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Research Report

Can reading rate acceleration improve error monitoring and cognitive abilities underlying reading in adolescents with reading difficulties and in typical readers?

Tzipi Horowitz-Kraus[a,b,*], Zvia Breznitz[a]

[a]The Edmond J. Safra Brain Research Center for the Study of Learning Disabilities, Faculty of Education, University of Haifa, Haifa, Israel

[b]Pediatric Neuroimaging Research Consortium, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, United States

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ABSTRACT

Dyslexia is characterized by slow, inaccurate reading and by deficits in executive functions. The deficit in reading is exemplified by impaired error monitoring, which can be specifically shown through neuroimaging, in changes in Error-/Correct-related negativities (ERN/CRN). The current study aimed to investigate whether a reading intervention program (Reading Acceleration Program, or RAP) could improve overall reading, as well as error monitoring and other cognitive abilities underlying reading, in adolescents with reading difficulties. Participants with reading difficulties and typical readers were trained with the RAP for 8 weeks. Their reading and error monitoring were characterized both behaviorally and electrophysiologically through a lexical decision task. Behaviorally, the reading training improved "contextual reading speed" and decreased reading errors in both groups. Improvements were also seen in speed of processing, memory and visual screening. Electrophysiologically, ERN increased in both groups following training, but the increase was significantly greater in the participants with reading difficulties. Furthermore, an association between the improvement in reading speed and the change in difference between ERN and CRN amplitudes following training was seen in participants with reading difficulties. These results indicate that improving deficits in error monitoring and speed of processing are possible underlying mechanisms of the RAP intervention. We suggest that ERN is a good candidate for use as a measurement in evaluating the effect of reading training in typical and disabled readers.

*Corresponding author at: Cincinnati Children's Research Foundation, Pediatric Neuroimaging Research Consortium, Cincinnati Children's Hospital Medical Center, 3333 Burnet Ave, Cincinnati, OH 45229-3039, United States. Fax: +1 513 803 1911.
E-mail address: Tzipi.Horowitz-Kraus@cchmc.org (T. Horowitz-Kraus).

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1. Introduction

Developmental Reading Disability (RD) is a difficulty in acquiring fluent reading skill (Fletcher et al., 2007). The definition of RD depends on the criteria applied (e.g., low reading achievements, discrepancy between verbal and non-verbal ability, limited response to intervention, etc.) (Fletcher et al., 2007). Individuals with RD also share deficits in other cognitive domains, such as working memory and speed-of-processing (Breznitz and Misra, 2003). In addition to these academic and functional issues, children with untreated RD are at increased risk for emotional and social problems as well as for juvenile delinquency (Johnson, 2002). RD continues into adulthood despite remedial intervention and repeated exposure to written language (Breznitz, 2006).

Reading is a higher-order cognitive ability that relies on phonology, orthography and semantics, and also on more basic cognitive abilities such as working memory (De Jong, 1998), speed measures (Breznitz and Misra, 2003), the ability to switch/shift attention and cognitive control (inhibition and attention) (Houde et al., 2010). In a previous study, we found that by using the Reading Acceleration Program (RAP) (Breznitz andNevat, 2004), a speed-of-processing and working memory-based training program, we saw improvements in reading ability, working memory and error monitoring in adults with RD (Horowitz-Kraus and Breznitz, 2010).

RAP is a computer-based program that manipulates the rate of the reading materials presented to each individual, based on his or her self-paced reading rate, and in a time-constrained manner. The program has been shown to minimize the discrepancy between the potential reading abilities and the actual reading performance of each individual (Breznitz, 2006). As a result of RAP training, the reading speed, word-decoding accuracy and reading comprehension improved in individuals with dyslexia and in typical readers (Breznitz 1997a, 1997b), for both young readers (Breznitz, 1987, 1997a, 1997b, 1992,) and adult readers (Breznitz 2006; Breznitz, 2008; Horowitz-Kraus and Breznitz, 2010; Breznitz and Leikin, 2001). The effect of RAP has been observed in several orthographies as well: Hebrew (Breznitz et al., 2013; Breznitz and Berman, 2003; Horowitz-Kraus and Breznitz, 2010), English (Niedo et al., in press), German (Korinth et al., 2009) and Dutch (Snellings et al., 2009). It was suggested that RAP training leads to increased attention span, reduced distractibility, (Breznitz, 1997b; Breznitz and Berman, 2003), increased reliance on larger phonological chunks of information (see Grain Size Theory by Ziegler and Goswami (2005)), and engaged working memory (Breznitz, 1997a; Breznitz and Share, 1992). A recent study validated the effect of RAP training by showing that RAP training significantly reduced decoding errors, induced reading fluency and increased reading comprehension in 40 adults with dyslexia and 40 age-matched typical readers, as compared to a control group of 15 dyslexics and 15 typical readers who trained on the same reading materials but without the acceleration condition (Breznitz et al., 2013). The positive effects, especially the improvement in reading comprehension, persisted long-term (at 6 month follow-up examination). It was suggested that, due to the forced acceleration, readers adjusted by processing more meaningful units of information at a time.

One way to test the effect of RAP on reading is by examining the error-detection monitoring mechanism after individuals commit reading errors (Horowitz-Kraus and Breznitz, 2008; 2011; Horowitz-Kraus, 2011). The error-detection system is a cognitive mechanism that is activated following a response to a given stimulus (Falkenstein et al., 1991). It is represented electrophysiologically by two negative Event-related Potential (ERP) components: Error-related Negativity (ERN) after erroneous responses, and Correct-related Negativity (CRN) after correct responses (Falkenstein et al., 1991; Gehring et al., 1993; Pailing and Segalowitz, 2004). Different explanations have been put forth to account for the mechanisms underlying the activation of the error-detection components: the conflict theory (Yeung, Cohen, and Botvinick, 2004), the negative feedback signal theory (Miltner, Braun, and Coles, 1997), the learning reinforcement theory (Holroyd and Coles, 2002), the impulsive responses theory (Herrmann et al., 2004) and the mismatch theory (Falkenstein et al., 1991). The mismatch theory suggests that the ERN component is evoked when the neural representations of the desired response do not match those of the actual response. Bernstein and colleagues suggested that the degree of discrepancy between the actual and desired responses, would be reflected in the ERN amplitudes (Bernstein, Scheffers, and Coles, 1995). The learning reinforcement theory states that, following learning, the mismatch gets larger, which results in an increase of ERN. In our previous electroencephalographic (EEG) study, adults with RD underwent 8 weeks of RAP training and experienced increased ERN when making reading errors, as well as a faster reading rate, suggesting an improvement in error monitoring (Horowitz-Kraus and Breznitz, 2010). We suggested that individuals with RD experience a "bottleneck" in their working memory system that impedes processing of words and decoding, thus preventing the construction of a stable mental lexicon (Breznitz and Share, 1992). We further suggested that the post-training increase in ERN and the decreased difference between ERN and CRN amplitudes might be due to an improvement in working memory, thereby allowing readers to overcome the bottleneck and experience an improvement in speed of processing (Horowitz-Kraus and Breznitz, 2010; Breznitz and Share, 1992). According to the self-teaching theory, the phonological deficit may prevent the brain from constructing a stable mental lexicon (Share, 2008). Therefore, the fast reading pace of RAP may result in the construction of a mental lexicon in adults that is able to improve the mismatch when a reading error is committed (Horowitz-Kraus and Breznitz, 2008). The increase in ERN and the increase in reading rate were not seen in the control groups – those participants (both RD and TRs) who read the same RAP materials but without the acceleration condition (Horowitz-Kraus and Breznitz, 2010).

Differences in error-monitoring also have been found between adolescents with RD and typical readers (TR) (Horowitz-Kraus, 2011). Adolescents with RD had smaller ERN and smaller ERN–CRN differences than their TR peers, though the differences were smaller than those seen between adults with RD and in adult TRs (Horowitz-Kraus, 2011). We assumed that the differences between the two age groups were due to the immature mental lexicon of adolescents (Horowitz-Kraus, 2011).