Research in Developmental Disabilities 47 (2015) 318–333

Contents lists available at ScienceDirect

Research in Developmental Disabilities

Present and past: Can writing abilities in school children be associated with their auditory discrimination capacities in infancy?

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ARTICLE INFO

Article history:
Received 4 March 2015
Received in revised form 24 September 2015
Accepted 6 October 2015
Available online 23 October 2015

Keywords:
Mismatch response
Auditory discrimination
Writing abilities
Infants
School children
Longitudinal

ABSTRACT

Literacy acquisition is highly associated with auditory processing abilities, such as auditory discrimination. The event-related potential Mismatch Response (MMR) is an indicator for cortical auditory discrimination abilities and it has been found to be reduced in individuals with reading and writing impairments and also in infants at risk for these impairments. The goal of the present study was to analyze the relationship between auditory speech discrimination in infancy and writing abilities at school age within subjects, and to determine when auditory speech discrimination differences, relevant for later writing abilities, start to develop. We analyzed the MMR registered in response to natural syllables in German children with and without writing problems at two points during development, that is, at school age and at infancy, namely at age 1 month and 5 months. We observed MMR related auditory discrimination differences between infants with and without later writing problems, starting to develop at age 5 months–an age when infants begin to establish language-specific phoneme representations. At school age, these children with and without writing problems also showed auditory discrimination differences, reflected in the MMR, confirming a relationship between writing and auditory speech processing skills. Thus, writing problems at school age are, at least, partly grounded in auditory discrimination problems developing already during the first months of life.

1. Introduction

Reading and writing are two of the most important cultural abilities, not only for children during schooling, but also for later everyday life challenges. According to the Diagnostic and Statistical Manual of Mental Disorders: DSM-V (American Psychiatric Association, 2013), impairments in reading and/or writing belong to the category of specific learning disorders (SLD) and occur in 4–5% of German school children (Schulte-Körne & Remschmidt, 2003). SLD are diagnosed if reduced

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http://dx.doi.org/10.1016/j.ridd.2015.10.002
0891-4222/

reading and/or writing abilities cannot be explained by intellectual disabilities, uncorrected visual or auditory acuity, and other mental or neurological disorders (American Psychiatric Association, 2013). SLD are neurodevelopmental disorders of biological origin leading to difficulties to perceive or process verbal or non-verbal information efficiently (American Psychiatric Association, 2013).

According to the model of Vellutino, Fletcher, Snowling, and Scanlon (2004), different types of knowledge and cognitive abilities are required for learning to read and write. Here, importantly, phonological coding abilities are thought to influence the successful formation of sublexical knowledge important for literacy acquisition (Vellutino et al., 2004). Phonological coding and processing deficits are in the focus of the majority of theories on the development of reading and writing impairments. The *phonological deficit theory*, as one of the most widely accepted views, postulates a specific phonological processing deficit (Snowling, 1998). Phonological processing involves phoneme identification, phoneme discrimination, and verbal short-term memory, and has been discussed as one of the main abilities for success in learning to read and write. Preschool phonological abilities were shown to serve as one of the best predictors for later literacy acquisition (Mann & Liberman, 1984; Moll et al., 2014; Snowling, 1998). However, there is still a debate on whether phonological deficits cause reading and writing difficulties or whether they are secondary to more general auditory processing deficits (e.g., Lachmann, Berti, Kujala, & Schroger, 2005; Richardson, Thomson, Scott, & Goswami, 2004). The *rapid auditory processing deficit theory* generally approves of phonological deficits in individuals with reading and writing impairments, but postulates a different core deficit. Here, more basic auditory processing deficits of short or rapidly varying sounds are thought to be the underlying cause for reading and writing impairments (Tallal, 1980; Tallal, Miller, & Fitch, 1993). Some studies, using non-speech stimuli, could confirm the *rapid auditory processing deficit theory* in children (e.g., Cohen-Mimran & Sapir, 2007) and adults with reading and writing impairments (e.g., Ben-Artzi, Fostick, & Babkoff, 2005), but others failed to find such evidence (e.g., Breier, Fletcher, Foorman, Klaas, & Gray, 2003). Interestingly, there is longitudinal evidence showing that both postulated deficits uniquely contribute to reading and writing impairments (Boets et al., 2011), suggesting a more general auditory deficit including phonological and rapid auditory processing in individuals with SLD.

Electrophysiological methods are widely used to investigate auditory deficits in SLD. Specifically, cortical auditory discrimination can be investigated by an event-related brain potential (ERP) component called Mismatch Negativity (MMN), which was first discovered by Näätänen, Gaillard, and Mäntysalo (1978) in adult listeners. The authors found that in a sequence of stimuli (i.e., standards), a differing stimulus (i.e., deviant) normally elicits a negative Mismatch Response (MMR) at about 100–200 ms after stimulus onset in the adult brain. The MMR has been shown to be relatively independent of conscious attention (Alho, Woods, & Algazi, 1994; Alho, Woods, Algazi, & Näätänen, 1992; Näätänen, Paavilainen, Tiitinen, Djiang, & Alho, 1993), making it suitable for investigating auditory discrimination not only in adults, but also in infants (e.g., Alho, Sainio, Sajaniemi, Reinikainen, & Näätänen, 1990; Molfese, 1997). Since then, it has been shown that the MMR in the developing brain can also be positive in polarity (e.g., Friederici, Friedrich, & Weber, 2002; Friedrich, Weber, & Friederici, 2004; Leppänen et al., 2004; Trainor et al., 2003). The positive MMR has been associated with individual neural maturation of infants (Mueller, Friederici, & Männel, 2012). For example, He, Hotson, and Trainor (2007) found a developmental shift from a positive MMR in 2-month-old infants to a negative, adult-like MMR in 4-month-old infants. At the age of 3 months a coexistence of a positive and negative MMR was observed, indicating a transition from positivity to negativity during development (He et al., 2007). However, stimulus-related factors, such as length of the inter-stimulus interval (ISI) and magnitude of discriminability between standard and deviant stimuli can lead to the elicitation of a positive MMR even in preschool and older children (Ahmmed, Clarke, & Adams, 2008; Lee et al., 2012), suggesting that a positive MMR is not only specific for infants. In studies on individuals with reading and writing impairments, the MMR has been extensively used to investigate deficient auditory discrimination abilities. The *phonological deficit theory* would predict reduced MMRs in response to speech sounds, but not in response to nonverbal sounds. In line, some studies report significantly reduced negative MMR amplitudes in German school children and adults with reading and writing impairments in response to speech sounds, but not in response to nonverbal sounds (Paul, Bott, Heim, Wienbruch, & Elbert, 2006; Schulte-Körne, Deimel, Bartling, & Remschmidt, 1998). Furthermore, some studies did not find reduced MMRs in response to duration changes during the processing of nonverbal sounds in individuals with reading and writing impairments (Baldeweg, Richardson, Watkins, Foale, & Gruzelier, 1999; Kujala, Lovio, Lepistö, Laasonen, & Näätänen, 2006). These findings would speak in favor of a core phonological deficit (Snowling, 1998) and against a more general auditory processing deficit of short or rapidly varying sounds (Tallal, 1980). However, there are also studies supporting the *rapid auditory processing deficit theory*, finding reduced negative MMRs in individuals with reading and writing impairments in response to duration changes of both, speech and nonverbal sounds (Corbera, Escera, & Artigas, 2006; Huttunen-Scott, Kaartinen, Tolvanen, & Lyytinen, 2008; Lovio, Näätänen, & Kujala, 2010). Additionally, in individuals with reading and writing impairments, there is evidence for deficits in the discrimination of frequency changes (Baldeweg et al., 1999; Kujala et al., 2006), but, again, results are inconsistent (for reviews, see Bishop, 2007; Schulte-Körne & Bruder, 2010). Thus, the current evidence does not provide the ground to decide for or against one of the above mentioned theories, but generally suggests impaired auditory processing in individuals with reading and writing difficulties, evolving early in development.

Studies with preliterate individuals with familial risk for reading and writing impairment showed that 5-year-old kindergarteners at risk for reading and writing impairments differ in their MMR to speech and nonverbal sounds from their peers without such risks (Maurer, Bucher, Brem, & Brandeis, 2003a). Already at age 6 months, differences between the MMR of at risk and not at risk infants in responses to short and long vowels (/ka/ vs. /kaa/) can be reported, which, however, were not yet present in newborns (Pihko et al., 1999). Confirming these results, Leppänen et al. (2002) demonstrated different