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Different behavioral and eye movement patterns of dyslexic readers with and without attentional deficits during single word reading☆

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ABSTRACT

Comorbidity of learning disabilities is a very common phenomenon which is intensively studied in genetics, neuropsychology, prevalence studies and causal deficit research. In studies on the behavioral manifestation of learning disabilities, however, comorbidity is often neglected. In the present study, we systematically examined the reading behavior of German-speaking children with dyslexia, of children with attentional problems, of children with comorbid dyslexia and attentional problems and of normally developing children by measuring their reading accuracy, naming latencies and eye movement patterns during single word reading. We manipulated word difficulty by contrasting (1) short vs. long words with (2) either low or high sublexical complexity (indexed by consonant cluster density). Children with dyslexia only (DYS) showed the expected reading fluency impairment of poor readers in regular orthographies but no accuracy problem. In contrast, comorbid children (DYS + AD) had significantly higher error rates than all other groups, but less of a problem with reading fluency than DYS. Concurrently recorded eye movement measures revealed that DYS made the highest number of fixations, but exhibited shorter mean single fixations than DYS + AD. Word length had the strongest effect on dyslexic children, whereas consonant cluster density affected all groups equally. Theoretical implications of these behavioral and eye movement patterns are discussed and the necessity for controlling for comorbid attentional deficits in children with reading deficits is highlighted.

1. Introduction

In the research field of learning disabilities, it is undisputable that comorbidity is a very common phenomenon (e.g., Gross-Tsur, Manor, & Shalev, 1996; Lewis, Hitch, & Walker, 1994). Typically comorbidity of learning disorders is studied in genetics (e.g., Barr et al., 2008; Friedman, Chhabildas, Budhiraja, Willcutt, & Pennington, 2003; Willcutt, Pennington, Olson, & DeFries, 2007), neuropsychology (e.g., Burd, Freeman, Klug, & Kerbeshian, 2005; Hendriksen et al., 2007), prevalence studies (e.g., Brook & Boaz, 2005; Capano, Minden, Chen, Schachar, & Ickowicz, 2008; Manor, Medad, Zamishlani, & Vurmbrand, 2008) and causal deficit research (e.g., Brookes, Nicolson, & Fawcett, 2007; Crawford & Dewey, 2008; Donfrancesco, Mugnaini, & Dell'Uomo, 2005; Haslum & Miles, 2007). In many studies (e.g., Ackerman & Dykman, 1995; Jongmans, Bouwien, Smits-Engelsman, & Schoemaker, 2003; Landerl, Bevan, & Butterworth, 2004; Purvis & Tannock, 1997; Shalev, Gross-Tsur, & Manor, 1997) it was shown that comorbidity mostly aggravates the symptoms and problems of children with a learning disability; Crawford and Dewey (2008), for example, concluded that deficits in visual memory skills seem to be specific for children with developmental coordination disorder (DCD) and co-occurring reading disabilities and/or ADHD. Brook and Boaz (2005) found that high school pupils with ADHD and comorbid learning disabilities (dyscalculia, dysgraphia, social science difficulties, fine motor skill difficulties and spatial adaptation problems) had lower academic achievement. These studies exemplify the importance of controlling for comorbid deficits; only by ensuring that children with dyscalculia or dyslexia do not suffer from additional comorbid disorders, it will be possible to identify the typical patterns or possible causes of a specific disorder.

1.1. Comorbidity of dyslexia and attentional deficits

Capano et al. (2008) showed that especially for reading disabilities the association with ADHD is high. While 18% of their ADHD population had a comorbid mathematical disability, about 26% had

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a comorbid reading disability. Yu, Buka, McCormick, Fitzmaurice, and Indurkhya (2006) further demonstrated that verbal learning disabilities are much more likely associated with behavioral problems (i.e., externalizing and internalizing behavioral disabilities) than other non-verbal learning disabilities. In their review, Vellutino, Fletcher, Snowling, and Scanlon (2004) reported a comorbidity rate of attentional problems between 30% and 70% in dyslexic children. In light of this figure, it seems essential to control children with reading problems for comorbid attentional problems. We will be able to isolate the characteristic deficits underlying the reading-problems, only when we ensure that the observed effects result from a pure dyslexic group without comorbid attentional problems.

1.2. Attentional deficit/hyperactivity disorder (ADHD)

ADHD is a developmental disorder characterized by increased distractibility, inattention and errors caused by carelessness (DSM-IV-TR German Version: Saß, Wittchen, & Zaudig, 2003; ICD-10 German version, Dilling, Mombour, & Schmidt, 2004). Error and reaction time patterns of children with attentional deficits are typically measured with continuous performance tasks (e.g., Epstein et al., 2003; Newcorn et al., 2001), flanker tasks (e.g., van Meel, Heslenfeld, Oosterlaan, & Sergeant, 2007), go/no go tasks (e.g., Koschak, Kunert, Derichs, Weniger, & Irle, 2003) or visual search tasks (e.g., Wilding, 2003; Wilding, Pankhania, & Williams, 2007). Children with attentional deficits show similar reaction time patterns compared to unimpaired subjects, but drastically increased error rates. In a recent ERP study the error-related negativity (ERN) of ADHD children was measured with a modified Eriksen flanker paradigm (van Meel et al., 2007). ADHD children made more errors than controls especially under time pressure. ERN analyses revealed that, although the behaviorally measured post-error slowing was normal in children with ADHD, the ERN amplitude was diminished. The authors suggested that ADHD is correlated with a disruption in the brain's error checking system which leads to a failure of employing adequate cognitive control in speeded reaction tasks. This lack of cognitive control further prevents children with ADHD from predicting the likelihood of an error and to adapt their performance strategy accordingly.

1.3. Developmental dyslexia

For many decades, developmental dyslexia research was dominated from labs in English speaking countries (see Share, 2008 for a recent critique). As a consequence, it has long been assumed that dyslexia is typically characterized by a high error rate during reading. Studies in more regular orthographies, however, revealed that the symptoms of dyslexia are highly correlated with the transparency of certain orthographies. In one of his pioneering studies, Wimmer (1993) analyzed the reading behavior of German speaking dyslexic children in Grade 2, 3 and 4. He found that, independent of reading material (high-frequency words, pseudowords or continuous text), dyslexic children exhibited high reading accuracy, but extremely slow reading fluency. He, therefore, concluded that the typical problem of German speaking poor readers is a pervasive reading speed deficit. There is now an abundance of studies which support the critical role of transparency for defining dyslexic symptoms; whereas dyslexia in deep orthographies (e.g., English, Danish) is mainly characterized by high error rates, in transparent orthographies (e.g., Italian, Spanish, Finish, Norwegian, Dutch, German) dyslexia is defined by significantly prolonged reading latencies, whereas accuracy is relatively preserved (Seymour, Aro, Erskine, & COST Action A8 Network, 2003; Wimmer, 1993; Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Körne, 2003).

Many studies on reading and dyslexia revealed that different word characteristics differentially affected good and poor readers. Examples are the word frequency effect (e.g., Barca, Burani, Di Filippo, & Zoccolotti, 2006; Katz et al., 2005; Stenneken, Conrad, & Hutzler, 2005), the regularity effect (e.g., Coltheart & Rastle, 1994; Katz et al., 2005; Visser & Besner, 2001), and differences in nonword reading (e.g., Svensson & Jacobson, 2005; Wimmer, 1996; for review see Rack, Snowling, & Olson, 1992). Other well-established effects of dyslexic reading are the word length effect and the large-unit effect (Di Filippo, De Luca, Judica, Spinelli, & Zoccolotti, 2006; Juphard, Carbonnel, & Valdois, 2004; Landerl, Wimmer, & Frith, 1997; Martens & de Jong, 2006; Treiman, Goswami, & Bruck, 1990; Ziegler & Goswami, 2005; Ziegler & Perry, 1998; Ziegler et al., 2003; Zoccolotti et al., 2005).

1.3.1. The word length effect

The *word length effect* refers to the observation that the reading time of poor readers increases quasi-linearly with every additional letter, regardless of whether they read words or pseudowords. In contrast, proficient readers show hardly any length effects for words and only a moderate effect for pseudowords (Ferrand & New, 2003; Valdois et al., 2006; Weekes, 1997). This difference between normal and poor readers indicates that the latter typically rely on a serial decoding strategy for word recognition, whereas normal readers read whole words or large sublexical units in a parallel fashion (Di Filippo et al., 2006; Juphard et al., 2004; Landerl et al., 1997; Martens & de Jong, 2006; Ziegler et al., 2003; Zoccolotti et al., 2005). In trying to better understand the reading patterns of poor readers, Zoccolotti and collaborators (De Luca, Borrelli, Judica, Spinelli, & Zoccolotti, 2002; De Luca, Di Pace, Judica, Spinelli, & Zoccolotti, 1999) complemented accuracy and reaction time measures by examining the eye movements of Italian dyslexic and normal readers. Crucially, they demonstrated that the eye movements of dyslexic children only deviated from normal readers when the task required reading, whereas there was no group differences in non-reading control tasks. Hutzler, Kronbichler, Jacobs, and Wimmer (2006) expanded this finding. They reported a completely normal performance of poor readers in a visual search task. For task which requires reading, De Luca et al. (1999) showed that dyslexics (10–17 years) typically exhibit prolonged single fixation durations (290 ms, controls: 230 ms) and a doubled number of fixations per word. Furthermore, for the dyslexic readers, number of fixations significantly increased with increasing word length which was not the case for unimpaired readers. Eye movement studies in different regular orthographies underlined the hypothesized serial nature of the reading process in reading-disabled children (De Luca et al., 2002, 1999; Hutzler & Wimmer, 2004; MacKeben et al., 2004). In a recent study from our lab (Thaler, Heine, Engl, & Jacobs, in preparation), 50 disabled readers and 45 normal readers were tested during single word reading. All participants attended Grade 3–5 and had a mean age of 8.5 years. Children had to read single words with 3–12 letters on a computer screen while their eye movements were recorded. For normal readers, the average number of fixations increased from three fixations for words with three letters to four fixations for words with six letters and six fixations for words with twelve letters. Their reading time increased approximately 65 ms for each additional letter. In marked contrast, the reading time of reading-disabled children increased approximately 350 ms for each additional letter. On average, words with three letters were fixated three times, words with six letters seven times and words with twelve letters were fixated twelve times. These results suggest that disabled readers fixate every letter of a word at least once while normally developing children between Grade 3 and 5 start to read words by utilizing larger sublexical units. Thus, the notion of a serial decoding strategy of poor readers—at least in transparent orthographies—is generally supported. However, whether or not reading in regular orthographies is strictly letter-based or whether the grain size (Ziegler & Goswami, 2005) is influenced by orthography and/or linguistic fac-