Research in Developmental Disabilities 70 (2017) 138–151

Contents lists available at ScienceDirect

Research in Developmental Disabilities

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

Research paper

Do prereaders' auditory processing and speech perception predict later literacy?

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ARTICLE INFO

Keywords:
Dyslexia
Auditory processing
Speech perception
Prereaders

ABSTRACT

Developmental dyslexia has frequently been linked to deficits in auditory processing and speech perception. However, the presence and precise nature of these deficits and the direction of their relation with reading, remains debated. In this longitudinal study, 87 five-year-olds at high and low family risk for dyslexia were followed before and during different stages of reading acquisition. The processing of different auditory cues was investigated, together with performance on speech perception and phonology and reading. Results show no effect of family risk for dyslexia on prereading auditory processing and speech perception skills. However, a relation is present between the performance on these skills in kindergarten and later phonology and literacy. In particular, links are found with the auditory processing of cues characteristic for the temporal speech amplitude envelope, rather than with other auditory cues important for speech intelligibility. Hereby, cues embedded in the speech amplitude envelope show to be related to a broad range of phonological precursors for reading. In addition, speech-in-noise perception demonstrates to operate as the most contributing factor for later phonological awareness and to be a predictor for reading mediated by the association with phonology. This study provides behavioral support for the link between prereading speech amplitude envelope processing and speech perception for future phonology and reading.

What this paper adds?

- 87 prereaders are followed before and during different step of reading acquisition
- No effect of family risk for dyslexia on prereading auditory and speech processing
- Processing of speech amplitude envelope cues are linked to later phonological skills
- Speech-in-noise operates as a predictor for literacy mediated by phonology

1. Introduction

Developmental dyslexia is a neurological learning disorder which manifests through severe and persistent reading and spelling problems, despite adequate intelligence and education (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Dyslexia is often genetically based, but it is not a monogenic disorder linked to the mutation of only one single gene. Inheritance seems to be based rather on a

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http://dx.doi.org/10.1016/j.ridd.2017.09.005
Received 4 January 2016; Received in revised form 31 July 2017; Accepted 9 September 2017

multifactorial genetic etiology in combination with a range of risk factors (Olson, 2006). Individually, these genetic variants may have a small likelihood of developing the condition, but combined they can create a high risk (Bishop, 2015). Therefore, individuals with dyslexic relatives are more likely than others to develop reading and spelling problems. It has been widely shown that phonological skills – that is, the ability to manipulate small speech units such as syllables and phonemes – are disrupted in the majority of individuals with dyslexia (Snowling, 2000). Yet, the exact origin of dyslexia remains largely unknown and remains debated by different theories. In recent decades evidence has been provided in favor of theories proposing that sensory deficits in auditory processing underlie developmental dyslexia (e.g. Goswami, 2011; Stein, 2001; Tallal, 2004). Most of these theories commonly suggest a deviant perception of certain auditory cues and subsequently of speech as an underlying cause for the difficulties in the use and representation of phonological information. More specifically, it is thought that impaired auditory processing impedes speech perception by degrading the ability to accurately segment the speech stream into its important phonetic components such as rhymes, syllables and phonemes. The latter leads to problems in pairing speech sounds with letters, a prerequisite for learning to read (Snowling, 2000). One of the early auditory theories posits that individuals with dyslexia have difficulties in processing rapidly changing information in speech, such as the spectral changes of formant transitions in stop consonants (Farmer & Klein, 1995; Tallal & Gaab, 2006). Another hypothesis states that the nature of the auditory processing deficit in dyslexia specifically relates to temporal, dynamic features in speech, i.e. cues that vary over time such as amplitude and frequency modulations (Studdert-Kennedy & Mody, 1995; Talcott et al., 2000; Witton et al., 1998). According to a slightly different hypothesis, difficulties particularly occur with the processing of amplitude modulations at relatively low temporal rates (Goswami et al., 2002). More precisely, impairments in discriminating the rate of change in amplitude at the onset of a speech sound (i.e., rise time) would occur in individuals with dyslexia, affecting the detection of supra-segmental cues such as speech rhythm, intonation and stress. Indeed, rhythm as assessed by musical metrical perception has been shown to predict later phonology and reading development most probably via speech prosody (Goswami, Huss, Mead, Fosker, & Verney, 2013; Huss, Verney, Fosker, Mead, & Goswami, 2011). Next to deviances regarding the perception of auditory cues to rhythm, also impairments are found in tapping to a rhythmic beat (Cumming, Wilson, Leong, Colling, & Goswami, 2015). Additionally, a deviant detection of aspiration contrasts in individuals with dyslexia in tone languages has been observed (Cheung et al., 2009). In addition, Goswami (2011) recently proposed an integrative theoretical framework that emphasizes the importance of auditory processing at the level of the temporal speech amplitude envelope. According to this theory, individuals with dyslexia are unable to track temporal fluctuations of the speech amplitude envelope. Together with deficits in the auditory processing of basic auditory cues and temporal dynamic features, it is hypothesized that individuals with dyslexia exhibit difficulties with the perception of speech cues and speech stimuli such as words and sentences (e.g. Pennala et al., 2013; Vandermosten et al., 2011; Ziegler, Pech-Georgel, George, & Lorenzi, 2009). Speech perception difficulties may especially arise when speech intelligibility is challenged by competing background noise, which is the most common everyday listening situation. Coincidentally, it is in this particular situation that speech intelligibility relies the most on the tracking of the temporal speech amplitude envelope (Zion Golumbic, Poeppel, & Schroeder, 2012). In the current paper we will jointly refer to the above mentioned auditory approaches as the 'dynamic auditory processing theory'.

The dynamic auditory processing theory has been supported by many behavioral studies reporting difficulties in individuals with dyslexia on auditory temporal processing (e.g. Goswami et al., 2002; Talcott & Witton, 2002; see Hämäläinen, Salminen, & Leppänen, 2012 for an overview) and speech perception tasks (e.g. Vandermosten et al., 2010, 2011; Ziegler, Pech-Georgel, George, & Lorenzi, 2009). Additionally, it has been shown that auditory processing and speech perception skills predict reading development (e.g. Boets et al., 2011; Hämäläinen et al., 2013; Huss et al., 2011) Two recent longitudinal studies in prereaders showed by recording brain event-related potentials (ERPs), that auditory processing and speech perception at preschool age and even in infancy predicted phonoloical and prereading skills, as well as later reading and writing skills at school-age. (Lyytinen, Erskine, Hämäläinen, Torppa, & Ronimus, 2015; van der Leij, 2013). These studies suggest that early auditory processing exerts an effect on critical processes for learning to read and therefore might play a role in the development of dyslexia. However, many unresolved questions remain.

First, in dyslexia literature poorer performance has been reported in individuals with dyslexia on a variety of auditory tasks, but there is no consensus regarding which auditory features specifically account for processing problems. A comprehensive review of 61 studies showed that the processing of stimuli such as amplitude and frequency modulations, varying rise times and changes in syllable and phoneme duration, are often found to be deviant in individuals with dyslexia (Hämäläinen et al., 2012). Yet, most of these studies investigated only one kind of auditory feature in the same population. In order to better understand the nature of these dynamic auditory processing problems, a study that differentiates between speech amplitude envelope cues and other dynamically changing cues in the same group of participants is necessary.

Second, although basic auditory processing deficits as well as speech perception deficits have been found in a large number of studies, the literature often fails to find a clear relation between both deficits (Rosen, 2003). The fact that the causal link between impaired basic auditory processing and difficulties with speech perception as postulated by the dynamic auditory processing theory has not yet been demonstrated, questions the viability of the theory.

A final remaining question involves the extent to which differences observed in individuals with dyslexia are related to the cause or the consequence of the disability itself. Most studies were carried out in adults and school-aged children with an age of seven years or older (Hämäläinen et al., 2012) and were only performed at one single time point, which makes it impossible to address this question. In addition, the studies that did investigate prereading children in a longitudinal design often examined either basic auditory processing (Plakas, van Zuijen, van Leeuwen, Thomson, & van der Leij, 2013) or speech perception (Guttorm, Leppänen, Poikkeus, Eklund, & Lyytinen, 2005; Noordenbos, Segers, Serniclaes, Mitterer, & Verhoeven, 2012) instead of both. Furthermore, in most cases the auditory features that were studied in prereaders (Boets, Wouters, van Wieringen, & Ghesquière, 2007; Leppänen et al.,