Temporal organization during oral reading in children and adolescents who stutter

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Reading aloud is an essential part of school education. A group that is highly challenged by reading aloud, but which is rarely examined in relation to reading abilities in the literature, is the population of children with speech fluency disorders, such as stuttering. Here, speech production is particularly affected while comprehension processes are largely preserved (Janssen et al., 1983). Stuttering has a prevalence of about 2% in the school-age population (Yairi & Ambrose, 2013). The breakdown of speech fluency that is symptomatic for stuttering has been linked to malfunctioning timing mechanisms (see Etchell et al., 2014, for review) causing timing abnormalities in the verbal (e.g. Max & Gracco, 2005) and non-verbal (e.g. Falk et al., 2015) domain, as well as altered prosodic patterns (e.g., intonational patterns, Arbisi-Kelm, 2010; Bergmann, 1986).

Therefore, in the present study we aimed at pinpointing whether some dimensions of temporal organization in reading aloud performances are especially affected by stuttering in young individuals who stutter. In particular, we investigated 1) prosodic phrasing patterns, that is, the number and quality of phrasal boundaries (Pierrehumbert, 1980), providing information about the local temporal organization of the text, and 2) hierarchical temporal structure, measured via Allan Factor analysis, a new measure in the literature to investigate different speech styles and contexts that displays the global temporal organization of speech across time (e.g., Falk & Kello, 2017). We hypothesize to find altered patterns of temporal organization of read text in individuals who stutter, for example, stronger prosodic phrasing (i.e. more and shorter phrases), and differences to the control group in global temporal organization. By testing children (9-12) and adolescents (13-16), we also aimed to investigate the development of reading performance across age groups.

26 German-speaking children (CWS, 2 females) and adolescents (AWS, 2 females) who stutter and a control group consisting of 26 age- and sex-matched German-speaking children (CTF) and adolescents (ATF) with typically fluent speech development participated in the study. Children had a mean age of 10.85 years and adolescents were 14.92 years on average. Participants had no language- or attention or any other cognitive impairment nor dyslexia. Participants who stutter (PWS) were recruited through an intensive therapy course near Munich (ww.staerker-als-stottern.de). The stuttering severity of each PWS was determined with the SSI-3 by trained speech therapists on the day of testing. Most of the PWS were recorded after they had some therapy, since we wanted them to be able to read as fluent as possible.

The participants were asked to read an excerpt from a popular German children's book recommended for readers from 8 years on, which contained 690 words (1063 syllables). Prosodic phrases were annotated in each participant's rendition of a short excerpt of the text and categorized into intermediate and intonational phrase boundaries (using GToBI standards (Baumann et al., 2000)). The number of produced phrase boundaries was normalized across participants using the reading performance of a professional audiobook reader.

Allan Factor analysis provides information about hierarchical temporal clustering of a time series of discrete events over long stretches of speech. Using the Hilbert method, events were derived from amplitude peaks in the speech envelope at multiple timescales, reaching from about 15ms to 15sec. The average degree of clustering is quantified by Allan Factor variance A(T) for a given window size T. A(T) was computed over 11 timescales, so that the Allan Factor function represents nested clustering logarithmically across time (short timescales

<300ms, long timescales >300ms). Finally, to ensure that participants had no major problems with reading per se, we also measured decoding ability, that is, the percentage of read words without errors within the overall number of words read per 60sec (Rasinski, 2004).

As to phrasal structure (see Fig.1), results (2x2 between-subjects ANOVA) revealed that children (effect of age-group, $p < 0.05$) and readers who stutter (effect of participant-group, $p < 0.05$) produced significantly more phrase boundaries than adolescents and the control group. Regarding the global temporal structure, results revealed significant participant-group ($p < 0.05$) and age-group ($p < 0.01$) differences at short timescales with higher temporal clustering in the group who stutters as well as in children pointing towards more mature articulatory processes during reading in the control group and adolescents. Overall, decoding ability of the majority of all participants was at the level of advanced readers, but scores were slightly higher in adolescents than in children ($p < 0.05$). In sum, these results suggest that readers who stutter struggle with both local and global aspects of temporal organization in reading aloud despite the fact that they read as accurately as the group that is typically fluent. This finding also contributes to the discussion of whether the notion of rhythmic deficits in stuttering should include prosodic aspects (e.g. Arbisi-Kelm, 2010; Bergmann, 1986).

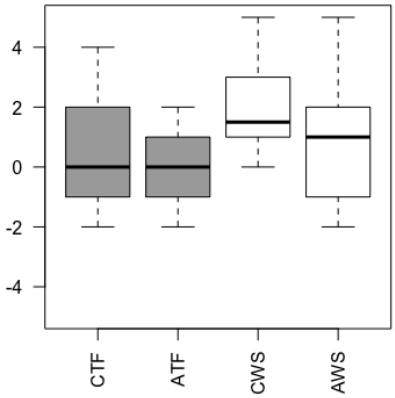

Figure 1. Amount of produced phrase boundaries in relation to an audiobook reader (x-axis) per participant- and age-group (y-axis)

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