Neuropsychologia 47 (2009) 907–915

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Relationships between global motion and global form processing, practice, cognitive and visual processing in adults with dyslexia or visual discomfort

Elizabeth G. Conlon*, Mary A. Sanders, Craig M. Wright

School of Psychology, Gold Coast Campus, Griffith University, Queensland 4222, Australia

ARTICLE INFO

Article history:
Received 15 May 2008
Received in revised form 24 December 2008
Accepted 30 December 2008
Available online 8 January 2009

Keywords:
Dyslexia
Visual discomfort
Global motion processing
Phonological processing
Magnocellular
Parvocellular

ABSTRACT

The aim of the first of two experiments was to investigate the effect of practice on sensitivity to global motion and global form in a group of adults with dyslexia, a group of normal readers with visual discomfort, a group with dyslexia and visual discomfort, and a control group. In comparison to the control group, and regardless of the effect of practice, the group with dyslexia was significantly less sensitive to global motion. No differences in global motion sensitivity were found when individuals with dyslexia, with or without visual discomfort, were compared. The normal reading group with visual discomfort was less sensitive to global motion than the control group at baseline, but not when a second estimate of motion sensitivity was obtained. About 30% of the group with dyslexia had a global motion deficit on each threshold estimate. In contrast, there were no significant effects of practice or group on sensitivity to global form. In Experiment 2, performance on a number of cognitive and visual processing tasks was measured in four groups: two with dyslexia; one with and one without a global motion deficit, a normal reading group with visual discomfort, and a control group. The group with visual discomfort had reduced visual processing speed only. Regardless of whether a global motion processing deficit was present or absent in individuals with dyslexia, reduced accuracy was found on the language and visual processing measures, and on a rapid temporal sequencing task. Individuals with dyslexia and a global motion deficit had poorer accuracy than individuals with dyslexia and no motion deficit on the phonological processing and verbal short term memory tasks. We concluded that some adults with dyslexia have a persistent deficit when processing global motion but not global form. This is consistent with reports of a magnocellular pathway deficit in this group. Individuals with visual discomfort do not have a magnocellular processing deficit, but have perceptual difficulties when performing complex visual processing tasks.

Dyslexia is a neurocognitive disorder that affects between 5 and 15% of individuals in English speaking countries (Shaywitz, 1998). Research has shown that dyslexia may persist into adulthood in individuals who have been either assessed with dyslexia in childhood (Shaywitz et al., 2003), or who report an undiagnosed history of significant reading difficulty in childhood (Lefly & Pennington, 2000). The behavioural characteristics of both groups include poor reading fluency, difficulties with phonological decoding (Bruck, 1990, 1992; Hatcher, Snowling, & Griffiths, 2002; Wilson & Lesaux, 2001) and poor verbal short term memory (Brosnan et al., 2002). Many adults with dyslexia have word decoding skills in the low average range (Fink, 1998; Shaywitz et al., 2003), and also show a reduced sensitivity on measures that assess processing in the magnocellular visual pathway (Johnson et al., 2008; Stein & Walsh, 1997; Talcott et al., 1998).

The magnocellular deficit hypothesis in dyslexia is based on convergent evidence of reduced sensitivity to stimuli that are in rapid transition such as motion, but not in response to stationary or near stationary stimuli about form (Lovegrove, Martin, & Slaghuis, 1986; Stein, 2001). Stimuli in rapid transition are preferentially processed in distinct subcortical magnocellular and extrastriate dorsal pathways, with stimuli about form predominantly processed in distinct parvocellular and extrastriate ventral pathways (Merigan & Maunsell, 1993). Supporting evidence for a magnocellular deficit in dyslexia has been revealed in physiological differences (Galaburda & Livingstone, 1993), electrophysiological differences (Demb, Boynton, & Heeger, 1998; Eden et al., 1996; Schulte-Korne, Bartling, Diemel, & Remschmikdt, 2004) and in psychophysical differences (Johnson et al., 2008; Slaghuis & Ryan, 2006; Wilmer, Richardson, Chen, & Stein, 2004). However, in contrast, research has demonstrated that groups with dyslexia show few sensitivity differences when processing stimuli in visual tasks that assess sensitivity to near stationary form (Hansen, Stein, Orde, Winter, & Talcott, 2001; Martin & Lovegrove, 1987).

* Corresponding author. Tel.: +61 7 555 28981; fax: +61 7 555 28291.
E-mail address: e.conlon@griffith.edu.au (E.G. Conlon).

0028-3932/$ – see front matter.
doi:10.1016/j.neuropsychologia.2008.12.037

A measure that is known to engage the magnocellular and dorsal pathways is sensitivity to global motion, which is generated using random dot kinematograms. A proportion of the stimuli in the random dot kinematogram contain a directional motion signal and the remainder are noise dots that contain no information concerning the global direction of motion. When generating a global representation of motion, observers must extract the visual motion signals from the global array of visual noise in the random dot kinematogram. These signals are then integrated to form a global motion percept (Newsome & Pare, 1988). Many studies have demonstrated that groups with dyslexia have reduced sensitivity to global motion (e.g., Conlon, Sanders, & Zapart, 2004; Cornelissen, Richardson, Mason, Fowler, & Stein, 1995; Hansen et al., 2001; Pellicano & Gibson, 2008; Raymond & Sorenson, 1998; Slaghuis & Ryan, 1999; Solan, Shelley-Tremblay, Hansen, & Larson, 2007; Talcott, Hansen, Assoku, & Stein, 2000; Talcott et al., 1998; Wilmer et al., 2004; Witton et al., 1998). A smaller number of studies have found no such sensitivity differences (Edwards et al., 2004; Hill & Raymond, 2002; Huslander et al., 2004; Knonblicher, Hutzler, & Wimmer, 2002; Reid, Szczerbinski, Iskierka-Kasperek, & Hansen, 2007; White et al., 2006).

The inconsistent findings in studies of global motion sensitivity have produced a controversy surrounding the magnocellular deficit hypothesis in dyslexia. The inconsistent findings may be partially explained by the sensitivity differences produced when different techniques and methods are used to measure global motion sensitivity (Stein, 2003; Talcott et al., 2000). For example, research has shown that groups with dyslexia have reduced sensitivity when the sample dot density of the random dot kinematogram is low (<9.2 dots/deg^2) (e.g., Hansen et al., 2001; Talcott et al., 2000) but not when it is high (>12.2 dots/deg^2) (Edwards et al., 2004; Hill & Raymond, 2002; Talcott et al., 2000). In addition, practice has been shown to increase sensitivity in groups with dyslexia on complex motion processing tasks (Cornelissen et al., 1995; Lawton, 2007). More generally, practice has been shown to produce greater processing efficiency and active attending when individuals perform complex psychophysical tasks (Gold, Bennett, & Sekuler, 1999; Watanabe et al., 2002; Zanker, 1999; Zohary, Celebrini, Britten, & Newsome, 1994).

The heterogeneous behavioural characteristics of individuals with dyslexia may also have contributed to the inconsistent results obtained on measures of global motion processing. For example, there are anecdotal reports and research evidence that some individuals with dyslexia report that the words move or disappear when reading (Kriss & Evans, 2005; Stein & Walsh, 1997). This disorder, referred to as Visual Discomfort[1] is characterised by perceptual and somatic difficulties induced with exposure to bright light and the repetitive patterns that are found on single spaced text pages (Borsting, Chase, & Ridder, 2007; Conlon, Lovegrove, Chekaluk, & Pattison, 1999; Wilkins, 1995; Wilkins et al., 1984). Individuals with visual discomfort show poor reading fluency (Wilkins, 1995; Wilkins & Nimmo-Smith, 1984) and reduced efficiency on complex visual search tasks (Conlon & Humphreys, 2001). In addition, while there is some evidence that individuals with visual discomfort also have reduced sensitivity to motion (Shepherd, 2001) and spatial frequency (Conlon, Lovegrove, Barker, & Chekaluk, 2001), some studies have reported that these individuals do not differ from control groups on measures of contrast sensitivity or motion processing (Evans, Busby, Jeanes, & Wilkins, 1995; Simmer, Bex, Smith, & Wilkins, 2001).

Most research on dyslexia and on visual discomfort has uniquely considered each disorder. That is, research on dyslexia has often not considered the co-morbid presence of visual discomfort and vice versa. The inconsistent results found on measures of visual processing in each of these research areas may be explained by the co-morbid presence of both disorders in some individuals. Recent reports have suggested that individuals with dyslexia are more likely than other individuals to report symptoms of visual discomfort (Kriss & Evans, 2005; Singleton & Trotter, 2005). The main aim of the present research was to investigate the effect of practice on sensitivity to global motion and to global form in different adult groups. These included a group with dyslexia, a group of normal readers with visual discomfort, a group with dyslexia and visual discomfort, and a control group with neither dyslexia nor visual discomfort.

1. Experiment 1. Effects of practice on global form and global motion sensitivity

We evaluated the influence of practice on sensitivity to global motion and global form in a group with dyslexia, a normal reading group with visual discomfort, a group with both dyslexia and visual discomfort, and a control group. If a magnocellular deficit is specific to the group with dyslexia, we expected that reduced sensitivity to global motion would be found in this group on a baseline measure of sensitivity and following practice. In comparison, no sensitivity differences were expected when measuring global form. The group of normal readers with visual discomfort was only expected to have poor sensitivity on the measures of global motion and global form at baseline. This is a consequence of the increased perceptual difficulties found previously for this group on complex visual processing measures. However, if the presence of both dyslexia and visual discomfort describes individuals with a magnocellular deficit, only the group with both disorders was expected to have persistently reduced sensitivity to global motion.

Deviance analysis has been used to determine the proportion of individuals with dyslexia who have a magnocellular deficit (Amitay, Ben-Yehudah, Banai, & Ahissar, 2002; Ramus et al., 2003; White et al., 2006). In previous studies, the range of normal sensitivity required to generate a deviance estimate has been derived from the distribution of sensitivity scores obtained from the relatively small control groups used in those studies. However, from a methodological perspective it has been proposed that the normal range of sensitivity can only be determined accurately by measuring sensitivity of large normative samples (Jacobson & Truax, 1991). Accordingly, in the present study the proportion of individuals in the dyslexia and visual discomfort groups with a global motion deficit was generated using both small and large control samples.

2. Method

2.1. Participants

Volunteers were 87 adult university students with normal or corrected to normal visual acuity. There were 31 individuals with dyslexia alone and 4 who had both dyslexia and visual discomfort. There were 17 normal readers who had visual discomfort and 35 normal readers who had low visual discomfort (see Table 1). All individuals with dyslexia reported a history of reading difficulties and had standard scores of below 94 for word decoding on the Wide Range Reading Test (WRAT-3; Wilkinson, 1993). This test consists of 42 words of increasing difficulty and has internal consistencies of .90–.95 for the age groups tested. Individuals with dyslexia also had scores at least two standard deviations below the mean of the control group on non-word and exception word reading tests. The non-word and exception word tests each had 25 items that are matched for word length. The internal consistencies for the non-word and exception word tests are .77 and .84, respectively. Standardised ability scores of the group with dyslexia were at least 100. These scores were obtained using the Kaufman Dyad which consists of the Information (verbal) and

[1] There have been various terms used to describe visual discomfort. These include visual stress, Meares-Irlen Syndrome, Irlen Syndrome, and scotopic sensitivity syndrome. This study has used the term visual discomfort to describe the collection of somatic, perceptual and functional difficulties experienced by individuals with this condition. It is measured using the Visual Discomfort Scale (Conlon et al., 1999), which has recently been further validated (Borsting et al., 2007).