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Temporal variability in sung productions of adolescents who stutter

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ABSTRACT

Singing has long been used as a technique to enhance and reeducate temporal aspects of articulation in speech disorders. In the present study, differences in temporal structure of sung versus spoken speech were investigated in stuttering. In particular, the question was examined if singing helps to reduce VOT variability of voiceless plosives, which would indicate enhanced temporal coordination of oral and laryngeal processes. Eight German adolescents who stutter and eight typically fluent peers repeatedly spoke and sang a simple German congratulation formula in which a disyllabic target word (e.g., /'ki:ta/) was repeated five times. Every trial, the first syllable of the word was varied starting equally often with one of the three voiceless German stops /p/, /t/, /k/. Acoustic analyses showed that mean VOT and stop gap duration reduced during singing compared to speaking while mean vowel and utterance duration was prolonged in singing in both groups. Importantly, adolescents who stutter significantly reduced VOT variability (measured as the Coefficient of Variation) during sung productions compared to speaking in word-initial stressed positions while the control group showed a slight increase in VOT variability. However, in unstressed syllables, VOT variability increased in both adolescents who do and do not stutter from speech to song. In addition, vowel and utterance durational variability decreased in both groups, yet, adolescents who stutter were still more variable in utterance duration independent of the form of vocalization. These findings shed new light on how singing alters temporal structure and in particular, the coordination of laryngeal-oral timing in stuttering. Future perspectives for investigating how rhythmic aspects could aid the management of fluent speech in stuttering are discussed.

Learning outcomes: Readers will be able to describe (1) current perspectives on singing and its effects on articulation and fluency in stuttering and (2) acoustic parameters such as VOT variability which indicate the efficiency of control and coordination of laryngeal-oral movements. They will understand and be able to discuss (3) how singing reduces temporal variability in the productions of adolescents who do and do not stutter and 4) how this is linked to altered articulatory patterns in singing as well as to its rhythmic structure.

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1. Introduction

Singing is a form of vocalization that has recently received an increased interest in speech therapy. It can benefit speech production skills, particularly in non-fluent or disfluent speakers suffering from non-fluent aphasia (and apraxia; e.g., Jungblut, Huber, Mais, & Schnitker, 2014; Stahl & Kotz, 2014), dysarthria (in Parkinson's desease, e.g., Kempler & Van Lancker, 2002; Van Lancker Sidtis, Cameron, & Sidtis, 2012), and stuttering (e.g., Colcord & Adams, 1979; Glover, Kalinowski, Rastatter, & Stuart, 1996). In these speech disorders, singing helps patients to produce speech with greater ease, intelligibility or fluency. In general, singing induces several dramatic changes to the temporal dynamics of articulatory patterns of segments and syllables. Vowel durations are prolonged in comparison to consonantal durations (on a 3:1 ratio in song vs. a 1:1 ratio in speech, Eckardt, 1999). In parallel, tonal targets in vowels (i.e., local maxima and minima of the intonation contour) are longer allowing for the perception of discrete pitch classes that underpin melody recognition (Kolinsky, Lidji, Peretz, Besson, & Morais, 2009; Sundberg, 1987; Zatorre, Belin, & Penhune, 2002). These segmental characteristics foster slower articulation rate and enhance phonation times in singing – factors that are known to foster speech production in speech motor disorders. Jungblut et al. (2014), studying apraxia of speech in aphasic patients, have put forward the idea that singing may enhance and reeducate speech motor capacities, in particular temporal planning, programming and sequencing of speech movements via its rhythmic structure. Following this idea, the present study investigates temporal aspects of articulation in singing and perceptually fluent speech in stuttering, a speech fluency disorder that is characterized by deficits in speech motor control (e.g., Civier, Tasko, & Guenther, 2010; Ludlow & Loucks, 2003; Namasivayam & van Lieshout, 2011; Zimmermann, 1980), but also potential deficits in temporal processing (Alm, 2004; Etchell, Johnson, & Sowman, 2014; Etchell, Ryan, Martin, Johnson, & Sowman, 2016; Falk, Müller, & Dalla Bella, 2015; Van Riper, 1982; Wieland, McAuley, Dilley, & Chang, 2015).

Indeed, singing has previously been reported to enhance fluent articulation in stuttering (Colcord and Adams, 1979; Glover et al., 1996; Johnson and Rosen, 1937; Metz, Conture, & Caruso, 1979; Wingate, 1969). Research confirms that singing naturally slows down articulation rate in individuals who stutter, with significant increases in utterance duration as well as in overall voicing time (Andrews, Howie, Dozsa, & Guitar, 1982; Colcord & Adams, 1979; Healey, Mallard, & Adams, 1976; Stager, Jeffries, & Braun, 2003). In particular, the percentage of short phonated intervals (i.e., 30–200 ms of vocal fold vibration) reduces significantly (Davidow, Bothe, Andreatta, & Ye, 2009; Ingham et al., 2001; Ingham, Ingham, Bothe, Wang, & Kilgo, 2015). Reductions in short phonated intervals have been identified as one of the strongest indicators of improved fluency in individuals who stutter (Davidow, 2014). Slower articulation rate and enhanced phonation times typical of singing are also used in different therapeutic approaches to decrease overt stuttering symptoms such as in the MPI stuttering treatment, comprehensive stuttering treatment programs or in the Camperdown Program (Boberg and Kully, 1985; Ingham et al., 2001; O'Brian, Onslow, Cream, & Packman, 2003). Moreover, singing regularizes the timing of prominent syllables due to musical beat structure (London, 2004). Temporal intervals between syllables carrying a musical beat become more regular and hence, more predictable than in speech (e.g., Gordon, Magne, & Large, 2011). These more precise temporal predictions have been deemed beneficial for speech processing through neural mechanisms of enhanced attending towards expected moments as well as better coupling of perception and production (e.g., as stated in predictive coding and dynamic attending theories, see overviews in Kotz & Schwartze, 2016; Schön & Tillmann, 2015). Predictable rhythm is a feature that is shared by other fluency-enhancing conditions in stuttering such as speech paced by a metronome (Davidow, Bothe, & Ye, 2011; Hanna & Morris, 1977). When speaking with a metronome, the rhythmic production yields decreased temporal variability of articulation in individuals who stutter (Janssen and Wieneke, 1987). Note that reduced segmental variability has also been associated with successful therapeutic intervention in stuttering, for example, by using prolonged-speech treatment (Onslow, van Doorn, & Newman, 1992). In sum, singing affects temporal parameters such as phonation times and segmental variability in speech that have been proven beneficial for stutterers' fluency and stability of articulation.

Increased temporal motor variability in verbal and even non-verbal tasks (e.g., Falk, Müller, & Dalla Bella, 2015; Olander, Smith, & Zelaznik, 2010) is characteristic of stuttering. This consistently replicated finding has been attributed to differing functioning of the (neural) timing network involved in motor control in stuttering (e.g., Chang & Zhu, 2013; Cooper & Allen, 1977; Etchell et al., 2014; Harrington, 1988). A recent neurophsyiologically underpinned hypothesis states that the internal timing network that sustains timing and rhythm of self-paced movements comprising the basal ganglia and supplementary motor area may be deficient in individuals who stutter (e.g., Chang & Zhu, 2013; Etchell et al., 2016; Fujii & Wan, 2014). Behaviorally, even perceptually fluent speech shows increased temporal variability in individuals who stutter. In an early study, Cooper and Allen (1977) found that participants who stutter showed consistently higher durational variability across repeated readings of phrases, sentences and paragraphs in the near-absence of overt stuttering symptoms. Variability of articulatory kinematics was equally found to be enhanced in a similar task of repeated sentence reading (Kleinow & Smith, 2000; Smith & Kleinow, 2000). At the segmental level, higher temporal variability of vowel and fricative durations was observed in individuals who stutter during perceptually fluent speech (Di Simoni, 1974; Onslow et al., 1992). Greater variability was also reported for stop articulation. Stops are produced through a complex temporal sequence of articulatory gestures involving a complete obstruction of the airflow in the vocal tract, subsequent accumulation of air pressure during closure (i.e., stop gap), a sudden closure release resulting in an audible burst and a transition phase from the stop into the following vowel, sometimes including an aspiration phase (Ladefoged & Johnson, 2011). Individuals who stutter have been found to be more variable in the duration of stop gaps (Max & Gracco, 2005). Compared to individuals who do not stutter, they were also consistently more variable in Voice Onset Time (henceforth VOT; Klatt, 1975; Lisker & Abramson, 1964), that is, the interval between the release of oral closure and the onset of vocal fold vibration (De Nil & Brutten, 1991; Dokoza,