DISORDERS?

13 We now turn to our own research which aims to demonstrate that visual  
14 attentional and phonological disorders can dissociate, that visuo-attentional skills  
15 predict reading performance independently of phonological skills, and that a  
16 visuo-attentional deficit thus constitutes a plausible alternative core disorder in  
17 developmental dyslexia. We first present two case studies which show a  
18 remarkable dissociation in their phonological versus visuo-attentional skills. We  
19 later demonstrate that the results observed in these case studies generalise to a  
20 larger sample of French- and English-speaking children. But, beforehand, we  
21 present some details of the tests that we used to assess dyslexic children, in  
22 particular with respect to their visuo-attentional abilities.

23

### 25 **Assessment of Phonological and Visuo-Attentional Deficits**

27 Our general methodology has been to submit dyslexic children, chronological-  
28 age (CA) matched controls and reading-age (RA) matched controls to a  
29 comprehensive battery of tests aimed to assess reading and spelling abilities,  
30 phonological skills and visuo-attentional skills. We present the visuo-attentional  
31 tasks in more detail here, because, to our knowledge, they have not been used  
32 before to assess visuo-attentional processing in developmental dyslexia.

33 To assess visuo-attentional abilities, we used two tasks of whole and partial  
34 letter-string report that were created by Averbach and his colleagues (Averbach &  
35 Coriell, 1961; Averbach & Sperling, 1968) to study the processing of letter  
36 information perceived during a single fixation. Since then, the whole and partial  
37 report procedures have been used in a wide range of visual attention studies and  
38 with several variants to assess both normal (Dixon, Gordon, Leung, & Di Lollo,  
39 1997; Giesbrecht & Dixon, 1999; Hagenaar & Van der Heijden, 1995; Mewhort,  
40 Campbell, Marchetti, & Campbell, 1981) and impaired (Arguin & Bub, 1993;  
41 Duncan *et al.*, 1999; Duncan *et al.*, 2003; Habekost & Bundesen, 2003; Rapp &  
42 Caramazza, 1991) visual attention processing. In our studies, the whole report  
43 task consisted in showing the participants arrays of five letters (e.g., R H S D M)  
44 and asking them to report the identities (not locations) of as many letters as they  
45 could. To avoid eye movements, each horizontally centred letter string remained  
46 on the screen for only 200 ms. In the partial report condition, the participants  
47 were shown similar arrays of five letters but were asked to report a single cued  
48 letter on each trial. The cue, a vertical bar, appeared at the offset of the letter  
49 string for 50 ms and indicated the location of the letter to be reported.

1 The whole report task is a classical experimental procedure in the study of  
2 attentional capacity. It provides an estimate of the total amount of information  
3 that can be extracted from a brief visual display and encoded in visual short-term  
4 memory (Bundesen, 1998). The partial report task measures how the total  
5 attentional capacity is distributed across letters in the string. The exogenous  
6 attentional system is used to select relevant information. When the cue is  
7 presented for a short time immediately after the letter display, as in our studies,  
8 performance essentially reflects visual feature information processing before  
9 decay in iconic memory. Even though they both involve reporting verbal  
10 material, the whole and partial report tasks cannot be considered as verbal or  
11 verbal short-term memory tasks. Consistent with this view, it has been shown  
12 that performance in the whole report task is barely affected by a concurrent  
13 verbal short-term memory task (Scarborough, 1972). In addition, the patterns of  
14 errors produced in the whole report task reflects visual rather than verbal  
15 confusions (Wolford, 1975). In partial report, a single letter has to be reported, so  
16 it is unlikely that verbal short term memory is a major factor. Indeed, Dixon and  
17 Shedden (1993) showed that partial report is only minimally affected by  
18 articulatory suppression. Thus, whole and partial report tasks are considered  
19 as primarily reflecting visual attention and visual short-term memory compo-  
20 nents. An extensive use of these tasks allowed Sperling to propose a theory of  
21 visual-information processing (Sperling, 1970) and, more recently, a computa-  
22 tional model of attention dynamics (Shih & Sperling, 2002). These tasks were also  
23 used to validate theories specifying visual attention mechanisms and their timing  
24 (Bundesen, 1990; 1998; for a review, see Gegenfurtner & Sperling, 1993). The  
25 whole and partial report tasks therefore appear quite appropriate to investigate  
26 visual attention skills in developmental dyslexia.

27

### 29 **Case Studies Showing a Dissociation Between Phonological and 30 Visuo-Attentional Skills**

31 Valdois *et al.* (2003) assessed the phonological and visual attentional skills of two  
32 teenagers who exhibited contrasted reading profiles: Laurent had a phonological  
33 dyslexia profile and Nicolas a surface dyslexia profile. They were submitted to a  
34 comprehensive battery of metaphonological tasks including sound categorisa-  
35 tion, phoneme and syllable deletion, phoneme segmentation and spoonerisms.  
36 When compared to CA matched controls, Laurent performed outside the normal  
37 range on all phonological awareness tasks. His performance was low even as  
38 compared to children matched on reading age. Laurent also showed poor formal  
39 verbal fluency and poor verbal short-term memory. Thus, Laurent's dyslexia was  
40 clearly accompanied by a general phonological deficit. In marked contrast,  
41 Nicolas's performance was above average as compared to children of the same  
42 chronological age. Nicolas's excellent metaphonological skills, his good pseudo-  
43 word reading and spelling, his phonologically accurate reading and spelling  
44 errors, his good verbal fluency and verbal short-term memory provided strong  
45 evidence that his difficulties in exception word reading and spelling were not  
46 due to an underlying phonological disorder.

47 In addition, Laurent and Nicolas were submitted to the whole and partial  
48 report tasks described above. In both tasks, Laurent's performance was well  
49 within the normal range of CA controls, whatever the position of the letters in the

1 string. Thus, Laurent showed good visual attentional skills despite poor  
2 phonological processing skills. In sharp contrast, Nicolas was able to report  
3 none of the 5-letter strings as a whole in the whole report condition, a score  
4 outside the range of both CA and RA controls. He further demonstrated a  
5 strong positional effect on this task. His ability to report the last two letters of the  
6 string was particularly impaired and his performance on these two positions was  
7 even worse than that of younger children matched on reading age. A quite  
8 similar pattern emerged in partial report with a lower performance than  
9 RA controls on the two last letters of the string. Nicolas's poor performance  
10 in both the whole report and partial report tasks provide evidence that he  
11 suffered from a visual attentional impairment despite good phonological  
12 skills. Valdois *et al.* (2003) also demonstrated that Nicolas exhibited similar  
13 positional effects when reading briefly presented real words, thus suggesting a  
14 relationship between the visual attentional disorder revealed in the report tasks  
15 and his reading performance. This study shows that phonological and visual  
16 attentional disorders can dissociate in developmental dyslexia. It further suggests  
17 that both disorders might independently contribute to impaired reading  
18 performance.

19

20

### 21 **Generalizing the Findings to Larger Samples in Different Languages**

22 To support the hypothesis that phonological and visual attentional disorders  
23 constitute two independent sources of reading impairment, Bosse, Tainturier, and  
24 Valdois (2004; see also Valdois & Bosse, 2004; Bosse, Tainturier, & Valdois,  
25 submitted) conducted two group studies on large samples of French and British  
26 developmental dyslexic children. The French study assessed 68 dyslexic children,  
27 whose performance was compared to that of two control groups matched on  
28 chronological age and reading age. All the participants were administered tasks  
29 of regular word, exception word and pseudo-word reading, tasks of phoneme  
30 awareness (phoneme deletion, phoneme segmentation and acronym) and the two  
31 visual-attentional tasks of whole and partial report. Both correlation and factor  
32 analyses showed that phonological and visual attentional scores were unrelated  
33 measures tapping independent cognitive mechanisms. Using the factorial scores  
34 derived from the principal component analysis in a hierarchical regression  
35 analysis, Bosse *et al.* (2004) found that both the phonological and visual  
36 attentional processing skills were significant and independent predictors of the  
37 dyslexic children reading scores. In addition, attentional processing skills  
38 accounted for a substantial amount of unique variance in both irregular word  
39 and pseudo-word reading, as did phonological skills.

40 Furthermore, the analysis of the distribution of phonological and visual  
41 attentional factorial coefficients revealed that dyslexic participants could belong  
42 to one of four distinct subgroups: a selective phonological deficit subgroup, a  
43 selective visual attentional deficit subgroup, a mixed subgroup showing both  
44 deficits, and finally a group of children who did not show abnormal performance  
45 on either phonological or visuo-attentional measures. More interestingly, most  
46 French dyslexic children (63%) were classified as having a selective phonological  
47 or visuo-attentional cognitive disorder, as expected under the hypothesis that the  
48 two deficits are independent sources of reading acquisition disorders.

49

1 A replication of the French study was conducted with British children in order  
2 to confirm previous findings while controlling for additional potentially  
3 confounded variables. The British participants were administered tests of  
4 intellectual efficiency, semantic verbal fluency and vocabulary level, in addition  
5 to the reading, metaphonological and visual attentional tasks. The results  
6 revealed that the contribution of visual attentional skills to reading performance  
7 remained even after controlling for the children's level of intellectual efficiency,  
8 verbal fluency, and vocabulary in addition to metaphonological skills. Further-  
9 more and as previously, most English dyslexic children (60%) were found to  
10 exhibit a single phonological or visual attentional disorder.

11 Overall, these data show that visual attentional disorders and phonological  
12 disorders dissociate in a good number of dyslexic children. Critically, they also  
13 demonstrate that phonological and visual attentional abilities make independent  
14 contributions to dyslexic reading performance. Thus, the visual attentional  
15 disorder appears as a plausible second core deficit in developmental dyslexia  
16 since it can predict dyslexic reading in the absence of a phonological deficit. In  
17 the next section, we will see that the hypothesis of a causal relationship between  
18 visual attentional problems and reading acquisition disability also has theoretical  
19 support.

21

## 22 A THEORETICAL ACCOUNT OF THE ROLE OF VISUAL 23 ATTENTIONAL PROCESSING IN SKILLED READING AND 24 READING ACQUISITION

25

26 Although models of eye movement control in reading (Reichle, Rayner, &  
27 Pollatsek, 2003) and some models of word recognition (Behrmann, Moscovitch, &  
28 Mozer, 1991; Laberge & Samuels 1974; Laberge & Brown, 1989) emphasise the  
29 role of visual attention, most reading theories do not specify the attentional  
30 processes involved in the visual analysis of letter strings, assuming that they are  
31 peripheral mechanisms that are not an integral part of the reading process  
(Coltheart *et al.*, 1993; Coltheart *et al.*, 2001; Harm & Seidenberg, 1999; Plaut *et al.*,  
32 1996; Seidenberg & McClelland, 1989).

33 On the contrary, the connectionist multi-trace model of polysyllabic word  
34 reading (Ans, Carbonnel, & Valdois, 1998) provides a theoretical description of  
35 how visual attentional processes operate in reading and how they can lead to  
36 specific reading disorders when damaged. The model postulates that reading can  
37 take place through two types of reading procedures, a global and an analytic one.  
38 The two procedures differ in the kind of visual attentional and phonological  
39 processing they involve. Global processing always proceeds first, the analytic  
40 procedure only coming into play if global processing has failed. An essential  
41 feature of this model is the inclusion of a visual attentional window (VAW)  
42 through which information from the orthographic input is extracted. The two  
43 reading procedures differ in the size of the VAW involved. In global reading  
44 mode, the VAW extends over the whole sequence of the input letter-string. When  
45 shifting in analytic mode, the VAW narrows down to focus attention on the first  
46 part of the orthographic input. Analytic processing then proceeds through a  
47 narrow VAW which shifts from left to right, focalising attention on the different  
48 parts of the input successively. Letters within the VAW are maximally activated  
49

1 and processed in parallel whereas letters outside the window are only minimally  
2 activated or not at all. In the analytic mode, a phonological output is generated  
3 for each group of letters that fall within the VAW, and this process is sequentially  
4 reiterated until the VAW has reached the end of the letter string.

5 The two reading procedures also differ with respect to phonological  
6 processing. In global processing, the entire phonological output is generated in  
7 a single step. In analytic processing, phonological outputs corresponding to each  
8 focal sequence (i.e. letters within the VAW) are successively generated and have  
9 to be maintained in short-term memory in order to remain available at the end of  
10 processing. In global mode, phonological information emerges from the  
11 activation of word traces in memory whereas sublexical memory traces are  
12 recruited in the analytic mode. Although the two procedures are not *a priori*  
13 dedicated to the processing of a particular type of letter string (real word or  
14 pseudo-word), most familiar words are processed as a whole by the network,  
15 whereas global processing typically fails for pseudo-words which are analytically  
16 processed.

17 The network was tested for its ability to account for acquired dyslexia  
18 following specific damage. Ans, Carbonnel, and Valdois (1998) demonstrated  
19 that a moderate reduction of the VAW size prevents reading in global mode. This  
20 reduction simulated a surface dyslexia profile, with a selective disruption of  
21 irregular word reading giving rise to regularization errors. Performance was  
22 more severely impaired following a more severe reduction of the VAW. Irregular  
23 words continued to be the most affected class of items, but the number of errors  
24 increased on both regular words and pseudo-words. It was further assumed that  
25 a very severe reduction of the VAW would result in the profile of letter by letter  
26 reading thus affecting the network ability to read all types of letter-strings. In  
27 contrast, acquired phonological dyslexia was interpreted as resulting from an  
28 independent disorder affecting phonological processing.

29 The multi-trace model has not yet been adapted to simulate reading acquisition  
30 and developmental dyslexia. Nonetheless, it provides new insights on the way  
31 selective visual attentional or phonological deficits might impact on reading  
32 acquisition and result in patterns of developmental surface or phonological  
33 dyslexia. In the network, each new word is learned in both global and analytic  
34 mode. In global mode, a new word memory trace is created during reading each  
35 time the entire orthographic input and the entire phonological output of the input  
36 item are simultaneously available. It follows that a new word trace can be created  
37 either following global processing (typically with a supervisor) or when the  
38 assembled phonology of the letter string is maintained in short term memory at  
39 the end of analytic processing. Thus, we propose that normally developing  
40 beginning readers acquire new lexical knowledge in two situations: (1) when  
41 they are provided with the entire phonological correspondence of the  
42 orthographic sequence or (2) after having generated the phonological sequence  
43 themselves through analytic processing, provided that they can also relate the  
44 entire phonological sequence with the entire input orthographic sequence.  
45 Hence, reading in analytic mode would also contribute to the development of  
46 lexical knowledge, an hypothesis which is in line with the self-teaching  
47 hypothesis proposed by Share (1995, 1999, 2004). In the model, learning in  
48 analytic mode also consists in creating memory traces which encode the  
49 relationship between simultaneously presented orthographic and phonological

1 sublexical segments. Similarly, it can be assumed that beginning readers acquire  
2 sublexical knowledge each time they are able to parse a whole phonological  
3 sequence into relevant phonological units together with processing in parallel the  
4 letters of the corresponding sublexical orthographic units.

5 Within this theoretical framework, a phonological deficit affecting the  
6 acquisition of sublexical knowledge and/or the maintenance of phonological  
7 information in short-term memory should affect analytic processing more than  
8 global processing. Thus, phonological deficits are expected to interfere primarily  
9 with pseudo-word reading (developmental phonological dyslexia profile).  
10 However, a purely phonological disorder could also interfere with the self-  
11 teaching mechanism which contributes to the acquisition of new word traces.  
12 This could in turn affect global processing, leading to a mixed dyslexia pattern  
13 characterized by poor pseudo-word and irregular word reading.

14 Furthermore, the model predicts that a visual attentional disorder reducing the  
15 number of letters that can be identified in parallel could also lead to  
16 developmental dyslexia, albeit of a different type. Indeed, a reduction of the  
17 VAW through which information from the orthographic input is extracted should  
18 result in an inability to create word traces, interfering with the normal  
19 development of the global reading procedure. This difficulty to establish lexical  
20 knowledge should be primarily detrimental to irregular word reading, leading to  
21 a pattern of developmental surface dyslexia. Regular word and pseudo-word  
22 reading should remain unaffected as far as the VAW is large enough to process  
23 groups of letters that correspond to relevant orthographic units. A more severe  
24 reduction in the size of the VAW would end up affecting regular word and  
25 pseudo-word reading as well. The model therefore predicts that a selective visual  
26 attentional impairment should result in a selective exception word reading  
27 disorder or in a mixed disorder affecting both exception word and pseudo-word  
28 reading, depending on the severity of the visuo-attentional deficit.

## 31 CONCLUSION

32 Notwithstanding the obvious importance of phonological abilities in reading  
33 acquisition and the clear relationship between phonological disorders and  
34 dyslexia, the phonological hypothesis fails to give a fully satisfactory account of  
35 the variability in dyslexic reading profile and associated deficits. In this paper, we  
36 have argued that a visual attentional deficit constitutes a plausible second core  
37 deficit in dyslexia. Using data from both single case and group studies, we have  
38 endeavoured to demonstrate that phonological and visual attentional deficits are  
39 independent sources of reading acquisition disorders. Our case studies further  
40 showed that a visual attentional disorder without a phonological disorder can  
41 produce the pattern of developmental surface dyslexia, which has been  
42 particularly difficult to account for within the phonological hypothesis. In  
43 contrast, the pattern of phonological dyslexia was found to be associated with a  
44 phonological disorder in the absence of visual attentional problems suggesting  
45 that a phonological disorder primarily affects pseudo-word reading.

46 The multi-trace memory model of polysyllabic word reading (Ans *et al.*, 1998)  
47 provides a useful framework to try to explain the respective roles of phonological  
48 and visual attentional disorders on reading acquisition difficulties. Surface  
49



1 dyslexia may be seen as arising from a reduction of the size of a visual attentional  
2 window through which information is extracted from the orthographic sequence  
3 to be read. Irregular words are particularly vulnerable to such a reduction  
4 because disambiguating their pronunciation requires distributing attention over  
5 the whole orthographic sequence. As for selective disorders in pseudo-word  
6 reading (phonological dyslexia profile), the multi-trace model proposes that they  
7 result from an independent phonological disorder affecting the establishment of  
8 sublexical memory traces and/or the maintenance of phonological information in  
9 verbal short term memory. However, the model further predicts that mixed  
10 reading profiles can result from either a selective phonological deficit, a selective  
11 visual attentional deficit, or a combination of both. Indeed, although less  
12 orthographic information is required for accurate pseudo-words processing, a  
13 severe visual attentional impairment that would limit orthographic encoding to,  
14 say, one or two letters at time would clearly affect the ability of the system to  
15 process multi-letter graphemes and contextual graphemes, thus affecting  
16 pseudo-word reading as well, at least in languages with relatively deep  
17 orthographies such as English or French. In line with the self-teaching theory  
18 of Share (1995), a phonological impairment is also expected to affect the  
19 establishment of lexical orthographic knowledge on top of pseudo-word reading  
20 abilities. Obviously, a double deficit would result in poor performance on both  
21 irregular words and pseudo-words. Accordingly, the multi-trace memory model  
22 provides a straightforward explanation of the preponderance of mixed reading  
23 profiles in developmental dyslexia.

24 At this stage, it is important to ask how our proposal of a visual attentional  
25 disorder as a core deficit in dyslexia relates to other alternative accounts put  
26 forward in the literature. As mentioned earlier, rapid naming speed disorders  
27 might also provide an explanation of cases of developmental dyslexia without  
28 associated phonological disorders. However, the rapid automatised naming task  
29 for letters, which involves the rapid naming of visually presented non-  
30 pronounceable letter strings, no doubt shares common processes with the global  
31 report task we have been using to investigate visual attentional abilities. The two  
32 tasks probably assess a number of shared visual (or visual attentional) and  
33 phonological processes, although the report task alone evaluates the contribution  
34 of visual attentional skills to encoding of information in visual short term  
35 memory. We believe that this specific role of visual attentional processing is of the  
36 utmost importance in the establishment of lexical orthographic knowledge in  
37 long term memory. Further research is required to evaluate the relative  
38 contribution of performance on letter report tasks versus naming speed tasks  
39 to reading performance. Our prediction is that the visual attentional abilities  
40 assessed in the report tasks should be stronger predictors of irregular word  
41 reading accuracy and speed than performance in rapid naming tasks.

42 In addition, we have seen earlier that several other studies have argued for the  
43 existence of a visuo-attentional disorder in dyslexia, although they did not  
44 establish the specific contribution of this disorder to reading performance over  
45 and above that of associated phonological skills. At this stage, it is not entirely  
46 clear to what extent the report tasks that we have been using tap on the same  
47 mechanisms as other tasks used in the literature to investigate visual attentional  
48 skills. It can be assumed that left mini-neglect and preferential processing of  
49 stimuli in the right visual field should affect performance in the global and

1 partial report tasks. In the same way, difficulties to focalize attention might  
 2 prevent the normal shifting of selective attention in global report or the selective  
 3 processing of the cued letter in partial report. However, in supporting the  
 4 hypothesis of a visual attentional disorder dissociated from phonological  
 5 problems, our approach dissociates from the sluggish attention shifting theory  
 6 which assumes problems in processing rapid stimulus sequences in all sensory  
 7 modalities.

8 In conclusion, it seems increasingly unlikely that a phonological disorder is  
 9 the sole cause of reading acquisition difficulties in developmental dyslexia.  
 10 Indeed, several hypotheses for alternative deficits have been proposed in the  
 11 last few years to try to account for the variability in dyslexic reading profiles  
 12 and associated deficits. We have argued that a visual attentional disorder  
 13 is the underlying cause of reading acquisition disorders in a non-negligible  
 14 number of dyslexia cases. Importantly, we provided evidence that visual  
 15 attentional skills contribute to reading performance independently of phonolo-  
 16 gical skills.

17

## 19 References

- 21 Aguiar, L., & Brady, S. (1991). Vocabulary acquisition and reading ability. *Reading and*  
*Writing: An Interdisciplinary Journal*, 3, 413–425.
- 23 Ans, B., Carbonnel, S., & Valdois, S. (1998). A connectionist multi-trace memory model of  
 polysyllabic word reading. *Psychological Review*, 105, 678–723.
- 25 Arguin, M., & Bub, D. N. (1993). Single-character processing in a case of pure alexia.  
*Neuropsychologia*, 31(5), 435–458.
- 27 Averbach, E., & Coriell, A. S. (1961). Short-term memory in vision. *Bell Systems Technical*  
*Journal*, 40, 309–328.
- 29 Averbach, E., & Sperling, G. (1968). Short term storage of information in vision. In Haber  
 R. N. (Ed.), *Contemporary theory and research in visual perception* (pp. 196–211). New York:  
 Holt, Rinehart & Winston.
- 31 Baldeweg, T., Richardson, A., Watkins, S., Foale, C., & Gruzeliier, J. (1999). Impaired  
 auditory frequency discrimination in dyslexia detected with mismatch evoked potentials.  
 33 *Annals of Neurology*, 45, 495–503.
- Bailey, C. E., Manis, F. R., Pedersen, W. C., & Seidenberg, M. S. (2004). Variation among  
 35 developmental dyslexics: Evidence from a printed-word-learning task. *Journal of*  
*Experimental Child Psychology*, 87, 125–154.
- 37 Behrmann, M., Moscovitch, M., & Mozer, M.-C. (1991). Directing attention to words and  
 nonwords in normal subjects and in a computational model: Implications for neglect  
 dyslexia. *Cognitive Neuropsychology*, 8, 213–248.
- 39 Boder, E. (1973). Developmental dyslexia: A diagnostic approach based on three typical  
 reading-spelling patterns. *Developmental Medicine and Child Neurology*, 15, 663–687.
- 41 Borsting, E., Ridder, W. H., Dudeck, K., Kelley, C., Matsui, L., & Motoyama, J. (1996). The  
 presence of a magnocellular defect depends on the type of dyslexia. *Vision Research*, 36(7),  
 43 1047–1053.
- Bosse, M.-L., Tainturier, M.-J., & Valdois, S. *New insights on developmental dyslexia subtypes:*  
 45 *Evidence for multiple underlying deficits*, submitted.
- Bosse, M.-L., Valdois, S., & Tainturier, M.-J. (2004, 27–30 March). Phonological and visual  
 47 processing deficits in developmental dyslexia: A French and English group study.  
*Paper presented at the British dyslexia association international conference*, University of  
 49 Warwick, UK.

- 1 Bowers, P. G., Sunseth, K., & Golden, J. (1999). The route between rapid naming and  
reading progress. *Scientific Studies of Reading*, 3, 31–53.
- 3 Bowers, P. G., Sunseth, K., & Newby-Clark (1998, April). Parametric explorations of single  
and double deficits in rapid naming and phonemic awareness in grade 3. *Paper presented at  
5 the annual meeting of the Society for Scientific Study of Reading*, San Diego, CA.
- 7 Bradley, L., & Bryant, N. R. (1978). Difficulties in auditory organisation as a possible cause  
of reading backwardness. *Nature*, 271, 746–747.
- 9 Bradley, L., & Bryant, P. (1983). Categorizing sounds in learning to read: A causal  
connection. *Nature*, 301, 419–421.
- 11 Brannan, J. R., & Williams, M. C. (1987). Allocation of visual attention in good and poor  
readers. *Perception and Psychophysics*, 41(1), 23–28.
- 13 Breier, J. I., Fletcher, J. M., Foorman, B. R., & Gray, L. C. (2002). Perception of speech and  
non speech stimuli by children with and without reading disability and attention deficit  
hyperactivity disorder. *Journal of Experimental Child Psychology*, 82, 226–250.
- 15 Breitmeyer, B. G. (1980). Unmasking visual masking: A look at the “why” behind the veil  
of “how”. *Psychological Review*, 87, 52–69.
- 17 Broom, Y. M., & Doctor, E. A. (1995). Developmental phonological dyslexia: A case study  
of the efficacy of a remediation programme. *Cognitive Neuropsychology*, 12, 725–766.
- 19 Bruck, M. (1992). Persistence of dyslexics’ phonological awareness deficits. *Developmental  
Psychology*, 28, 874–886.
- 21 Bryant, P., & Impey, L. (1986). The similarity between normal readers and developmental  
and acquired dyslexics. *Cognition*, 24, 121–137.
- 23 Bundesen, C. (1990). A theory of visual attention. *Psychological Review*, 97, 523–547.
- 25 Bundesen, C. (1998). Visual selective attention: Outlines of a choice model, a race model  
and a computational theory. *Visual Cognition*, 5, 287–309.
- 27 Campbell, R., & Butterworth, B. (1985). Phonological dyslexia and dysgraphia in a highly  
literate subject: A developmental case with associated deficits of phonemic processing and  
awareness. *The Quarterly Journal of Experimental Psychology*, 37, 435–475.
- 29 Casco, C., Tressoldi, P. E., & Dellantonio, A. (1998). Visual selective attention and reading  
efficiency are related in children. *Cortex*, 34, 531–546.
- 31 Castles, A., & Coltheart, M. (1993). Varieties of developmental dyslexia. *Cognition*, 47,  
149–180.
- 33 Castles, A., & Coltheart, M. (1996). Cognitive correlates of developmental surface dyslexia:  
A single case study. *Cognitive Neuropsychology*, 13(1), 25–50.
- 35 Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to  
success in learning to read? *Cognition*, 91, 77–111.
- 37 Castles, A., Datta, H., Gayan, J., & Olson, R. K. (1999). Varieties of developmental reading  
disorder: Genetic and environmental influences. *Journal of Experimental Child Psychology*,  
72, 73–94.
- 39 Cestnick, L. (2001). Cross-modality temporal processing deficits in developmental  
phonological dyslexics. *Brain and Cognition*, 46(3), 319–325.
- 41 Cestnick, L., & Coltheart, M. (1999). The relationship between language-processing and  
visual-processing deficits in developmental dyslexia. *Cognition*, 71, 231–255.
- 43 Chase, C. (1996). A visual deficit model of developmental dyslexia. In C. Chase, G. Rosen,  
& G. Sherman (Eds.), *Developmental dyslexia: Neural, cognitive and genetic mechanisms*.  
Baltimore: York Press.
- 45 Chase, C., Ashourzadeh, A., Kelly, C., Monfette, S., & Kinsey, K. (2003). Can the  
magnocellular pathway read? Evidence from studies of color. *Vision Research*, 43,  
1211–1222.
- 47 Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-  
route and parallel-distributed processing approaches. *Psychological Review*, 100(4), 589–608.
- 49

- 1 Coltheart, M., Masterson, J., Byng, S., Prior, M., & Riddoch, J. (1983). Surface dyslexia. *Quarterly Journal of Experimental Psychology*, *35*, 469–495.
- 3 Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108*, 204–256.
- 5 Cornelissen, P., Richardson, A., Mason, A., Fowler, S., & Stein, J. F. (1995). Contrast sensitivity and coherent motion detection measured at photopic luminance levels in dyslexics and controls. *Vision Research*, *35*, 1483–1494.
- 7 Curtin, S., Manis, F. R., & Seidenberg, M. S. (2001). Parallels between the reading and spelling deficits of two subgroups of developmental dyslexia. *Reading and Writing: An Interdisciplinary Journal*, *14*, 515–547.
- 9 Demb, J., Boynton, G. M., & Heeger, D. J. (1998). Functional magnetic resonance imaging of early visual pathways in dyslexia. *The Journal of Neuroscience*, *18*, 6939–6951.
- 11 Denckla, M. B., & Rudel, R. G. (1976). Rapid Automatised Naming (RAN): Dyslexia differentiated from other learning disabilities. *Neuropsychologia*, *14*, 471–479.
- 13 Dixon, P., Gordon, R.-D., Leung, A., & Di-Lollo, V. (1997). Attentional components of partial report. *Journal of Experimental Psychology: Human Perception and Performance*, *23*, 1253–1271.
- 15 Dixon, P., & Shedden, J. M. (1993). On the nature of the span of apprehension. *Psychological Research*, *55*, 29–39.
- 17 Duncan, J., Bundesen, C., Olson, A., Humphreys, G., Chavda, S., & Shibuya, H. (1999). Systematic analysis of deficits in visual attention. *Journal of Experimental Psychology: General*, *128*, 450–478.
- 19 Duncan, J., Bundesen, C., Olson, A., Humphreys, G., Ward, R., van Raamsdonk, M., Rorden, C., & Chavda, S. (2003). Attentional functions in dorsal and ventral simultanagnosia. *Cognitive Neuropsychology*, *20*, 675–701.
- 21 Eden, G. F., VanMeter, J. W., Rumsey, J. M., Maisog, J. M., Woods, R. P., & Zeffiro, T. A. (1996). Abnormal processing of visual motion in dyslexia revealed by functional brain imaging. *Nature*, *382*, 66–69.
- 23 Ehri, L. C., Nunes, S. R., Willows, D. M., Schuster, B. V., Yaghouh Zadeh, Z., & Shanahan, T. (2001). Phonemic awareness instruction helps children learn to read: Evidence from the National Reading Panel's meta-analysis. *Reading Research Quarterly*, *36*, 250–287.
- 25 Elbro, C. (1997). Early linguistic abilities and reading development: A review and a hypothesis about underlying differences in distinctiveness of phonological representations of lexical items. *Reading and Writing: An Interdisciplinary Journal*, *8*, 453–485.
- 27 Elbro, C., Borstrom, I., & Petersen, D. K. (1998). Predicting dyslexia from kindergarden: The importance of distinctness of phonological representations of lexical items. *Reading Research Quarterly*, *33*, 36–60.
- 29 Facchetti, A., Lorusso, M. L., Paganoni, P., Cattaneo, C., Galli, R., & Mascetti, G. G. (2003). The time course of attentional focusing in dyslexic and normally reading children. *Brain and Cognition*, *53*, 181–184.
- 31 Facchetti, A., Lorusso, M. L., Paganoni, P., Cattaneo, C., Galli, R., Umiltà, C., & Mascetti, G. G. (2003). Auditory and visual automatic attention deficits in developmental dyslexia. *Cognitive Brain Research*, *16*, 185–191.
- 33 Facchetti, A., & Molteni, M. (2001). The gradient of visual attention in developmental dyslexia. *Neuropsychologia*, *39*, 352–357.
- 35 Facchetti, A., Paganoni, P., & Lorusso, M. L. (2000). The spatial distribution of visual attention in developmental dyslexia. *Experimental Brain Research*, *132*, 531–538.
- 37 Facchetti, A., Paganoni, P., Turatto, M., Marzola, V., & Mascetti, G. G. (2000). Visual-spatial attention in developmental dyslexia. *Cortex*, *36*, 109–123.
- 39 Facchetti, A., & Turatto, M. (2000). Asymmetrical visual field distribution of attention in dyslexic children: A neuropsychological study. *Neuroscience Letters*, *290*, 216–218.
- 41
- 43
- 45
- 47
- 49

- 1 Facchetti, A., Turatto, M., Lorusso, M. L. & Mascetti, G. G. (2001). Orienting of visual  
attention in dyslexia: Evidence for asymmetric hemispheric control of attention.  
3 *Experimental Brain Research*, 138, 46–53.
- 5 Farmer, M. E., & Klein, R. M. (1995). The evidence for a temporal processing deficit linked  
to dyslexia: a review. *Psychonomic Bulletin & Review*, 2(4), 460–493.
- 7 Fawcett, A. J., & Nicolson, R. I. (1995). Persistence of phonological awareness deficits in  
older children with dyslexia. *Reading and Writing: An Interdisciplinary Journal*, 7, 361–376.
- 9 Fawcett, A. J., & Nicolson, R. I. (2004). Dyslexia: The role of the cerebellum. In G. Reid &  
A. J. Fawcett (Eds.), *Dyslexia in context*. London: Whurr Publishers.
- 11 Frith, C. (1997). Brain, mind and behaviour in dyslexia. In C. Hulme & M. Snowling (Eds.),  
*Dyslexia: Biology, cognition and intervention* (pp. 1–19). London: Whurr Publishers.
- 13 Frith, U., Landerl, K., & Frith, C. (1995). Dyslexia and a verbal fluency: More evidence for a  
phonological deficit. *Dyslexia*, 1, 1–23.
- 15 Funnell, E., & Davison, M. (1989). Lexical capture: A developmental disorder of reading  
and spelling. *The Quarterly Journal of Experimental Psychology*, 41A, 471–487.
- 17 Gegenfurtner, K., & Sperling, G. (1993). Information transfer in iconic memory  
experiments. *Journal of experimental Psychology: Human, Perception and Performance*, 19,  
845–866.
- 19 Geiger, G., Lettvin, J. Y., & Zegarra-Moran, O. (1992). Task-determined strategies of visual  
process. *Cognitive Brain Research*, 1, 39–52.
- 21 Genard, N., Mousty, P., Content, A., Alegria, J., Leybaert, J., & Morais, J. (1998). Methods to  
establish subtypes of developmental dyslexic children. In P. Reitsma & L. Verhoeven  
(Eds.), *Problems and interventions in literacy development* (pp. 163–177). Dordrecht: Kluwer  
Academic Publishers.
- 23 Giesbrecht, B., & Dixon, P. (1999). Isolating the interference caused by the cue duration in  
partial report: A quantitative approach. *Memory and Cognition*, 27(2), 220–233.
- 25 Goswami, U., & Bryant, P. (1990). *Phonological skills and learning to read*. Hove: Lawrence  
Erlbaum Associates.
- 27 Goulandris, N. K., & Snowling, M. (1991). Visual memory deficits: A plausible cause of  
developmental dyslexia? Evidence from a single case study. *Cognitive Neuropsychology*,  
29 8(2), 127–154.
- 31 Griffiths, Y. M., & Snowling, M. (2002). Predictors of exception word and nonword  
reading in dyslexic children: The severity hypothesis. *Journal of Educational Psychology*,  
94(1), 34–43.
- 33 Habekost, T., & Bundesen, C. (2003). Patient assessment based on a theory of visual  
attention (TVA): Subtle deficits after a right frontal-subcortical lesion. *Neuropsychologia*, 41,  
35 1171–1188.
- 37 Hagenaar, R., & Van Der Heijden, A. H. C. (1995). On the relation between type of arrays  
and type of errors in partial-report bar-probe studies. *Acta Psychologica*, 88, 89–104.
- 39 Hanley, J. R., & Gard, F. (1995). A dissociation between developmental surface and  
phonological dyslexia in two undergraduate students. *Neuropsychologia*, 33, 909–914.
- 41 Hanley, R., Hastie, K., & Kay, J. (1992). Developmental surface dyslexia and dysgraphia:  
An orthographic processing impairment. *Quarterly Journal of Experimental Psychology*,  
44A(2), 285–319.
- 43 Hari, R., & Keisila, P. (1996). Deficit of temporal auditory processing in dyslexic adults.  
*Neuroscience Letters*, 205, 138–140.
- 45 Hari, R., & Renvall, H. (2001). Impaired processing of rapid stimulus sequences in  
dyslexia. *Trends in Cognitive Sciences*, 5(12), 525–532.
- 47 Hari, R., Renvall, H., & Tanskanen (2001). Left minineglect in dyslexic adults. *Brain*, 124,  
1373–1380.
- 49 Hari, R., Valta, M., & Utela, K. (1999). Prolonged attentional dwell time in dyslexic adults.  
*Neuroscience Letters*, 271, 202–204.

- 1 Harm, M. W., & Seidenberg, M. S. (1999). Phonology, reading acquisition, and dyslexia: Insights from connectionist models. *Psychological Review*, 106, 491–528.
- 3 Ho, C. S. H., Chan, D. W. O., Tsang, S. M., & Lee, S. H. (2002). The cognitive profile and multiple-deficit hypothesis in Chinese developmental dyslexia. *Developmental Psychology*, 38, 543–553.
- 5 Ho, C. S. H., Chan, D. W. O., Lee, S. H., Tsang, S. M., & Luan, V. H. (2004). Cognitive profiling and preliminary subtyping in Chinese developmental dyslexia. *Cognition*, 91, 43–75.
- 7 Howard, D., & Best, W. (1996). Developmental phonological dyslexia: Real word reading can be completely normal. *Cognitive Neuropsychology*, 13(6), 887–934.
- 9 Iles, J., Walsh, V., & Richardson, A. (2000). Visual search performance in dyslexia. *Dyslexia*, 6, 163–177.
- 11 Job, R., Sartori, G., Masterson, J., & Coltheart, M. (1984). Developmental surface dyslexia in Italian. In R. N. Malatesha, & H. A. Whitaker (Eds.), *Dyslexia: A global issue* (pp. 133–141). The Hague: Martinus Nijhoff.
- 13 Laberge, D., & Brown, V. (1989). Theory of attentional operations in shape identification. *Psychological Review*, 96(1), 101–124.
- 15 Laberge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology*, 3, 293–323.
- 17 Livingstone, M. S., Rosen, G. D., Drislane, F. W., & Galaburda, A. M. (1991). Physiological and anatomical evidence for a magnocellular defect in developmental dyslexia. *Proceeds of the National Academy of Science*, 88, 7943–7947.
- 19 Lovegrove, W. J., Garzia, R. P., & Nicholson, S. B. (1990). Experimental evidence for a transient system deficit in specific reading disability. *Journal of the American Optometric Association*, 61, 137–146.
- 21 Lovegrove, W. J., Martin, F., & Slaghuis, W. L. (1986). A theoretical and experimental case for a visual deficit in specific reading disability. *Cognitive Neuropsychology*, 3, 225–267.
- 23 Manis, F. R., Doi, L. M., & Bhadha, B. (2000). Naming speed, phonological awareness and orthographic knowledge in second graders. *Journal of Learning Disabilities*, 33, 325–333.
- 25 Manis, F. R., Seidenberg, M. S., & Doi, L. M. (1999). see dick RAN: Rapid naming and the longitudinal prediction of reading subskills in first and second graders. *Scientific Studies of Reading*, 3(2), 129–157.
- 27 Manis, F. R., Seidenberg, M. S., Doi, L. M., McBride-Chang, C., & Petersen, A. (1996). On the bases of two subtypes of development dyslexia. *Cognition*, 58, 157–195.
- 29 Marendaz, C., Valdois, S., & Walch, J. P. (1996). Dyslexie développementale et attention visuo-spatiale. *L'Année Psychologique*, 96, 193–224.
- 31 Martinet, C., & Valdois, S. (1999). L'apprentissage de l'orthographe d'usage et ses troubles dans la dyslexie développementale de surface. Learning to spell words: Difficulties in developmental surface dyslexia. *Année Psychologique*, 99, 577–622.
- 33 McCloskey, M., & Rapp, B. C. (2000). A visually based developmental reading deficit. *Journal of Memory and Language*, 43, 157–181.
- 35 Merzenich, M. M., Jenkins, W. M., Johnston, P., Schreiner, C., Miller, S., & Tallal, P. (1996). Temporal processing deficits of language-learning impaired children ameliorated by training. *Science*, 271, 77–80.
- 37 Mewhort, D. J. K., Campbell, A. J., Marchetti, F. M., & Campbell, J. I. D. (1981). Identification, localization, and 'iconic memory': An evaluation of the bar-probe-task. *Memory and Cognition*, 9(1), 50–67.
- 39 Mody, M., Studdert-Kennedy, M., & Brady, S. (1997). Speech perception deficits in poor readers: auditory processing or phonological coding? *Journal of Experimental Child Psychology*, 64(2), 199–231.
- 41
- 43
- 45
- 47
- 49

- 1 Morris, R. D., Stuebing, K. K., Fletcher, J. M., Shaywitz, S. E., Lyon, G. R., Shankweiler, D.  
 2 P., Katz, L., Francis, D. J., & Shaywitz, B. A. (1998). Subtypes of reading disability:  
 3 Variability around a phonological core. *Journal of Educational Psychology, 90*, 347–373.
- 4 Nelson, H., & Warrington, E. K. (1980). An investigation of memory functions in dyslexic  
 5 children. *British Journal of Psychology, 71*, 487–503.
- 6 Nicolson, R. I., Fawcett, A. J., & Dean, P. (2001). Dyslexia, development and the cerebellum.  
 7 *Trends in Neurosciences, 24*(9), 515–516.
- 8 Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding  
 9 normal and impaired word reading: Computational principles in quasi-regular domains.  
*Psychological Review, 103*, 56–115.
- 10 Rack, J. (1985). Orthographic and phonetic coding in normal and dyslexic readers. *British*  
 11 *Journal of Psychology, 76*, 325–340.
- 12 Ramus, F. (2004). Putting the cart before the horse. *Proceedings of the sixth British dyslexia*  
 13 *association international conference* (p. 21), Warwick, UK.
- 14 Ramus, F., Pidgeon, E., & Frith, U. (2003). The relationship between motor control and  
 15 phonology in dyslexic children. *Journal of Child Psychology and Psychiatry and Allied*  
*Disciplines, 44*, 712–722.
- 16 Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003).  
 17 Theories of developmental dyslexia: Insights from a multiple case study of dyslexic adults.  
 18 *Brain, 126*(4), 841–865.
- 19 Rapp, B. C., & Caramazza, A. (1991). Spatially determined deficits in letter and word  
 20 processing. *Cognitive Neuropsychology, 8*(3/4), 275–311.
- 21 Rayner, K., Murphy, L. A., Henderson, J. M., & Pollatsek, A. (1989). Selective attentional  
 22 dyslexia. *Cognitive Neuropsychology, 6*(4), 357–378.
- 23 Reichle, E. D., Rayner, K., & Pollatsek, A. (2003). The E-Z reader model of eye movement  
 24 control in reading: Comparisons to other models. *Behavioral and Brain Sciences, 26*.
- 25 Romani, C., & Stringer, M. (1994). Developmental dyslexia: A problem acquiring  
 26 orthographic/phonological information in the face of good visual memory and good short  
 27 term memory. *Brain and Language, 47*, 482–485.
- 28 Romani, C., Ward, J., & Olson, A. (1999). Developmental surface dysgraphia: What is the  
 29 underlying cognitive impairment? *The Quarterly Journal of Experimental Psychology, 52A*,  
 97–128.
- 30 Samuelsson, S. (2000). Converging evidence for the role of occipital regions in  
 31 orthographic processing: a case of developmental surface dyslexia. *Neuropsychologia, 38*,  
 32 351–362.
- 33 Scarborough, D. L. (1972). Memory for brief visual displays of symbols. *Cognitive*  
 34 *Psychology, 3*, 408–429.
- 35 Seidenberg, M. S. (1992). Dyslexia in a computational model of word recognition in  
 36 reading. In P. Gough, L. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 243–274).  
 37 Hillsdale, NJ: Erlbaum.
- 38 Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word  
 39 recognition. *Psychological Review, 96*, 523–568.
- 40 Serniclaes, W., Sprenger-Charolles, L., Carré, R., & Démonet, J.-F. (2001). Perceptual  
 41 discrimination of speech sounds in developmental dyslexia. *Journal of Speech, Language and*  
*Hearing Research, 44*, 384–399.
- 42 Seymour, P. H. K., & McGregor, C. J. (1984). Developmental dyslexia: A cognitive  
 43 experimental analysis of phonological morphemic and visual impairments. *Cognitive*  
 44 *Neuropsychology, 1*, 43–82.
- 45 Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading  
 46 acquisition. *Cognition, 55*, 151–218.
- 47 Share, D. L. (1999). Phonological recoding and orthographic learning: A direct test of the  
 48 self-teaching hypothesis. *Journal of Experimental Child Psychology, 72*, 95–129.
- 49

- 1 Shaywitz, S., Fletcher, J. M., Holahan, J., Shneider, A., Marchione, K., Steubing, K., Francis,  
 2 D., Pugh, K., & Shaywitz, B. (1999). Persistence of dyslexia: The Connecticut Longitudinal  
 3 Study at adolescence. *Pediatrics*, *104*, 1–9.
- 4 Shih, S.-I., & Sperling, G. (2002). Measuring and modelling the trajectory of visual spatial  
 5 attention. *Psychological Review*, *109*, 260–305.
- 6 Skottun, B. C. (2000). The magnocellular deficit theory of dyslexia: The evidence from  
 7 contrast sensitivity. *Vision Research*, *40*, 111–127.
- 8 Skottun, B. C., & Parke, L. A. (1999). The possible relationship between visual deficits and  
 9 dyslexia: Examination of a critical assumption. *Journal of Learning Disabilities*, *32*, 2–5.
- 10 Slaghuys, W. L., Lovegrove, W. J., & Davidson, J. A. (1993). Visual and language processing  
 11 deficits are concurrent in dyslexia. *Cortex*, *29*, 601–615.
- 12 Snowling, M. (1981). Phonemic deficits in developmental dyslexia. *Psychological Research*,  
 13 *43*, 219–234.
- 14 Snowling, M. (1994). Towards a model of spelling acquisition: The development of some  
 15 component skills. In G. D. A. Brown & N. C. Ellis (Eds.), *Handbook of Spelling: Theory,  
 16 Process and Intervention* (pp. 111–128). John Wiley and Sons.
- 17 Snowling, M. (2000). *Dyslexia*. Oxford: Blackwell.
- 18 Snowling, M. (2001). From language to reading and dyslexia. *Dyslexia*, *7*(1), 37–46.
- 19 Snowling, M., Goulandris, N., & Stakhouse, J. (1994). Phonological constraints on learning  
 20 to read: Evidence from single case studies of reading difficulty. In C. Hulme & M.  
 21 Snowling (Eds.), *Reading development and dyslexia* (pp. 86–104). London: Whurr.
- 22 Snowling, M., Stakhouse, J., & Rack, J. P. (1986). Phonological dyslexia and dysgraphia:  
 23 A developmental analysis. *Cognitive Neuropsychology*, *3*, 309–339.
- 24 Snowling, M., Wagtenonk, B., & Stafford, C. (1988). Object-naming deficit in develop-  
 25 mental dyslexia. *Journal of Research in Reading*, *11*, 67–85.
- 26 Sperling, G. (1970). Short-term memory, long-term memory, and scanning in the  
 27 processing of visual information. In F. A. Young & L. D. B. (Eds.), *Early experience and visual  
 28 information processing in perceptual and reading disorders*. Washington: National Academic of  
 29 Sciences.
- 30 Spinelli, D., Angelelli, P., De Luca, M., Di Pace, E., Judica, A., & Zoccolotti, P. (1997).  
 31 Developmental surface dyslexia is not associated with deficits in the transient visual  
 32 system. *Neuroreport*, *8*, 1807–1812.
- 33 Sprenger-Charolles, L., Colé, P., Lacert, P., & Serniclaes, W. (2000). On subtypes of  
 34 developmental dyslexia: Evidence from processing time and accuracy scores. *Canadian  
 35 Journal of Experimental Psychology*, *54*, 87–101.
- 36 Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual  
 37 differences in the acquisition of literacy. *Reading Research Quarterly*, *21*, 360–364.
- 38 Stanovich, K. E., Cunningham, A. E., & Cramer, B. B. (1984). Assessing phonological  
 39 awareness in kindergarden children: Issues of task comparability. *Journal of Experimental  
 40 Child Psychology*, *38*, 175–190.
- 41 Stanovich, K. E., & Siegel, L. S. (1994). The phenotypic performance profile of reading-  
 42 disabled children: A regression-based test of the phonological core variable-difference  
 43 model. *Journal of Educational Psychology*, *86*, 24–53.
- 44 Stanovich, K. E., Siegel, L. S., & Gottardo, A. (1997). Converging evidence for phonological  
 45 and surface subtypes of reading disability. *Journal of Educational Psychology*, *89*, 114–127.
- 46 Stein, J. F. (2001). The magnocellular theory of developmental dyslexia. *Dyslexia*, *7*(1),  
 47 12–36.
- 48 Stein, J. F. (2003). Visual motion sensitivity and reading. *Neuropsychologia*, *41*, 1785–1793.
- 49 Stein, J. F., & Fowler, M. S. (1993). Unstable binocular control in children with specific  
 reading retardation. *Journal of Research in Reading*, *16*, 30–45.
- Stein, J. F., & Talcott, J. (1999). Impaired neuronal timing in developmental dyslexia: The  
 magnocellular hypothesis. *Dyslexia*, *5*, 59–77.



- 1 Stein, J. F., & Walsh, V. (1997). To see but not to read: The magnocellular theory of dyslexia. *Trends in Neuroscience*, 20, 147–152.
- 3 ~~Suk-Han Ho, C., Wai-Ock Chan, D., Suk-Man Tsang, & Suk-Han Lee. (2002). The cognitive profile and multiple-deficit hypothesis in Chinese developmental dyslexia. *Developmental Psychology*, 38(4), 543–553.~~
- 5 ~~Suk-Han Ho, C., Wai-Ock Chan, D., Lee, S. H., Tsang, S. M., & Luan, V. H. (2004). Cognitive profiling and preliminary subtyping in Chinese developmental dyslexia. *Cognition*, 91, 43–75.~~
- 7
- 9 Talcott, J., Hansen, P.C., Assoku, E.L., & Stein, J. F. (2000). Visual motion sensitivity in dyslexia: Evidence for temporal and energy integration deficits. *Neuropsychologia*, 38, 935–946.
- 11 Talcott, J., Hansen, P.C., & Stein, J. F. (1998). Visual magnocellular impairment in developmental dyslexics. *Neuroophthalmology*, 20, 187–201.
- 13 Tallal, P. (1980). Auditory temporal perception, phonics, and reading disabilities in children. *Brain and Language*, 9(2), 182–198.
- 15 Tallal, P., Miller, S., Bedi, G., Byma, G., Wang, X., Nagarajan, S., Schreiner, C., Jenkins, W.M., & Merzenich, M. M. (1996). Language comprehension in language-learning impaired children improved with acoustically modified speech. *Science*, 271(81–84).
- 17
- 19 Tallal, P., Miller, S., & Fitch, R. H. (1993). Neurological basis of speech: A case for the prominence of temporal processing? In P. Tallal, A. Galaburda, R. Llinas, & C. V. Heuler (Eds.), *Annals of the New York academy of sciences* (Vol. 682, pp. 27–37). New York: New York Academy of Sciences.
- 21
- 23 Temple, C. M. (1984). Surface dyslexia in a child with epilepsy. *Neuropsychologia*, 22, 569–576.
- 25 Torgesen, J. K., Wagner, R. K., Rashotte, C. A., Burgess, S., & Hecht, S. (1997). Contributions of phonological awareness and rapid automatic naming ability to the growth of word-reading skills in second-to fifth-grade children. *Scientific Studies of Reading*, 1, 161–185.
- 27 Valdois, S. (1996). A case study of developmental surface dyslexia and dysgraphia. *Brain and Cognition*, 32, 229–231.
- 29 Valdois, S., & Bosse, M.-L. (2004). Selective visual attentional disorder in developmental dyslexia. *Paper presented at the First European Neuropsychology Societies Meeting*, Modena.
- 31 Valdois, S., Bosse, M.-L., Ans, B., Carbonnel, S., Zorman, M., David, D., & Pellat, J. (2003). Phonological and visual processing deficits can dissociate in developmental dyslexia: Evidence from two case studies. *Reading and Writing: An Interdisciplinary Journal*, 16, 541–572.
- 33
- 35 Valdois, S., Gérard, C., Vanault, P., & Dugas, M. (1995). Peripheral developmental dyslexia: A visual attentional account? *Cognitive Neuropsychology*, 12(1), 31–67.
- 37 Van Ingelghem, M., Van Wieringen, A., Wouters, J., Vandenbussche, E., & Onghena, P. (2001). Psychophysical evidence for a general temporal processing deficit in children with dyslexia. *Neuroreport*, 12(16), 3603–3607.
- 39 Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry*, 45, 2–40.
- 41 Vidyasagar, T. R. (1999). A neuronal model of attentional spotlight: Parietal guiding the temporal. *Brain Research Reviews*, 30, 66–76.
- 43 Vidyasagar, T. R., & Pammer, K. (1999). Impaired visual search in dyslexia relates to the role of the magnocellular pathway in attention. *Neuroreport*, 10, 1283–1287.
- 45 Wilding, J. (1989). Developmental dyslexics do not fit in boxes: Evidence from the case studies. *European Journal of Cognitive Psychology*, 1, 105–127.
- 47 Wilding, J. (1990). Developmental dyslexics do not fit in boxes: Evidence from six new case studies. *European Journal of Cognitive Psychology*, 2, 97–131.
- 49

- 1 Wimmer, H., Mayringer, H., & Landerl, K. (1998). Poor reading: A deficit in skill-  
automatization or a phonological deficit? *Scientific Studies of Reading*, 2(4), 321–340.
- 3 Wimmer, H., Mayringer, H., & Landerl, K. (2000). The double-deficit hypothesis and  
difficulties in learning to read a regular orthography. *Journal of Educational Psychology*, 92,  
5 668–680.
- 7 Wimmer, H., Mayringer, H., & Raberger, T. (1999). Reading and dual-task balancing:  
Evidence against the automatization deficit explanation of developmental dyslexia. *Journal  
of Learning Disabilities*, 32, 473–478.
- 9 Witton, C., Talcott, J., Hansen, P. C., Richardson, A., Griffiths, T., Rees, A., Stein, J. F., &  
Green, G. (1998). Sensitivity to dynamic auditory and visual stimuli predicts nonword  
reading ability in both dyslexic and normal readers. *Current Biology*, 8, 791–797.
- 11 Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental  
dyslexias. *Journal of Educational Psychology*, 91(3), 415–438.
- 13 Wolf, M., Goldberg O'Rourke, A., Gidney, C., Lovett, M., Cirino, P., & Morris, R. (2002).  
The second deficit: An investigation of the independence of phonological and naming-  
15 speed deficits in developmental dyslexia. *Reading and Writing: An Interdisciplinary Journal*,  
15, 43–72.
- 17 Wolford, G. (1975). Perturbation model for letter identification. *Psychological Review*, 82,  
184–199.
- 19 Yap, R., & van der Leij, A. (1993). Rate of elementary symbol processing in dyslexics. In  
S. F. Wright & R. Groner (Eds.), *Facets of dyslexia and its remediation* (pp. 337–347).  
Amsterdam: Elsevier Science Publishers.

21

23

25

27

29

31

33

35

37

39

41

43

45

47

49