A few remarks on the relationship between visuo-spatial attention deficits and dyslexia.

Bernt C Skottun
Ullevålsalleen 4C, 0852 Oslo, Norway

John R Skoyles
Centre for Mathematics and Physics in the Life Sciences and Experimental Biology (CoMPLEX), University College London, London, NW1 2HE, UK;
Centre for Philosophy of Natural and Social Science (CPNSS), London School of Economics, London, WC2A 2AE, UK
e-mail j.skoyles@ucl.ac.uk

Abstract

Dyslexia and attentional problems are often comorbid. This raises the question whether reading deficits might etiologically follow from attentional difficulties, a hypothesis that has been proposed in regard to visuo-spatial attention deficits. This visuo-spatial attention deficit hypothesis would predict that attention deficits should be specific to dyslexia. However, it is here estimated that at the population level there are more non-dyslexic individuals than dyslexic individuals with visuo-spatial attention deficits. The reason for this is that in the overall population level there are far more individuals without dyslexia than with dyslexia. Thus, a relatively modest percentage presence of attention problems in the non-dyslexic population can result in a greater absolute number of non-dyslexic individuals with such problems. It is concluded that attention problems are unlikely to be specific to dyslexia.

Keywords*:* dyslexia, attention, visuo-spatial attention deficit

Introduction

In spite of having been the subject to much research the cause of dyslexia has proved elusive. A number of proposals have been suggested. One conjecture is that dyslexia is the result of a deficiency linked to spatial visual attention (Steinman et al. 1998; Vidyasagar, 1999, 2001, 2004, 2005; Laycock & Crewther, 2008; Vidyasagar & Pammer, 2010). This suggestion faces a number of problems.

At a general level, it is hard to relate the visual deficiencies of dyslexic individuals to attentional factors (Skottun & Skoyles, 2007a). Moreover, many of the tests that have been used to assess attention in connection with dyslexia are not well suited to this task. For instance, the line-motion illusion (Steinman et al. 1997) is problematic since the illusion can be obtained with several simultaneously presented spatially separate stimuli (Kawahara et al. 1996; see also Skottun & Skoyles, 2006b). This is incompatible with the spatial focusing of resources which is an essential characteristic of attention. Another task that has been proposed is visual search (Vidyasagar, 2001, 2004). But this also is problematic. While slower search might indicate an attentional impairment, it also could merely reflect greater task difficulty. That is to say, task difficulty could slow the search and cause attention to linger longer at each element in the array without this being the result of a problem linked specifically, or primarily, to attention (Skottun & Skoyles, 2007b).

The link between dyslexia and attentional deficits has in many cases been made in the context of magnocellular deficiencies (Steinman et al. 1998; Vidyasagar, 1999; Laycock & Crewther, 2008; Vidyasagar & Pammer, 2010). This faces several additional problems. First, the evidence for magnocellular deficits in dyslexia is itself weak (Victor et al. 1993; Skottun, 2000; Lueder et al. 2009). Second, Roach and Hogben (2004) have shown that dyslexic readers can have attentional problems without magnocellular deficits. Third, attention can be directed by isoluminant color stimuli (Snowden, 2002) which suggests that attention is not specifically linked to the magnocellular system since isoluminance images are poor stimuli for the magnocellular system (Schiller et al. 1991).

In the course of reading the eyes make a number brief fixations separated by very short saccades. The model proposed by Vidyasagar (1999) and Vidyasagarr and Pammer (2010) assumes that attention is shifted from letter to letter during each fixation. This suggestion faces the difficulty that it is not clear whether such shifting of attention actually takes place in reading. One study that examined attention in relation to reading has indeed concluded that "covert attention in reading is not a letter-by-letter scan" (Inhoff, Pollatsek, Posner & Rayner, 1989, p. 64).

Elsewhere we have reviewed more extensively the relating of attention deficits to dyslexia (Skottun & Skoyles, 2006a). Here we focus upon another, as of yet unexplored issue, namely whether or not visual attention problems are linked specifically to dyslexia. If dyslexia were the result of an attentional deficiency, one would expect reduced attention to be specific to this condition. That is to say, one would not expect these problems to be prevalent among persons who do not suffer from dyslexia. In this connection one needs to take note of the fact

that the number of non-dyslexic individuals in the overall population is much larger than the number of individuals with dyslexia. This entails that even if only a relatively small percentage of the non-dyslexic individuals demonstrate attentional problems, the number of individuals in the total population with such problems but without dyslexia could be quite large. Failure to take account of this fact leads to what we have earlier termed the "control group fallacy" by which a small percentage of the non-dyslexic population can hide a high number in absolute terms (Skoyles & Skottun, 2004).

Method

The present report seeks to determine the number of non-dyslexic individuals with attentional problems relative to the number of dyslexic readers with such problems. The fraction of dyslexic readers in the total population with attention problems is given by:

$d_a = a_d \; d$ (Eqn. 1)

where a_d represents the fraction of dyslexic readers who have attention deficits, and d denotes the fraction of persons with dyslexia in the population. The fraction of non-dyslexic individuals in the overall population with attention problems is given by:

$c_a = a_c(1-d)$ (Eqn. 2)

where a_c denotes the fraction of controls with attention problems. In order to determine the number of individuals without dyslexia but with attentional problems relative to the number of dyslexic individuals with such problems Equation 2 is divided by Equation 1:

$c_a / d_a = (a_c (1-d))/ (a_d \; d)$ (Eqn. 3).

Results

In order to make use of Equation 3, it is necessary to obtain values for a_d and a_c. These values were provided by two recently published reports.

The first study is that of Facoetti et al. (2010). In this study it was found that all dyslexic readers (i.e., all in the DDN- group) fell below one standard deviation of the chronological age matched control group (i.e. the CA group) in regard to attention. However, one standard deviation means that also about 16% of the controls fell below this limit. This give a_d and a_c values of 1.0 and 0.16, respectively.

The second study is that of Bosse, Tainturier, and Valdois (2007). The Visual Attention measures in their Figure 2 shows that 40 out of 68 dyslexic individuals have visual attention performance below the tenth percentile of the control group. This gives an a_d of 0.59. With regard to the control group, the tenth percentile means, per definition, that ten percent fall below this level. Thus, a_c is 0.10 in this study.

The proportion of dyslexic readers in the population (*d*) needs to be entered into Equation 3. Since this proportion has not been established exactly, Equation 3 was solved for a range of *d*-values. Vidyasagar and Pammer (2010) stated that dyslexic individuals make up between 5% and 10% of the population. We therefore plotted the ratio of non-dyslexic individuals with attention problems to dyslexic persons suffering from attention problems over this range. The results are shown in Figure 1.

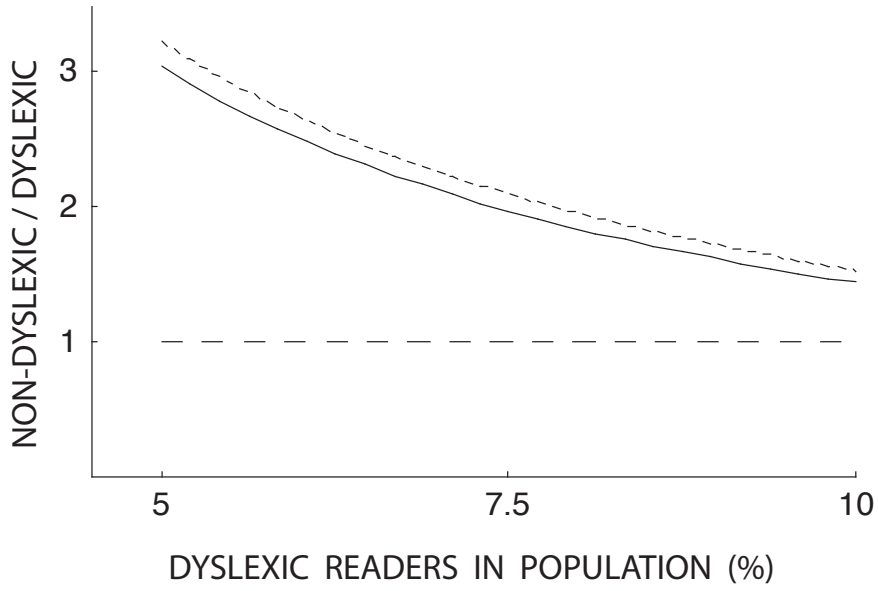

Figure 1. The number of non-dyslexic readers with attentional deficits relative to dyslexic readers with such deficits. This number (i.e. c_a / d_a) is shown as a function of the percentage of dyslexic readers in the population (i.e as a function of *d*). Solid line gives estimates based on the results of Facoetti et al. (2009) and dotted line gives data based on the data of Bosse et al. (2007). The horizontal dashed line denotes equal number of non-dyslexic and dyslexic individuals with attentional problems (i.e. $c_a / d_a = 1.0$). As can be seen, over the whole range, from 5% to 10%, the results are well above this line signifying that there are more individuals without dyslexia who have attentional deficits than dyslexic readers with such deficits.

In Figure 1 solid and dotted lines represent estimates based on, respectively, the data of Facoetti et al. (2010) and Bosse et al. (2007). As can be seen, the data based on the two studies are similar, with the ratio of non-dyslexic individuals to dyslexic readers (i.e. c_a / d_a) decreasing as the proportion of dyslexic individuals in the population is raised. However, over the full range from 5% to 10% this ratio is well above 1.0. (c_a / d_a = 1.0 is indicated by the dashed horizontal line in Figure 1). For a percentage of dyslexic readers in the population of

7.5% (i.e. midways between 5% and 10%), the ratio for both sets of data are approximately 2.0. (2.1 and 1.97, to be exact). As a consequence, these results indicate that there exist about twice as many non-dyslexic readers with attention problems as dyslexic individuals with such problems. These results show, therefore, that attentional deficits are not specific to dyslexic individuals but are also prevalent among individuals who do not suffer from dyslexia.

Discussion

The present analysis indicates that it is difficult to link dyslexia specifically to attentional problems since such problems are not restricted to those with dyslexia. Indeed, it appears the majority of individuals with deficits in visual attention do not have reading problems.

One potential objection to the present analysis is that the data on which it is based are not representative of the type of attentional deficits postulated to cause dyslexia. In regard to this, it should be pointed out that the two studies (Facoetti et al. 2010; Bosse et al. 2007) were cited by Vidyasagar and Pammer (2010) as providing support for such attentional deficits in dyslexia (other papers that were also cited lacked the required data for this analysis). It would seem that if these data are appropriate to provide support for the view that attention deficits cause dyslexia, then they should also be appropriate for the present analysis.

In conclusion, the population level analysis of the incidence of attentional deficits in connection with normal reading abilities raises questions as to how far such deficits might be responsible for dyslexia. Any attempts to explain dyslexia in terms of deficits of visual attention needs therefore to account for why only some--in the present estimates only a minority--of individuals with attention deficits end up developing reading impairments.

References

Bosse ML, Tainturier MJ, Valdois S. Developmental dyslexia: the visual attention span deficit hypothesis. Cognition 2007;104:198–230.

Facoetti A, Trussardi AN, Ruffino M, Lorusso ML, Cattaneo C, Galli R, Zorzi M. Multisensory spatial attention deficits are predictive of phonological decoding skills in developmental dyslexia. J Cogn Neurosci 2010;22:1011-1025.

Inhoff AW, Pollatsek A, Posner MI, Rayner K. Covert attention and eye movements during reading. Quart J Experiment Psychol A 1989;41:63-89.

Kawahara J, Yokosawa K, Nishida S, Sato T. Illusory line motion in visual search: attention facilitation or apparent motion. Perception 1996;25:901-920.

Laycock R, Crewther SG.Towards an understanding of the role of the 'magnocellular advantage' in fluent reading. Neurosci Biobehav Rev 2008;32:1494–1506.

Lueder GT, Ruben JB, Blocker RJ, Granet DB, Karr DJ, Lehman SS, Skipper SM. Joint statement--Learning disabilities, dyslexia, and vision. Pediatrics 2009;124:837-844.

Roach NW, Hogben JH. Attentional modulation of visual processing in adult dyslexia: a spatial cuing deficit. Psychol Sci 2004;15:650-654.

Schiller PH, Logothetis NK, Charles ER. Parallel pathways in the visual system: Their roles at isoluminance. Neuropsychologia 1991;29:433-441.

Skottun BC. The magnocellular deficit theory of dyslexia: the evidence from contrast sensitivity. Vision Res 2000;40:111-127.

Skottun, BC, Skoyles JR. Attention, reading, and dyslexia. Clin Exp Optom 2006a; 89:241-245.

Skottun BC, Skoyles JR. Attention, dyslexia, and the line-motion illusion. Optom Vis Sci 2006b;83:843-849.

Skottun BC, Skoyles J. Dyslexia: sensory deficits or inattention? Perception 2007a; 36:1084-1088.

Skottun BC, Skoyles J. The use of visual search to assess attention. Clinical and Experimental Optometry 207b;90,:20-25. doi:10.1111/j.1444-0938.2006.00074.x

Skoyles J, Skottun BC. On the prevalence of magnocellular deficits in the visual system of non-dyslexic individuals. Brain Lang 2004;88:79-82.

Snowden RJ. Visual attention to color: parvocellular guidance of attentional resources? Psychol Sci 2002;13:180-184.

Steinman BA, Steinman SB, Lehnmuhle S.Transient visual attention is dominated by the magnocellular stream. Vision Res 1997;37:17-23.

Steinman SB, Steinman BA, Garzia RP. Vision and attention. II: Is visual attention a mechanism through which a deficient magnocellular pathway might cause reading disability? Optom Vis Sci 1998;75:674-681.

Victor JD, Conte MM, Burton L, Nass RD. Visual evoked potentials in dyslexics and normals: Failure to find a difference in transient or steady-state responses. Vis Neurosci 1993;10:939-946.

Vidyasagar TR. A neuronal model of attentional spotlight: parietal guiding the temporal. Brain Res Rev 1999;30:66-76.

Vidyasagar TR. From attentional gating in macaque primary visual cortex to dyslexia in humans. Prog Brain Res 2001;134:297-312.

Vidyasagar TR. Neural underpinnings of dyslexia as disorder of visuo-spatial attention. Clin Exp Optom 2004;87:4-10.
Vidyasagar TR. Attentional gating in primary visual cortex: a physiological basis for dyslexia. Perception 2005;34:903-911.
Vidyasagar TR, Pammer K (2010) Dyslexia: a deficit in visuo-spatial attention, not in phonological processing. Trends Cogn Sci 2010;14;57-63.