Verbal timing deficits in stuttering

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Although stuttering is a neurodevelopmental speech fluency disorder affecting many people around the whole world and of nearly any age, the actual causes still remain unknown. In the child population five per cent are affected by stuttering at times and in one per cent stuttering persists into adolescence and adulthood, throughout all different cultures and languages (Yairi & Ambrose, 2013). Over the past two decades, remarkable progress has been made in understanding the underlying mechanisms of fluent and dysfluent speech in stuttering. One prominent hypothesis is that deficient temporal predictions may be one of the main reasons of this fluency disorder (Etchell et al., 2014).

In the present study we investigated predictive timing processes in stuttering using a paced speech paradigm. Synchronization to a beat demands high precision in timing as well as precise temporal predictions. Moreover stuttering symptoms are drastically reduced in paced speech, allowing to investigate perceptually fluent speech. Recent studies have shown alterations of non-verbal synchronization patterns (i.e., more negative asynchronies) in young and adult participants who stutter (Falk et al. 2015, Sares et al., 2019). By testing children and adolescents who do and do not stutter (9-17 years) on their verbal synchronization capacities, we aimed to investigate potentially altered syllable timing (i.e., more positive or negative asynchronies in vowel and consonantal onset timing) in paced speech.

Forty children and adolescents who stutter (mean age = 12.5, SD= 2.6, 6 females) and forty age and gender matched controls (mean age = 12.2, SD= 2.5, 6 females) participated in the study. All participants were German-native speaking and had - besides stuttering - no other speech or cognitive impairments. Participants who stutter were recruited and tested prior to a therapy course held near Munich in the summer of 2017, 2018 and 2019 (www.staerker-als-stottern.de).

To test verbal synchronization abilities, i.e. paced speech, participants were asked to repeatedly utter simple, as well as complex syllables (“ba” and “bla”) and to read two lists of 53 concrete monosyllabic words which had either simple or complex onsets in synchrony with an external beat (i.e., a metronome). Participants were asked to time one syllable/word per tone of the metronome. The inter-onset-intervals (IOI) of the beat were set to 750ms for the syllable task and to 900ms for the wordlists. Before starting the synchronization task, all participants completed one unpaced trial, that is, they uttered the syllables/words at a comfortable pace, without any specification on the tempo, but with the instruction to speak as steady and evenly as possible.

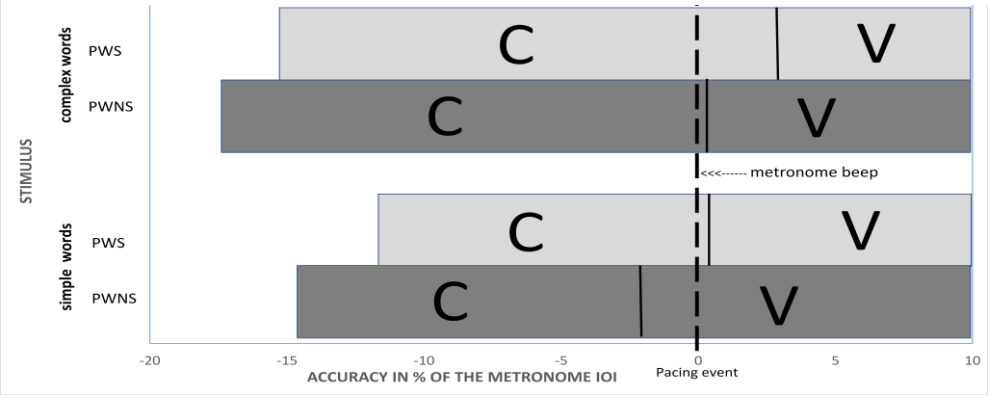
In unpaced reading, Inter-Vowel-Intervals (IVIs) were measured as well as the variability (Coefficient of Variation) of these IVIs. For the two paced conditions, synchronization consistency and accuracy were acoustically measured, by evaluating the time of the vowel and syllable onset and relating it to the time of the metronome using circular statistics (see Falk et al., 2015). In unpaced speech, participants who do not stutter chose a faster tempo for words (~ 860 ms IVI) than syllables (~ 950ms, $p < .01$), but no difference between stimuli was found in participants who do and do not stutter (~ 910 ms IVI). No group differences were present concerning CV of IVIs. In paced speech, mean word/syllable duration was included as

a covariate in the analyses (ANCOVA), as participants who stutter showed slower word / syllable production times compared to the control group. Participants who stutter did not differ from the control group in terms of consistency of synchronization. However, they differed in terms of onset-vowel timing to the beat in paced speech. Participants who stutter showed larger positive lags between vowels and the pacing beat than the control group across all pacing conditions ($p < .01$). They also started the syllable onset later than participants who do not stutter ($p < .05$). In other words, children and adolescents who stutter consistently timed their speech production later to the beat compared to the control group (see example in Fig.1). Finally, when comparing age groups, no differences in accuracy were visible, although children (9-12 years) were significantly more variable when reading words (in unpaced and paced conditions) than adolescents (13-17 years), probably due to less mature reading skills.

The observed timing delay in participants who stutter could be the result of at least two temporal processes. It is one possibility that altered temporal predictions in individuals who stutter lead to delayed temporal targets during production (Harrington, 1988). It is another possibility that generally more unreliable timing mechanisms generate delays in the activation of syllable motor programs during articulation in participants who stutter (Civier et al., 2013).

In sum, these results support the idea of altered timing in young speakers who stutter. Whether these are of motor or predictive timing origin is an interesting question for future research.

Figure 1. *Consonant-vowel timing of simple and complex words in relation to the metronome (PWS: participants who stutter, PWNS: participants how do not stutter).*



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