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SINGING AND STUTTERING

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Over the last few decades, singing has gained more and more interest in the clinical domain. Group singing enhances wellbeing of the elderly and persons who have various neurological diseases including Parkinson's disease and dementia (Osman, Tischler, & Schneider, 2016; Wan, Rübner, Hohmann, & Schlaug, 2010). Singing has also been reported to have beneficial effects for individuals with language and speech production disorders. For example, group singing has been demonstrated to help people with non-fluent aphasia to better repeat and recall new words (e.g., Racette, Bard, & Peretz, 2006). Speech therapists use melodic intonation therapy with severe (non-verbal) aphasic patients, a treatment that combines singing with hand movements to stimulate basic language and communication skills (Zumbansen, Peretz, & Hébert, 2014).

Moreover, some individuals who cannot speak fluently are fluent while singing: This surprising effect has long been known for individuals who stutter. It is often reported as a curiosity in the press when, during a song contest, a severely stuttering young artist who struggles with every word, is suddenly beautifully singing without any interruption of the song. There are many cases of famous singers and actors who stutter. Ed Sheeran stuttered as a child, and he attributes rapping and singing as instrumental to his recovery (Doyle, 2017). Marilyn Monroe also stuttered as a child and, on the advice of a speech therapist, took up singing to help mitigate the effects (McDermott, 2016). She eventually developed a distinctive and highly stylized manner of speech that was song-like, breathing from the diaphragm, with exaggerated emotional expression, stretched vowels, and slowed articulation rate. This adopted style of speech seems to have served her well, but it is not clear how exactly the fluency-enhancing effects of singing are to be explained.

Different hypotheses suggest that these effects might be attributable to enhanced motor control emerging through: (1) altered articulation patterns in singing, especially altered prosody and rhythmic-temporal structure; and (2) socio-emotional and cognitive factors, which might promote social connectedness, while easing the burden of communication. The present contribution will examine these hypotheses, with particular emphasis on the role of rhythm, and discuss how singing could be integrated in therapeutic intervention.

What Is Stuttering?

Stuttering is a neuro-developmental speech disorder that is characterized by dysfluencies – frequent and involuntary interruptions of the onward flow of speech (Bloodstein & Bernstein Ratner, 2008; van Riper, 1982). Dysfluencies occur as blocks, prolongations and repetitions of segments, syllables, or parts of words. They often go along with high tension and effort of the speaker who struggles to end the involuntary interruption (Guitar, 2014; Starkweather, 1987). Excessive body tension can evolve into secondary symptoms such as grimacing or involuntary limb movements. Another set of additional symptoms may arise from the speaker's perception of and reaction to his or her stuttering as he or she tries to end or avoid dysfluencies. Those reactions, like the interjection of extra sounds (e.g., “uh”) or eye blinks start out randomly, but soon transform into well-learned strategies to either escape or avoid stuttering symptoms (Guitar, 2014). Although people who stutter know what they want to say, they find themselves unable to articulate their utterances fluently. Feelings of excitement, embarrassment or irritation often accompany the audible and visible disruptions of fluency and can lead, in severe cases, to a complete disruption of communication and isolation of the individual. The feeling of loss of control over one's own speech is a core characteristic of stuttering, which carries a psychosocial as well as emotional burden. In sum, stuttering is a complex speech disorder that is best described as a syndrome consisting of linguistic, motor and psychosocial symptoms (Smith & Weber, 2017).

Developmental stuttering tends to appear suddenly with onset occurring typically in early language acquisition. In 60% of children who stutter, first symptoms appear between 24 and 35 months of age (Yairi & Ambrose, 2005). The incidence of stuttering, an index of the number of individuals who have newly started stuttering, is dependent on the age group under investigation. There is a high onset rate between the age of two to four years, but also a similar number of naturally remitting children during those two years. Since, in stuttering, this number can vary significantly depending on the age group, it is the lifetime incidence, an index of how many people have stuttered at some point in their life, that is used most frequently. Recent estimates suggest an 8% incidence rate over the lifespan (Bloodstein & Bernstein Ratner, 2008; Yairi & Ambrose, 2013). Prevalence of stuttering that is, how many people are currently affected by stuttering, is only about 1% in the adult population across different countries and language backgrounds. In contrast, prevalence in children varies between 5 to 11% (Yairi & Ambrose, 2013). Eighty percent of all children naturally remit from stuttering (Yairi & Ambrose, 2005). Studies of natural recovery report wide variations, depending on methodological differences. Natural recoveries are most likely to occur within two years after the onset of stuttering, although there are reports of recoveries in adolescence or even in later adulthood (Bloodstein & Bernstein Ratner, 2008; Kell et al., 2009; Yairi & Ambrose, 2005, 2013).

So far, studies cannot explain why many children stop stuttering – with or without treatment – but they point to certain factors that have a positive influence on the probability to remit from stuttering. These factors are good phonological skills, a young age at the onset of stuttering, no family history of stuttering and being female (Guitar, 2014; Yairi & Ambrose, 1999, 2013). As with many developmental speech and language disorders, stuttering shows a gender bias. More male than female children are affected by stuttering, and stuttering in females persists more rarely into adulthood. This bias results in 80% of the adult stuttering population being male (Bloodstein & Bernstein Ratner, 2008). Finally, stuttering shows a genetic basis as evidenced by various family- and twin-studies (e.g., Dworzynski, Remington, Rijdsdijk, Howell, & Plomin, 2007). Heritability estimates are moderate to high, ranging from 42% to 85%, with surprisingly close numbers for boys and girls in a family, given the gender bias in the general population (Fagnani, Fillbiger, Skyttke, & Hjelmberg, 2011; Frigerio-Domingues & Drayna, 2017). To date, mutations

on four genes have been identified to be involved in the appearance of persistent stuttering, but only 20% of cases of persistent stuttering can be reliably linked to these genes (see Frigerio-Domingues & Drayna, 2017). However, if a child has the genetic predisposition, it is more likely that stuttering can occur during development than in individuals without the predisposition.

Singing as a Fluency-enhancing Condition

Stuttering is a phenomenon of great variability. It can vary depending on the communicative situation, the emotional state, the person one is communicating with or the word one is trying to articulate. Some situations are especially known for their ability to evoke constant fluency in speakers who stutter. Singing is one of those so-called fluency-enhancing conditions (Healey, Mallard, & Adams, 1976; Wingate, 1981). During these situations, speakers who stutter show prolonged episodes of fluency which they can barely reach during normal conversations. Besides singing, chorus speech and chorus reading, shadowed speech (i.e., imitating speech of someone else immediately after hearing it), paced speech (i.e., speaking along with an external rhythm such as a metronome), and delayed auditory feedback (i.e., having a retarded feedback of one's own speech production) are known to boost fluency in individuals who stutter (e.g., Andrews, Howie, Dozsa, & Guitar, 1982; Davidow, Bothe, Andreatte, & Ye, 2009; Toyomura, Fujii, & Kuriki, 2011). Andrews et al. (1982) compared the effect of 15 different fluency-enhancing conditions, including singing. During the singing condition in which participants were asked to sing a self-chosen song for ten minutes, the frequency of stuttering could be reduced by over 90%. Similar percentages of fluency-enhancement have been reported in other studies (e.g., Glover, Kalinowski, Rastatter, & Stuart, 1996).

Brain Correlates of Fluency-enhancement during Singing

Recent brain research has shown that individuals who stutter show altered brain connectivity and activation patterns which are widely distributed in cortical and subcortical structures (see e.g., Etchell, Civier, Ballard, & Sowman, 2018). However, whether these alterations are at the origin or the effect of stuttering is still an unresolved issue. During speech production, abnormal activation patterns are found in motor areas responsible for the planning of complex movements, such as articulatory movements (i.e., motor and premotor areas and the supplementary motor area), in language processing areas associated with speech planning and control, auditory and sensorimotor integration areas (such as the inferior frontal gyrus), and subcortical structures (such as the basal ganglia, and parts of the cerebellum; e.g., Brown, Ingham, Ingham, Laird, & Fox, 2005; Kell et al., 2009; Watkins, Smith, Davis, & Howell, 2008).

Moreover, research findings suggest that different activations in individuals who stutter compared to normally fluent speakers relate to reduced connectivity in the larger cortico-subcortical speech and speech motor network in stuttering. Density of white matter (i.e., the fiber tissue connecting nerve cells in the brain) is reduced in several important fiber tracts for language processing (i.e., the arcuate fasciculus, see Chang & Zhu, 2013; Sommer, Koch, Paulus, Weiller, & Büchel, 2002; the frontal aslant tract, Kemerdere et al., 2016; Kronfeld-Duenias, Amir, Ezrati-Vinacour, Civier, & Ben-Shachar, 2016). Some of the subcortical-cortical connections linked to motor and timing functions (e.g., basal-ganglia-cortical, cortico-cerebellar connections) and cortico-spinal connections also show weaker connectivity (e.g., Chang, Zhu, Choo, & Angstadt, 2015). Some of the white matter anomalies found in individuals who stutter were found to normalize in individuals who recovered from stuttering (e.g., Kell et al., 2009). In sum, it appears that brain networks underpinning sensory-motor integration and timing are compromised in people who stutter.

Singing, as well as other fluency-inducing conditions, helps in normalizing abnormal activation patterns observed during speech in speakers who stutter. In one of the few brain studies on singing in adults who stutter, Stager, Jeffries, and Braun (2003) used positron emission tomography (PET) to examine brain activation patterns during singing and metronome-paced speech compared to a rest condition as baseline, as well as to spontaneous speech tasks prone to provoke disfluencies in stuttering (i.e., sentence construction and event narration). All speakers, normally fluent as well as participants who stutter, showed higher bilateral activation in auditory areas that process speech and receive somato-sensory feedback, as well as in motor and premotor regions during the fluency-inducing tasks compared to the control and baseline conditions. Moreover, participants who stutter showed particularly robust activations in some of the left-hemispheric auditory and sensorimotor areas involved in auditory self-monitoring and speech production.

Hence, a key aspect as to why singing might help fluent articulation in speakers who stutter could be improved self-monitoring and sensorimotor integration leading to more effective motor control during articulation (e.g., Stager et al., 2003). This view is in line with models of speech production that localize the main deficit in stuttering in erroneous internal models and more variable feedback timing causing errors in auditory-motor integration during speech production (e.g., Civier, Bullock, Max, & Guenther, 2013). Findings on other fluency-inducing conditions, such as paced and choral speech, support this hypothesis (e.g., Toyomura et al., 2011). In a functional magnetic resonance imaging (fMRI) study, Toyomura et al. (2011) scanned 12 adults who stutter and 12 normally fluent participants while reading a text spontaneously, in a chorus condition, or paced by a metronome compared to a rest condition. Similar to findings of Stager et al. (2003), chorus and paced speech evoked higher activations in auditory areas. Moreover, the authors found a normalization of subcortical activation in the basal ganglia in speakers who stutter in the rhythmic paced speech condition. As the activation pattern in the basal ganglia is a good predictor of persistent stuttering severity and success of therapeutic intervention (e.g., Giraud et al., 2008), this result suggests that clear rhythmic structure is a good candidate for enhancing fluency in speakers who stutter.

Anecdotal evidence for this comes from a recent workshop on singing and stuttering at the 2018 Meeting of the Canadian Stuttering Association (Russo & Fallah, 2018). The workshop was attended by approximately 20 adult stutterers who were asked to perform the lyrics of “Love Me Tender” by Elvis Presley in choral speech with and without a rhythmic cue. Choral speech without a rhythmic cue was highly variable in timing with some participants finishing well ahead of others and with many episodes of stutter. Choral speech with the rhythmic cue, however, displayed a high level of temporal synchronization and almost no instances of stutter. While these observations were informal, they reinforce the notion that rhythmic aspects of song might contribute to fluency.

Fluency-enhancing Articulatory Aspects of Singing

Wingate (1981) hypothesized that fluency-inducing conditions provide altered prosodic structure that might help stabilize rhythmic irregularities during speech production in individuals who stutter. Moreover, these conditions would promote continuous phases of phonation. In singing, musical structure provides both novel prosodic patterns through melody and rhythm, and continuous phonation through altered articulatory patterns.

In singing, the temporal planning and execution of sounds in itself changes as sung vowel durations are stretched, and consonant durations are either the same or reduced compared to speech (e.g., Falk, Maslow, Thum, & Hoole, 2016). In particular, increased overall phonation duration and reduction of short phonated intervals (i.e., 30–200 ms of vocal fold vibration) have been identified to promote stuttering reduction during singing and other fluency-enhancing conditions (e.g., Davidow et al., 2009). Altered articulatory timing patterns in singing might also play a role in fluency-enhancement. Falk et al. (2016) studied the timing variability of consonant–vowel transitions (i.e.,

Voice onset time (VOT) variability) during singing and reading. Eight German-speaking adolescents who stutter and an age- and musicality matched control group read and sang unfamiliar lyrics to the tune of the song “Happy Birthday”, well-known to all participants. Participants who stutter were equally fluent in both experimental conditions, but they were overall more variable in phrase or vowel durations in singing and reading than the control group. However, the timing variability of consonant–vowel transitions, that is, VOT variability, was reduced in adolescents who stutter during singing compared to reading. As VOT variability is an index of maturation of speech motor control, the authors concluded that singing enhances motor control parameters, at least for oral-laryngeal articulation. Another noteworthy result of this study was that the reduction of VOT variability occurred exclusively on accented syllables. Accented syllables in “Happy Birthday” are associated with a musical beat, a predictable prominent rhythmic event occurring at regular temporal intervals. Falk et al. (2016) hypothesized that it is the predictability of the musical beat in singing that might have generated an advantage for speech motor planning and control processes on the accented syllables compared to reading. Studies on other adult and developmental populations with speech and language disorders share the idea that precise temporal predictions through a musical rhythm might be beneficial for speech production (e.g., Schön & Tillmann, 2015).

Slower articulation rate in singing than in speech was discussed as another factor facilitating articulatory planning and execution. Glover et al. (1996) examined whether slower production rates were beneficial for fluency during singing. However, no difference concerning the rates in singing compared to reading could be shown in their study, although stuttering was significantly less frequent during singing. Hence, rate might not be the primary parameter to generate fluency during song in stuttering speakers.

Generally, the altered prosodic structure in singing compared to speech increases demands in precision when encoding and producing melody and rhythm. More precise encoding of melody and rhythm can enhance memorization of songs (Calvert & Tart, 1993; Good, Russo, & Sullivan, 2015). Moreover, melody and rhythm might also serve as constraints to stabilize vocal motor control during production, potentially relevant for stuttering reduction. Increased precision in an internal model due to prosodic factors might lead to a generally increased capacity for monitoring of auditory feedback allowing for rapid self-corrections when vocal production deviates from a motor plan (e.g., Perkell et al., 1997). In this respect, the effect of singing could be examined in parallel to the intentional imitation of different prosodic patterns or voice characteristics, for example when acting or imitating someone else, a vocal behavior that is anecdotally reported to lead to a reduction in stuttering. Both types of vocal modification, singing and intentional imitation, could yield similar motor planning constraints, and, potentially, enhanced self-monitoring subserving fluency-enhancement.

Finally, musical rhythm might play a prominent role in enhancing speech motor control during singing in speakers who stutter. One prominent hypothesis on the origins of stuttering is that the disorder emerges from a rhythmic deficit (Wingate, 1981), generated in the larger timing network used for motor planning and execution (Etchell, Johnson, & Sowman, 2014). Indeed, several studies have shown that rhythmic sensorimotor processes other than speech are altered in participants who stutter. For example, children and adults who stutter show poorer abilities synchronizing to a given rhythm. Results on the differences in the ability of tapping, clapping or speaking syllables and words to a beat (music or a metronome) can be specified as less accurate and more variable in their timing to rhythmic events than normally fluent speakers (Falk, Müller, & Dalla Bella, 2015; Olander, Smith, & Zelaznik, 2010). In addition, the perception of non-verbal rhythms and the discrimination of rhythmic units seems to be impaired in individuals who stutter (Wieland, McAuley, Dilley, & Chang, 2015). Note that other studies failed to find differences in (oro)motor or articulatory parameters between participants who do and do not stutter (e.g., Max & Yudman, 2003; McClean, Kroll, & Loftus, 1990). Divergent findings on the timing

abilities in stuttering and fluently speaking persons may be attributed to various parameters such as age and methodological differences. Although more evidence is needed, those studies that find differences throughout different age groups and modalities strengthen the idea of different timing mechanisms in stuttering speakers.

Falk et al. (2015) proposed that poorer synchronization abilities in stuttering are indicative of impaired rhythmic predictions in the motor timing network. Recent neuroscientific research underpins the notion of altered rhythmic predictions in stuttering by showing that children who stutter display abnormal synchronization of neural oscillations to rhythmic sounds, particularly at the onset of a rhythmic event (Etchell, Ryan, Martin, Johnson, & Sowman, 2016). Starting from this point of view, producing sung rhythms might help improve rhythmic predictions during motor planning and execution, ultimately leading to enhanced motor control and fluency in speakers who stutter (see also Falk et al., 2016). Future studies should assess whether singing can aid normalizing neural entrainment processes to rhythmic structure. In sum, further research on this topic is needed to get a better understanding as to whether different motor planning strategies and better rhythmic predictions, and/or self-monitoring via altered prosody lead to different or improved motor control during singing in speakers who stutter.

Fluency-enhancing Cognitive and Socio-emotional Aspects of Singing

In addition to enhanced motor control, cognitive and social-emotional factors might contribute to fluent articulation while singing. For example, Healey et al. (1976) found that familiarity of lyrics contributes to disfluency reduction in singing. In their study, participants who stutter read or sang a song with the original, familiar lyrics and with altered, unfamiliar lyrics. Singing familiar lyrics displayed the greatest reduction of disfluencies. First, this finding might relate to the tendency of listeners to attribute greater significance to familiar lyrics. Thompson and Russo (2004) found that sung lyrics were judged as more meaningful than spoken lyrics, and that meaningfulness of lyrics increased with familiarity. Increased meaning might provide a boost in motivation that reduces stress and, thereby, stuttering symptoms. Second, a high degree of familiarity with lyrics might also reduce motor planning demands as the internal model for vocal motor control should be well developed, which might facilitate activation of motor planning areas (see, e.g., Raichle et al., 1994).

Yet another possibility to consider is that singing might preferentially engage the right hemisphere. There is a long history of research demonstrating processing of emotional information tends to be biased toward the right hemisphere (e.g., Schwartz, Davidson, & Maer, 1975). The emotional content of song may thus minimize the load or even completely bypass the dysfunctional motor planning areas in the left hemisphere, as is thought to occur in the case of melodic intonation therapy (Zumbansen et al., 2014).

It is also important to recognize that singing can lead to neurochemical changes that reduce overall stress levels. In particular, group singing has been shown to lead to a decrease in the stress hormone cortisol (e.g., Beck, Cesario, Yousefi, & Enamoto, 2000; Kreutz, Bongard, Rohrmann, Hodapp, & Grebe, 2004). This neurochemical response might support fluency-enhancement in at least subgroups of individuals who stutter.

A final related point to consider is the mitigation of disfluency that might arise in the context of group singing. A number of studies have found evidence to suggest that group singing increases feelings of social connectedness (Good & Russo, 2016; Wiltermuth & Heath, 2009). These feelings might lead singers to be more resilient (Weinstein, Launay, Pearce, Dunbar, & Stewart, 2016). In speakers who stutter, feelings of social connectedness and inclusion as well as higher levels of resilience might help on a long-term basis to better cope with stuttering and persevere more through stressful communication situations.

Singing and Stuttering Therapy

When stuttering persists into adulthood, specific techniques can be learned with the help of a speech therapist. These techniques can strongly improve fluency, although they cannot completely stop the involuntary interruptions of the onward flow of speech. So far, there is no entrenched therapeutic intervention that treats stuttering by singing, although we already know about its fluency-enhancing effect. This is mainly due to the fact that singing and the associated fluency cannot meet the daily demands of communication of speakers who stutter.

Current therapeutic techniques can be divided into two subgroups: stuttering modification and fluency shaping. *Stuttering modification* aims to manage stuttering moments directly. The speaker must monitor his/her own speaking precisely to intervene before, during or after a stuttering event. This skill demands a lot of experience and practice. *Fluency shaping* therapies, in contrast, aim to change the process of articulation in order to generate fluent speech. In a highly structured program, individuals who stutter learn to change their breathing, their speech rate and voicing to achieve high levels of fluency. The initially quite unnatural way of speaking can converge into a natural way of speaking with practice and generalization (Guitar, 2014; Webster, 1977). In the initial stages of this therapy, speech might sound similar to a recitative or a chant. In both fluency shaping and modification therapies, a major component is the prolongation of vowels to generate continuous phonation. This therapeutic feature is shared with singing. Prolonged vowels are also used in a fluency-enhancing technique that is referred to as *prolonged speech* (Ingham, 1984). These observations show that some elements of singing have already found their way into the therapy of stuttering.

Therapeutic singing could still be a useful tool in stuttering therapy, as it reaches a wide range of emotional and physical functions. It can help to promote relaxation and provide a comfortable environment to practice and regain some confidence in one's own speech, and it regularizes the coordination of breathing and vocalizing (Bullack, Gass, Nater, & Kreutz, 2018). Group singing could foster social connectedness and minimize feelings of social isolation in speakers who stutter (e.g., Good & Russo, 2016). These effects could generate benefits for patients with distress and anxiety in relation to their stuttering, including children and younger adults. Moreover, it would be worth considering the benefits of singing for individuals who stutter and who have lost faith in their ability to produce words fluently at all. As an anecdote, remember the scene in the popular movie *The King's Speech* in which the future King George VI is depicted in one of his visits to a speech therapist, Lionel Logue, specialized in stuttering (Canning, Sherman, Unwin, & Hooper, 2010). In this scene, the king reveals his family history and his suffering because of his stuttering. In addition to his embarrassment to unveil his most intimate feelings, stuttering hinders him to tell the story. Suddenly, he sings out loudly what he wanted to say, to the melody of "Swanee River", completely without stuttering. This effect of singing might also be useful in a therapeutic way, because it helps individuals affected by stuttering to regain some faith in their capability to speak flawlessly and thereby giving them a positive feeling and motivation for therapy, which is essential for any further therapeutic invention and the success of it (Altenmüller & Schlaug, 2015).

Glossary

Arcuate fasciculus A fiber tract, occurring in both hemispheres, which connects speech production and perception areas in the frontal and temporal lobes in the left hemisphere.

Basal ganglia A group of neurons which, among other functions, are relevant for movement and timing related information located deep beneath the cerebral cortex (i.e., subcortical structure). Dysfunction in these nuclei can lead, for example, to involuntary movements (e.g. like tremors).

Cerebellum A subcortical part of the brain located at the base of the skull. It plays an important role in the execution of voluntary actions, motor control, balance and posture, among other functions.

Cortex Surface layer of the brain, consisting of folded grey matter and very rich in neurons (cortical means belonging to the cortex).

Fluency The effortless and rather constant flow of speech

Frontal aslant tract A fiber tract connecting motor planning and motor areas within the frontal lobe.

Functional magnetic resonance imaging (fMRI) A brain imaging technique which measures and maps neuronal activity via changes in the brain's blood flow.

Hemisphere The brain has two distinct cortical structures, the left and the right hemisphere. Many language and speech functions are biased toward the left hemisphere in the majority of individuals.

Inferior frontal gyrus A ridge in the cerebral cortex of the frontal lobe associated, among others, with response inhibition and – if in the left hemisphere – also relevant for speech production.

Internal model In motor control theory, an internal model provides a simulation of the motor systems' current action in order to estimate the outcome of the system and correct for possible disturbances.

Natural recovery An individual recovers naturally from stuttering when symptoms disappear up to two years after their first appearance without any special kind of treatment but rather of natural causes.

Phonological skills Phonological skills comprise the ability to analyze the specific sound structure of a language; they include the skill to segment and recognize sounds, syllables and words.

Positron emission tomography (PET) A type of brain imaging technique with radioactive tracers used to visualize metabolic processes in the brain. It helps in localizing neuronal activity in the brain associated with specific tasks.

Sensorimotor integration The ability of the central nervous system to integrate information about a stimulus coming from different sensory modalities (e.g., motor, auditory, visual) and simultaneously generate a motor response to the input.

Supplementary motor area An area in front of the primary motor area in the brain which contributes to movement control.

Voice onset time (VOT) The duration of time between the release of a plosive (stop consonant, e.g., the sound /p/) and the beginning of the vocal fold vibration (voicing, i.e., that would arise with the onset of any vowel following /p/)

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