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# Characterizing the morphosyntactic processing deficit and its relationship to phonology in developmental dyslexia

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ABSTRACT

This study explores the morphosyntactic processing deficit in developmental dyslexia, addressing the on-going debate on the linguistic nature of the disorder, and directly testing the hypothesis that the deficit is based on underlying processing difficulties, such as acoustic and/or phonological impairments. Short German sentences consisting of a pronoun and a verb, either correct or containing a morphosyntactic violation, were auditorily presented to 17 German-speaking adults with dyslexia, and 17 matched control participants, while an EEG was recorded. In order to investigate the interaction between low-level phonological processing and morphosyntactic processing, the verbal inflections were manipulated to consist of different levels of acoustic salience. The event-related potential (ERP) results confirm altered morphosyntactic processing in participants with dyslexia, especially when morphosyntactic violations are expressed by both lexical and inflectional changes. Moreover, ERP data on phoneme discrimination and behavioural data on phonemic awareness and verbal short-term memory reveal phonological deficits in dyslexic participants. However, a causal relationship between phonological and morphosyntactic processing was not conclusive, because anomalous morphosyntactic processing in dyslexia is not directly mediated by acoustic salience, rather it correlates with high-level phonological skills and is mediated by lexical cues.



## 1. Introduction

Developmental dyslexia is a specific and persistent difficulty in acquiring adequate reading and/or writing skills, in spite of normal intelligence, conventional classroom experience, and adequate socio-cultural opportunities. Although sensory processing and attentional deficits have often been reported as causal explanations for reading difficulties (Nicolson & Fawcett, 2007), there is a general belief that the core impairment is of a linguistic nature. The *Phonological Deficit Hypothesis* (Ramus et al., 2003; Snowling, 2000) is the most well-known and long-standing explanation for dyslexia, pointing to an underlying deficit in the processing and representation of speech sounds. Reading is related to phonology in that learning to read requires the mapping of letters to mental representations of the corresponding phonemes. Additionally, reading aloud a new and unfamiliar word requires the ability to identify and assemble the phonemic constituents and utter the word. Evidence for phonological impairments in dyslexia has been well documented. First, individuals with dyslexia show difficulties in tasks that require deliberate activation of phonological abilities, i.e., phonemic awareness, such as phoneme deletion or synthesis and rhyme detection (Bradley & Bryant, 1983; Stanovich & Siegel, 1994). Second, deficits have also been demonstrated in tasks depending on implicit phonological processing, such as tasks of verbal short-term memory (Jorm, 1983), particularly digit span and non-word repetition tasks (Stone & Brady, 1995). Finally, a third, widely demonstrated deficit in dyslexia concerns phonological recoding in lexical access, as assessed by rapid automatic naming (Catts, 1986).

This short review of phonological impairments in dyslexia evidences the existence of a phonological deficit and its contribution to reading disorders. What is still unclear, however, is the nature of these difficulties. The question is whether they constitute the primary deficit of the disorder or whether they stem from deviant perception of low-level auditory cues that constitute speech sounds. Originally it was proposed that individuals with

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dyslexia have problems perceiving and processing short and rapidly presented acoustic stimuli (Tallal, 1980). More recently, different acoustic dimensions characterised by dynamic changes, such as amplitude and frequency modulations, have received more attention (e.g., Goswami et al., 2002). According to both views, processing deficits at the acoustic level compromise the temporal and dynamic analyses of speech at the phoneme level, and thus limit the building of correct phoneme representations. With such constraints, the development of language skills, both oral and written, would be difficult. Several studies showed that individuals with dyslexia have difficulties in extracting discrete phonological representations from phonetic features embedded in the speech signal (Manis et al., 1997; Serniclaes, Sprenger-Charolles, Carre, & Demonet, 2001). In addition to behavioural studies, electrophysiological experiments using Mismatch Negativity (MMN) paradigms have investigated the presence of a phonemic discrimination deficit in dyslexia (for a review see Bishop, 2007). The MMN, as a measure of the brain's ability to detect differences between frequent standard and rare deviant stimuli, has often shown attenuated responses in individuals with dyslexia compared to controls, especially for stop consonant-vowel syllables (Hommet et al., 2009; Lachmann, Berti, Kujala, & Schröger, 2005; Schulte-Körne, Deimel, Bartling, & Remschmidt, 1998; Sharma et al., 2006). This field of literature, however, has also revealed discrepant results across studies, i.e. not supporting phoneme discrimination difficulties in dyslexia, most likely due to methodological inconsistencies (see Bishop, 2007).

In the study of dyslexia, other high-level linguistic domains such as semantic, morphological, and syntactic skills have not received the same attention as phonology, and have been only sporadically investigated. A few behavioural and electrophysiological studies have focused on semantic processing in dyslexia, mostly showing no impairments (Sabisch, Hahne, Glass, von Suchodoletz, & Friederici, 2006) or subtle, specific impairments (Betjemann & Keenan, 2008; Jednorog, Marchewka, Tacikowski, & Grabowska, 2010; Rüsseler, Becker, Johannes, & Münte, 2007). In most cases, however, the semantic difficulties could be traced back to anomalous phonological processing. For example, in a magnetoencephalography (MEG) study, good and poor readers (7–13 years old) were compared on their auditory perception of words with varying phonological contrasts in congruent versus incongruent sentence contexts (Mody, Wehner, & Ahlfors, 2008). The results showed that poor readers processed semantically incongruent sentences as being congruent in the phonologically similar condition (e.g., "The boy rolled the *doll*"; congruent word *ball*), but not in the phonological dissimilar condition (e.g., "The boy rolled the *hall*"; congruent word *ball*). Other MEG and event-related potential (ERP) experiments have reported similar phonetic–phonological deficits occurring while processing at semantic and lexical levels proceeds normally (Bonte & Blomert, 2004; Helenius et al., 2002).

Behavioural and electrophysiological studies have addressed morphosyntactic and syntactic skills in populations with dyslexia. Recent studies in children and adults with dyslexia revealed a lack of sensitivity to subject-verb agreement morphology (Rispens, Roeleven, & Koster, 2004), impaired production of inflectional morphology (Altmann, Lombardino, & Puranik, 2008; Joanisse, Manis, Keating, & Seidenberg, 2000) and weakness in morphological awareness tasks (Leikin & Hagit, 2006). Moreover, studies on dyslexia reported impaired comprehension and/or production of complex syntactic constructions, such as relative clauses, passive sentences or *wh*-questions (Barshalom, Crain, & Shankweiler, 1993; Guasti, Vernice, Barbieri, & Arosio, in press; Leikin & Assayag-Bouskila, 2004; Waltzman & Cairns, 2000). Additionally, studies conducted with preschool children at-risk for dyslexia have found developmental delays, particularly concerning perception and production of grammatical morphology (Scarborough, 1990; van Alphen et al., 2004). These studies, showing language delays before the development of a formal reading impairment, also imply that poor language skills in dyslexia cannot be simply due to the lack of exposure to printed text. Furthermore, electrophysiological studies have reported anomalous cortical responses in Hebrew-speaking adults with dyslexia when processing sentence components with different grammatical functions during a reading task (Breznitz & Leikin, 2000, 2001). Rüsseler et al. (2007) investigated the ERP response to syntactic violations in adults with dyslexia using a gender judgement task that followed the presentation of written word pairs formed by definite articles and nouns, which were matching or non-matching with respect to gender. The results showed that individuals with dyslexia differed from their matched controls in their response times and in the onset and the duration of the negativity elicited by gender disagreement. This generally indicates syntactic processing difficulties in dyslexia during reading. Moreover, electrophysiological anomalies have been found in response to the auditory presentation of (morpho-)syntactic violations in German children with dyslexia (Sabisch et al., 2006) and in Dutch (Rispens, Been, & Zwarts, 2006), and Italian (Cantiani, Lorusso, Perego, Molteni, & Guasti, 2012) adults with dyslexia. Sabisch et al. (2006) found that phrase structure violations elicited a similar P600 in control children and children with dyslexia. Instead of the early-starting bilaterally-distributed anterior negativity shown by control children, children with dyslexia presented a delayed, left-lateralised anterior negativity. The authors discuss this result as indicating that children with dyslexia experience a delay in the early, and presumably highly automatic, processes involved in phrase structure building, and a lack of recognition of the prosodic cues that can facilitate syntactic processing (reflected in the control participants' Right Anterior Negativity). Rispens et al. (2006) observed subtle differences between the ERP responses to subject-verb number agreement violations of adults with and without dyslexia. These differences were particularly related to the latency of the P600 component, which peaked later in the group with dyslexia, compared to the control group. Finally, using the same kind of violations in Italian, Cantiani et al. (2012) found different ERP patterns in the group with dyslexia compared to the control group: that is, a P600 for the control participants and a delayed P600 following a N400-like component for the group with dyslexia. The authors interpreted the result of a delayed P600 in participants with dyslexia as an indicator of a general slower processing speed. The finding of an additional N400-like component in the sample with dyslexia has been suggested to reflect an attempt to compensate for difficulties in constructing implicit rules to handle inflectional morphology. In particular, the hypothesised compensatory strategies concern reliance on storage or the need to exploit aspects of lexical-semantic predictability.

As is evident from the reported studies, deficits in several linguistic domains have been observed in dyslexia, particularly concerning phonology and morphosyntax/syntax. What is still unclear, however, is the relationship between these two linguistic domains. A hypothesis to explain morphosyntactic deficits in dyslexia, might trace them back to phonological or acoustic processing deficits. Such an approach has been extensively investigated in the literature on Specific Language Impairment (SLI). SLI is defined as a specific disorder in language acquisition, with deficits occurring in different linguistic domains (i.e., phonology, lexicon/semantics, morphosyntax/syntax and pragmatics), thus it shares many symptoms characteristic of dyslexia (Bishop & Snowling, 2004; Catts, Adlof, Hogan, & Weismer, 2005; Flax et al. 2003; McArthur, Hogben, Edwards, Heath, & Mengler, 2000). One of the main explanations of SLI, the *Surface Hypothesis*, traces syntactic and morphological difficulties in SLI children back to low-level phonological processing problems (i.e., Leonard, Eyer, Bedore, & Grela, 1997; Leonard, 1998). Employing a connectionist approach, it