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Specific problems in visual cognition of dyslexic readers: Face discrimination deficits predict dyslexia over and above discrimination of scrambled faces and novel objects

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ABSTRACT

Evidence of interdependencies of face and word processing mechanisms suggest possible links between reading problems and abnormal face processing. In two experiments we assessed such high-level visual deficits in people with a history of reading problems. Experiment 1 showed that people who were worse at face matching had greater reading problems. In experiment 2, matched dyslexic and typical readers were tested, and difficulties with face matching were consistently found to predict dyslexia over and above both novel-object matching as well as matching noise patterns that shared low-level visual properties with faces. Furthermore, ADHD measures could not account for face matching problems. We speculate that reading difficulties in dyslexia are partially caused by specific deficits in high-level visual processing, in particular for visual object categories such as faces and words with which people have extensive experience.

1. Introduction

Despite the high prevalence rate (5–17.5%) of developmental dyslexia (Shaywitz, 1998) and decades of research, its underlying cognitive and biological causes are still debated. Dyslexia is typically thought to be a language disorder, and there is good evidence for phonological deficits in dyslexia (Catts, 1989; Díaz, Hintz, Kiebel, & von Kriegstein, 2012; Pennington, Orden, Smith, Green, & Haith, 1990; Ramus et al., 2003; Shaywitz & Shaywitz, 2005; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Yet the role of phonological factors in reading varies across languages of different orthographic depth (Ziegler et al., 2010), and some dyslexic readers can perform well on phonological tests but do not read fluently (Valdois, Bosse, & Tainturier, 2004). Dyslexia is likely a multifaceted disorder, and phonological factors as well as other factors could contribute to reading problems.

1.1. Dyslexia and face perception

Recently, evidence of interdependencies of face and word processing mechanisms has sparked interest in a potential link between dyslexia and abnormal face processing (e.g. Behrmann & Plaut, 2012; Dehaene & Cohen, 2011; Dundas, Plaut, & Behrmann, 2013; but see Robotham & Starrfelt, 2017; Starrfelt, Klargaard, Petersen, & Gerlach, 2016). Of particular relevance are studies showing that (a) people who acquired what initially appeared to be specific reading problems after brain damage also had subtle problems with face perception, and (b) high-level ventral stream regions in or near the left fusiform gyrus that support word and face recognition are hypoactive in dyslexic readers (for an extended discussion of the theoretical underpinnings, see Sigurdardottir, Ívarsson, Kristinsdóttir, & Kristjánsson, 2015).

In Sigurdardottir et al. (2015), we reported that dyslexic readers were worse than matched typical readers at recognizing faces and other familiar objects at the individual level (within-category or subordinate-level recognition), consistent with the possibility that reading problems in developmental dyslexia might be a salient manifestation of a more general high-level visual deficit. High-level visual cognition, thought to be dependent on brain regions such as the fusiform gyrus in the ventral visual stream, involves visual processing dedicated not to the analysis of local image structure but to the structure of the external world, especially object perception and recognition (Cox, 2014; DiCarlo & Cox, 2007). Problems with high-level visual cognition therefore do not indicate that people have trouble seeing – they have problems with making sense of what they see. Nevertheless, there is no consensus in the literature on links between developmental dyslexia and high-level

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visual cognition in general or face perception in particular.

Rüsseler, Johannes, and Münte (2003) reported no significant differences between the ability of participants with and without dyslexia in judging whether particular faces had been presented before or not. There was, however, a numerical difference with a non-trivial effect-size so the study may have been underpowered. Additionally, as the same images were used in the learning and study phase, participants may have relied on low-level visual cues to recognize the faces. Holmes and McKeever (1979) reached a similar conclusion, but again, low-level cues were not adequately controlled for (see also Liberman, Mann, Shankweiler, & Werfelman, 1982).

Korinth, Sommer, and Breznitz (2012) found no differences in the ability of slow and fast reading university students to quickly decide whether photographs showed men or women. Performance was close to ceiling so possible differences in facial recognition abilities might not have been detectable. It is uncertain whether this task measures face recognition abilities, as gender identification can survive impairments in face recognition (Tranel, Damasio, & Damasio, 1988). It is also unclear whether participants could rely on non-facial gender cues such as hairstyle or hair length.

Smith-Spark and Moore (2009) found no differences in the ability of dyslexic and non-dyslexic university students to name celebrity faces. Non-dyslexic participants were, however, faster at naming famous faces that were learned early rather than late in life (age of acquisition effect), which was less apparent for dyslexic participants suggesting that experience with faces differentially affects people with and without dyslexia.

Brachacki, Fawcett, and Nicolson (1994) tested the face and voice recognition of seven dyslexic and eight non-dyslexic adults. While face recognition was at ceiling, dyslexic readers did worse than typical readers on a recognition test given a week later. The difference, while non-trivial, was not significant, which could reflect the small sample.

Aaron (1978) subdivided a sample of dyslexic children into dysphonetics (analytic-sequential deficient) and dyseidetics (holistic-simultaneous deficient) based on the nature of their spelling errors. All children were shown photographs of faces that had no readily distinguishable features such as a moustache, hair style, or dress. The dyseidetic children correctly identified significantly fewer photographs than the dysphonetic children whose performance was similar to a control group.

Tarkiainen, Helenius, and Salmelin (2003) tested eight adults with dyslexia and ten without dyslexia on a short version of the Benton facial recognition test (Benton, Sivan, Hamsher, Varney, & Spreen, 1978), and a computerized face recognition test where people saw a target face in the upper half of the screen and judged which of two choice faces in the lower half matched the upper face by quickly pressing a button. Dyslexic participants made more errors than controls on the Benton test and were slower at matching to facial identity in the computerized test.

Pontius (1976,1983) reported that dyslexic children were more likely than controls to draw so-called neolithic faces where spatial relations in the upper part of the human face are misrepresented, suggesting unusual or distorted facial representations. Pontius suggested that such configurations are analogous to the visual experience of people with prosopagnosia. Finally, Gabay, Dundas, Plaut, and Behrmann (2017) tested the face perception abilities of 12 matched pairs of dyslexic and non-dyslexic university students finding that the dyslexic group had atypical and comparatively deficient visual processing of faces.

In sum, there are reports of both intact as well as deficient face processing abilities of people with dyslexia. However, some studies were small-scale and lacked statistical power, did not control for low-level visual cues or other cues not related to face individuation, or suffered from problems that makes their interpretation difficult. Whether developmental dyslexia involves face processing problems is therefore still unclear.

1.2. The specificity of problems in face perception

If dyslexic readers do indeed have problems with face processing, the specificity of such deficits is also unknown. Face recognition deficits could reflect non-specific factors such as general problems with memory or attention, both of which have been reported in people with dyslexia (e.g. de Jong, 1998; Gathercole, Alloway, Willis, & Adams, 2006; Germano, Gagliano, & Curatolo, 2010). If the problems were visual, a visual deficit in dyslexia could be low-level (e.g. magnocellular; Skottun, 2000; Stein & Walsh, 1997) or more high-level (e.g. a problem with processing shape cues). A low-level deficit in the processing of fundamental characteristics of faces and words, such as their orientation and spatial frequency contents, could appear as a problem with recognizing visual faces and words.

If visual problems in dyslexic readers are high-level, they could be specific to particular object categories (specific mechanisms), such as faces, words, and other real-world objects that people have experience with, or they could generalize to all visual object classes, even novel ones (general mechanisms). While faces and words are perhaps the two categories that people in general have the most experience with, as people have to be able to tell apart thousands of similar-looking faces and words, they also have some experience with individuating other real-word objects. Our recent work indicates that dyslexic readers have problems with recognizing words, faces, and other real-world objects at the individual level (Sigurdardottir et al., 2015) and that they might not learn from their visual experience to the same extent as typical readers (Sigurdardottir et al., 2017). If visual experience does not successfully reshape the visual system of dyslexic readers to become selective for category-specific features important for individuating familiar object classes, then discriminating and recognizing objects of those categories would be impaired.

As Richler, Wilmer, and Gauthier (2017) point out, measuring performance for novel objects might be a preferable way of probing category-general object recognition mechanisms because performance is not “contaminated” by individual differences in category-specific experience, or – we add – potential individual differences in experiential effects on high-level visual mechanisms. Visual recognition abilities for novel objects are indeed dissociable from visual recognition abilities for familiar object classes, in line with these being supported by at least partially separable mechanisms (Richler et al., 2017).

Our previous work indicates that visual recognition problems in developmental dyslexia are not completely generic, as there were no significant differences between people with and without dyslexia on a challenging color recognition test (Sigurdardottir et al., 2015). Gabay et al. (2017) also found no consistent problems in people with dyslexia for individuating cars, although they noted that the dyslexic readers were relatively slow at responding to all categories. Our prior work (Sigurdardottir et al., 2015) indicates however that face recognition problems in dyslexia generalize to difficulties with subordinate-level recognition of at least some familiar non-face object classes (individuation of birds, butterflies, cars, houses, or planes). This is fully in line with the fact that the left fusiform and inferior temporal gyri are hypoactive in adult dyslexic readers (Richlan, Kronbichler, & Wimmer, 2011) and that the left fusiform gyrus is smaller in people who carry a genetic sequence variant associated with dyslexia (Ulfarsson et al., 2017). The fusiform and inferior temporal gyri support the individuation or subordinate-level categorization of faces as well as non-face objects (Gauthier, Anderson, Tarr, Skudlarski, & Gore, 1997; Haist, Lee, & Stiles, 2010), especially following experience with individuating the objects (e.g. Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; for a recent review, see Sigurdardottir and Gauthier (2015) but see e.g. Rhodes, Byatt, Michie, and Puce (2004). Whether such discrimination problems generalize to novel objects or even non-objects that share low-level visual properties with problematic object classes is unknown.