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Speech Recognition in Noise by Children with and without Dyslexia: How is it Related to Reading?

Susan Nittrouer*, Letitia M. Krieg, Joanna H. Lowenstein

University of Florida, United States

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ABSTRACT

Purpose: Developmental dyslexia is commonly viewed as a phonological deficit that makes it difficult to decode written language. But children with dyslexia typically exhibit other problems, as well, including poor speech recognition in noise. The purpose of this study was to examine whether the speech-in-noise problems of children with dyslexia are related to their reading problems, and if so, if a common underlying factor might explain both. The specific hypothesis examined was that a spectral processing disorder results in these children receiving smeared signals, which could explain both the diminished sensitivity to phonological structure – leading to reading problems – and the speech recognition in noise difficulties. The alternative hypothesis tested in this study was that children with dyslexia simply have broadly based language deficits.
Participants: Ninety-seven children between the ages of 7 years; 10 months and 12 years; 9 months participated: 46 with dyslexia and 51 without dyslexia.
Methods: Children were tested on two dependent measures: word reading and recognition in noise with two types of sentence materials: as unprocessed (UP) signals, and as spectrally smeared (SM) signals. Data were collected for four predictor variables: phonological awareness, vocabulary, grammatical knowledge, and digit span.
Results: Children with dyslexia showed deficits on both dependent and all predictor variables. Their scores for speech recognition in noise were poorer than those of children without dyslexia for both the UP and SM signals, but by equivalent amounts across signal conditions indicating that they were not disproportionately hindered by spectral distortion. Correlation analyses on scores from children with dyslexia showed that reading ability and speech-in-noise recognition were only mildly correlated, and each skill was related to different underlying abilities.
Conclusions: No substantial evidence was found to support the suggestion that the reading and speech recognition in noise problems of children with dyslexia arise from a single factor that could be defined as a spectral processing disorder. The reading and speech recognition in noise deficits of these children appeared to be largely independent.

What this paper adds?

Two clear trends are apparent across research studies into developmental dyslexia: (1) Children with dyslexia display a variety of deficits beyond just reading problems; and (2) These children appear to have subtle and as-yet unspecified perceptual processing problems that may account for their reading problems and other deficits. This paper adds to our understanding of these issues by

* Corresponding author at: Department of Speech, Language, and Hearing Sciences, University of Florida, 1225 Center Drive, Room 2147, PO Box 100174, Gainesville, FL 32610, United States.
E-mail addresses: snittrouer@ufl.edu, snittrouer@cox.net (S. Nittrouer).

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examining reading skill and one other deficit commonly found for children with dyslexia: problems recognizing speech in noise. The mirror hypotheses were posed that either a common source of difficulty – a spectral processing disorder – could explain both the reading and speech-recognition-in-noise deficits, or the deficits of these children may be largely independent of each other, even if comorbid. This paper reveals that for children with dyslexia the degree of severity in reading deficit and difficulty recognizing speech in noise are largely uncorrelated, and dependent on different levels of linguistic structure, with word-internal phonological structure playing the most important role in reading and lexical structure playing the larger role in speech recognition in noise. Thus it must be concluded that these children have broadly based language deficits, that although often comorbid are not necessarily related.

1. Introduction

Dyslexia is conventionally defined as an impairment in reading, in spite of there having been ample educational opportunity to learn and no apparent sensory or cognitive obstacle to that learning (e.g., Lyon, Shaywitz, & Shaywitz, 2003; Snowling, 2000). Although accurate in description, this definition places the locus of the problem solely on difficulty with visual forms of language. It may reflect the historical roots of the clinical diagnosis, which can be traced back more than a century to a time when dyslexia was viewed as a visual disturbance (Hinshelwood, 1900, 1917; Orton, 1928; Stephenson, 1907). But this view of dyslexia came under scrutiny in the latter half of the twentieth century when psycholinguists discovered that individuals with dyslexia commonly have difficulty recognizing word-internal, or phonological, structure (e.g., Bradley & Bryant, 1983; Fox & Routh, 1980; Liberman, 1973; Liberman, Shankweiler, Orlando, Harris, & Berti, 1971; Shankweiler & Liberman, 1972). In fact, the prevalence of phonological deficits among individuals with dyslexia is so striking that the disorder has been described as arising from a core phonological deficit (e.g., Ramus et al., 2003; Snowling, 2000; Vellutino, Fletcher, Snowling, & Scanlon, 2004), thus supplanting visual disturbances as the ostensible crux of the problem. With attention displaced from visual processing as the locus of the disorder, the question might legitimately be asked of how this impairment would be characterized, if we were to encounter it anew today. Would it be defined as primarily a reading disability? Or would it be seen as a multifaceted language problem, with reading difficulty as just one component of a broader impairment?

The legitimacy of that question hinges on the fact that individuals with dyslexia display many deficits related to language processing, beyond just reading. Dyslexia has been associated with a higher prevalence of poor short-term memory for verbal materials (Brady, Shankweiler, & Mann, 1983; Mann & Liberman, 1984; Nittrouer & Miller, 1999; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979), slow lexical retrieval (Law, Vandermosten, Ghesquiére, & Wouters, 2014; Stanovich & Siegel, 1994; Súarez-Coalla & Cuetos, 2015; Swan & Goswami, 1997), diminished speech intelligibility (Catts, 1989; Lewis et al., 2011; Smith, Pennington, Boada, & Shriberg, 2005), and poor recognition of spoken language, especially under conditions of signal degradation (Brady, Shankweiler, & Mann, 1983; Dole, Hoen, & Meunier, 2012; Johnson, Pennington, Lowenstein, & Nittrouer, 2011; Nittrouer & Lowenstein, 2013; Ziegler, Pech-Georgel, George, & Lorenzi, 2009). The breadth of language-related difficulties demonstrated by individuals with dyslexia suggests that a broad approach needs to be taken to understanding the disorder. One component of that approach should involve investigating the interconnectedness of the separately measured deficits to see if all children with dyslexia exhibit the same pattern of deficit across language skills. A second component of the study of dyslexia should involve searching for a potential common source of deficit across language skills. The current study focused on the potential relationship between two deficits previously observed in children with dyslexia, poor reading abilities and poor speech recognition in noise, and on exploring a potential common source of both deficits.

1.1. Speech perception in noise by children with dyslexia

In 1983, Brady, Shankweiler, and Mann tested the hypothesis that dyslexia may have at its source perceptual-processing problems, which could explain the phonological deficit exhibited by so many children with dyslexia. Specifically, these authors used a paradigm described earlier by Rabbitt (1968), showing that broadband noise added to recorded digits impairs the recall of those digits, even when added at a level that does not impair recognition of the digits. Rabbitt's conclusion from individuals with typical language abilities was that any condition that hinders perceptual processing of the sensory input impairs language functioning. Brady and colleagues used that finding to suggest that children with dyslexia may have persistent perceptual processing difficulties that interfere with their abilities to discover phonological structure in the acoustic speech signal, which would give rise to the phonological deficits. This hypothesis was tested by asking children with and without dyslexia to repeat words in quiet and in noise at a 0 dB signal-to-noise ratio. In quiet, accuracy was similar across groups, but when those words were embedded in noise, children with dyslexia showed significantly greater diminishment in recognition than children without dyslexia. From this finding the authors concluded that children with dyslexia have perceptual processing problems that hinder their abilities to recover clear speech from noisy signals and to form phonological representations. These ill-defined phonological representations subsequently make it more difficult for listeners with dyslexia to learn to read. According to this account, problems with reading and problems with speech-in-noise recognition arise from a common source: perceptual processing difficulties.

Since that study was conducted, a fair number of other investigators have similarly observed that children with dyslexia exhibit difficulty recognizing speech in noise (Bradlow, Kraus, & Hayes, 2003; Calcus, Deltenre, Colin, & Kolinsky, 2017; Ziegler et al., 2009). However, a few investigators have failed to replicate this effect, reporting instead that children with and without dyslexia are affected similarly by noise (Messaoud-Galusi, Hazan, & Rosen, 2011; Nittrouer, Shune, & Lowenstein, 2011). One study (Boets et al., 2011) revealed impaired speech-in-noise recognition for children at familial risk of dyslexia in kindergarten, but no deficit in first grade. Thus, a generally accepted description of the speech recognition in noise problems of children with dyslexia continues to elude the