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Sequential object recognition deficits in normal readers ☆

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The present work examined the relationship between sequential object recognition and variations in normal reading ability. A group of normal readers completed a battery of tests examining nonverbal intelligence, rapid-automatized naming, reading ability, and an attentional blink (AB) task in which they were asked to identify two sequential targets embedded amongst distractors. Consistent with previous studies, all participants showed a significant AB, with second-target identification improving as inter-target interval increased. More critically, low-normal readers showed a larger AB than high-normal readers. Considered in context with earlier work, these results imply that the ability to allocate capacity-limited processing resources to sequential visual inputs is linked to reading proficiency across the range of both disabled and normal readers.

1. Introduction

The ability to navigate through an airport, study a manual in preparation for a road test, or make a selection from a wine menu depends on reading. Although most of us develop this essential skill, approximately 15% of the population has significant impairments in reading achievement disproportionate to their chronological age, measured intelligence, and educational opportunities (DSM-IV; American Psychiatric Association., 1994). This disorder, known as dyslexia, is characterized not only by impairments in reading, but also frequently by problems with writing, spelling, short-term memory, and motor movements (Farmer & Klein, 1995; Rapala & Brady, 1990).

The heterogeneous nature of symptoms in dyslexia has led to a number of different theoretical explanations for the disorder. Perhaps the most prominent of these is the phonological hypothesis, which suggests that dyslexics are impaired in their ability to map letters and syllables onto speech sounds. However, while there is little doubt that phonology plays an important role in reading, there is ample evidence to suggest that phonological deficits alone cannot explain all cases of dyslexia. For example, (Castles & Coltheart, 1993; Castles & Coltheart, 1996) documented a 9-year old boy with surface dyslexia who could read regular words and pseudowords, but showed profound difficulties reading irregular words and had poor lexical and whole-word recognition skills.

In light of these and similar findings, numerous additional deficits have also been linked with dyslexia. For example, (Tallal, 1984; see also Farmer & Klein, 1995) argued that poor phonological skills in dyslexia stem from a general temporal processing deficit in auditory and visual modalities. On a related note, a number of researchers (e.g., Hogben, 1997; Lovegrove, Martin, & Slaghuis, 1986; Skottun, 1997) have suggested that dysfunctions in the magnocellular pathway result in insufficient inhibition of parvocellular visual processing (which is required for word recognition). As a result, during saccades, both visual subsystems are active resulting in a scrambling of visual information obtained from one fixation to the next.

Most recently, several studies have proposed an important role for capacity-limited visual processing resources (i.e., visual attention) in reading. These accounts appeal to the notion that efficient scanning of printed material requires the visual system to selectively encode relevant pieces of information, while excluding competing irrelevant information. This is assumed to require covert shifts of attention from word to word (Casco, Tressoldi, & Dellantonio, 1998), followed by an overt eye movement (Roach & Hogben, 2004). Consistent with a link between visual attention and reading, Casco et al. (1998) showed a relationship between target detection speed in a difficult search task that required effortful shifts of attention from item to item in a display, reading rates and reading errors. Similarly, Heiervang and Hugdahl (2003) found that a peripheral visual cue that validly predicted target location on 80% of trials was less beneficial for dyslexics than normal readers. This implied that readers with dyslexia were less able to use the information from the cue to allocate visual attention.

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Given the link between reading ability and performance on tasks requiring participants to allocate attentional resources across space, it seems plausible that a relationship might also exist between reading ability and performance on tasks requiring allocation of attention over time to sequential stimuli. As discussed by Visser, Bischof, and Di Lollo (2004), this proposal is broadly consistent with studies showing correlations between reading performance and visual attention shifts (Asbjornsen & Bryden, 1998), the hypothesized link between reading and temporal processing (Farmer & Klein, 1995; Tallal, 1984) and the fact that dyslexia has already been associated with deficits in both temporal processing and visual attention.

To investigate such a link, a number of studies have employed a rapid serial visual presentation (RSVP) paradigm consisting of two target items embedded in a stream of distractors with all items presented in the same spatial location at a rate of about 10 Hz. Under these conditions, while identification of the first target (T1) is nearly perfect, identification of the second target (T2) varies with inter-target interval (lag). Performance is lowest at lags of 200–300 ms, and steady improvement to the level of T1 by about 700 ms (e.g., Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992; Visser et al., 2004). This pattern of improving performance over lags is referred to as the attentional blink (AB).

The AB has conventionally been attributed to an inability to process T2 at brief lags while attentional resources are occupied with T1 (e.g., Chun & Potter, 1995; Jolicoeur, 1998; Visser, 2007). Several pieces of evidence are consistent with this interpretation. First, the AB is reduced or eliminated, under identical stimulus presentation conditions, if observers are simply asked to ignore T1 (Chun, 1997; Dell'Acqua & Jolicoeur, 2000; Jolicoeur & Dell'Acqua, 1998; Raymond et al., 1992). This implies that resources must be engaged by a prior target stimulus for T2 impairments to occur. Second, numerous studies have shown that the AB can be found when targets are presented to different sensory modalities (e.g., auditory/visual: Arnell & Jolicoeur, 1999; Arnell & Larson, 2002; Dell'Acqua & Jolicoeur, 2000; Potter, Chun, Banks, & Muckenhoupt, 1998; auditory/tactile: Dell'Acqua, Turatto, & Jolicoeur, 2001; visual-tactile: Soto-Faraco et al., 2002). These robust cross-modal deficits implicate an important role for central resource limitations in the AB. Finally, neurophysiological investigations of the AB have consistently shown a link with mechanisms involved in spatial selection and working memory (e.g., Martens, Munneke, Smid, & Johnson, 2006; Vogel, Luck, & Shapiro, 1998; Jolicœur, Sessa, Dell'Acqua, & Robitaille, 2006; Marois, Yi, & Chun, 2004).

One of the first studies to look at the AB and reading was done by Hari, Valta, and Uutela (1999) who evaluated a population of adults with dyslexia with a history of reading disorders, and who were significantly slower than a control group of normal readers at reading and word recognition. In their experiments, participants were presented with an RSVP stream of black-letter distractors at a central fixation location, along with a single white letter (T1) and a black 'X' (T2). Both the control and dyslexic groups showed pronounced ABs suggesting that readers with and without dyslexia processed sequential targets in a broadly similar manner. Importantly, however, the group with dyslexia showed a significantly longer AB, with T2 performance asymptoting at a lag of approximately 1200 ms, compared to the control group whose performance asymptoted at a lag of approximately 700 ms.

In a similar vein, Visser et al. (2004) compared the AB in three groups of children: those with dyslexia, reading-matched controls, and age-matched controls. To eliminate possible group differences in linguistic ability, observers were presented with an RSVP stream of random-dot distractors along with two target shapes. In the first experiment, when all items were presented at the same location, the dyslexic and reading-matched control groups showed similar AB deficits that were both larger than the age-matched controls. In the second experiment, when T1 and T2 were presented in different locations, the dyslexic group was significantly worse than both control groups. Taken together, this implied that children with dyslexia had a more pronounced AB that was particularly exacerbated when attention had to be shifted both over time and across space.

The studies of Hari et al. (1999), Visser et al. (2004) and analogous results from Lum, Conti-Ramsden, and Lindell (2007) and Buchholz and Davies (2007) all point to a reliable relationship between allocation of visual attention over time to sequential objects and reading impairment. However, what is not known is whether this relationship extends across the range of normal reading proficiency. One possibility is that to attain a normal level of reading proficiency, there is a certain minimum level of visual attention skill required. Once this minimum level of skill is achieved, no further benefits to reading accrue for those who are far above the minimum versus those who are only slightly above the minimum. On this view, while dyslexics and normal readers show a difference on tasks such as the AB, no such differences would be found across the range of normal reading proficiency. A second possibility is that the relationship between visual attention and reading is a continuous one, and that the difference between dyslexics and normal readers on tasks such as the AB reflect a more general relationship between reading skill and visual attention. On this view, differences on visual attention tasks should also be found across the range of normal reading proficiency. For example, highly proficient readers should show a smaller AB than less-skilled readers.

The present work was designed to test these alternatives. We compared performance on an AB task between low-skill and high-skill readers, all of whom scored within the normal range of reading proficiency on standardized tests (subsequently, we refer to these groups as low-normal and high-normal). To anticipate the results, we found reliable differences in AB performance between reading groups even when other variables such as nonverbal intelligence, age, and speed of memory retrieval were controlled for. This implies that the ability to allocate visual attention over time is related to reading proficiency across a range of abilities.

2. Methods

2.1. Participants

Eighty-seven university students (78.2% women; 21.8% men) participated in the study. Age ranged from 18 to 41 years ($M = 21.27$, $Mdn = 20.00$, $SD = 4.15$; women: $M = 21.37$, $Mdn = 19.96$, $SD = 4.39$; men: $M = 20.94$, $Mdn = 20.00$, $SD = 3.27$). Participants received course credit in exchange for participation in a 1-h session. All participants reported normal or corrected-to-normal (i.e., eye glasses or contact lenses) vision.

2.2. Measures

2.2.1. Reading efficiency

The phonemic decoding efficiency subtest from the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999) was used. This test measured observers' ability to rapidly name as many non-words as possible (top score of 63) without errors in 45 s. Non-words were divided into three equal lists printed vertically on a white form. Participants were instructed to read down each list, pronouncing items based on their common sounds, and skipping any items they could not pronounce. Participants were asked to stop reading after 45 s and a line was drawn after the last non-word read. If all the items were read in less than 45 s, the time required was noted. Incorrect responses were given for inaccurately pronounced non-words and non-words that had been skipped.