# The treatment of apraxia of speech

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# Summary

The aim of this thesis is to evaluate the effect of speech-music therapy on patients with apraxia of speech. Three issues are addressed: (1) the relation between speech motor control and musical parameters; (2) the evaluation of AoS treatment in rate-rhythm control strategies; and (3) the effectiveness of SMTA in patients with Apraxia of Speech and aphasia.

The process of speech motor control is described in **Chapter 1**. First, various levels of word production were discussed, related to the linear model of Levelt et al. (1999), specifically focusing on the process of phonological and phonetic encoding. Encoding the phonological word form is divided into two separate processes: (1) retrieval of phonemes and (2) retrieval of word structure: syllabification (Hartsuiker et al., 2005). Subsequently, articulatory gestures are assigned to the phonological word at the level of phonetic encoding, specifying which patterns of articulatory movements are required. However, in linear models, there is little attention to relations between phonemes (Miller, 2000). Other relevant components of phonetic encoding are underspecified in linear models as well, for example, supra-segmental aspects, such as prosody. These aspects are better described in nonlinear models of speech motor control. Ziegler (2005), for example, suggests that the complexity of syllable retrieval depends on higher-order phonetic units, in which rhymes and trochees are important motor units in a metrical tree. From a psycholinguistic perspective, it can be concluded that the process of speech motor control is a complex, nonlinear, hierarchical organisation of motor units extending from the level of articulatory gestures to the level of metrical feet.

Processes of speech motor programming and planning are needed to complete the description of the speech motor control process. These processes are described in speech motor theories, for example, Schmidt's

(2003) Schema Theory. In this theory it is assumed that speech production involves the determination of related groups of motor actions (i.e., motor programs) and that these programs are generalised. A Generalised Motor Program (GMP) captures the timing and force of the movement. Within an articulatory motor program, a GMP corresponds to the motor commands associated with a phoneme, syllable, word or even a frequently produced phrase (Varley et al., 2006). However, the speed and the amplitude of the movement are varied by assigning different values to the *parameters* of the GMP for each specific action (Clark & Robin, 1998) and this refers to speech motor planning. Planning speech production is a speaker's constant task during articulation; it functions as a control system. Speech motor planning can adjust speech production if necessary, for example, speech rate.

Apraxia of Speech (AoS) is the topic in **Chapter 2.** AoS is a neurogenic speech programming disorder characterised by a variety of symptoms, such as sound distortions, articulatory groping, reduction of speech rate and prosodic abnormalities, such as disturbances in the flow and melody of speech (McNeil et al., 2009; Lowit et al., 2014). The various symptoms of AoS can be classified into three categories (Ziegler, 2008): impairments in *accuracy* (segmental impairments), *consistency* (error variability) and *fluency* (prosodic disturbances). Most AoS definitions reflect a disorder of speech motor programming. Accordingly, AoS patients have a preserved knowledge of the phonological word form and no deficits in motor execution. However, recent studies have suggested that phonological encoding impairments may co-exist with AoS (Maas et al., 2013). Furthermore, with regard to aetiology, there is an inconsistency in the neuro-anatomic findings associated with AoS. There is no one-to-one mapping between a damaged brain area and AoS symptoms. Despite uncertainties, AoS is usually associated with a stroke to the left cerebral hemisphere (Ogar et al., 2006) and it occurs after lesions to the anterior perisylvian region.

**Chapter 3** describes behavioural methods to treat patients with AoS. First, general principles of motor learning are described since these principles function as the fundamentals of AoS treatment. Furthermore, this chapter describes articulatory-kinematic and rate-rhythm control strategies because these approaches relate to the process of speech motor programming and planning. *Articulatory-kinematic approaches* are connected to the level of speech motor programming. The treatments in this category concentrate on articulatory errors and have a 'spatial' focus, such as phonetic placement. *Rate and rhythm control strategies* are connected to motor planning. The techniques are more 'dynamic' in nature and are aimed at prosodic aspects of speech production, such as rhythm, stress, tempo and intonation. The most common treatment using melody and rhythm in the rate and rhythm control strategy is Melodic Intonation Therapy (MIT; Albert et al., 1973; Sparks et al., 1974) and this program has been used most frequently in efficacy studies.

**Chapter 4** addresses various aspects of music in relation to language and music therapy. First, the hierarchical structures of language and music resemble one another. Furthermore, there is a great interest in understanding the extent to which neural resources for processing music and speech are distinctive or shared. Neuropsychology has provided cases of dissociations between music and linguistic processing. However, a growing body of evidence from the neuroimaging studies suggests that speech and music at least recruit shared computational systems. Recent fMRI studies (Rogalsky et al., 2011; Abrams et al., 2011) correspond with the findings that music and speech processing share neural substrates, but that the temporal structure in the two domains is encoded differently. Finally, the multidisciplinary field of music therapy (MT) is described. Various *neurologic* MT approaches aim to improve verbal expression and communication, using musical elements, such as melody, rhythm, dynamics, tempo and meter.

The aim of the review in **Chapter 5** is to synthesise studies on the effects of music parameters in the treatment of neurological language and speech disorders as well as explain patient's recovery with various possible mechanisms. 1250 Articles have been identified and fifteen are selected for this study. MIT is the most studied programme. Accordingly, melody and rhythm are the music interventions that have been applied the most. Measurable recovery has been reported in all reviewed studies. However, the methodological quality of the studies is not convincing when using the ASHA level of evidence (2001) indicators. Therefore, conclusions regarding the efficacy of treatments that incorporate components of music for neurologically impaired patients should be interpreted with caution. Finally, three studies examined recovery mechanisms to explain the research findings; the results are contradictory and, therefore, mechanisms of recovery remain unclear.

Speech-Music Therapy for Aphasia (SMTA), a combination of speech and music therapy, is elaborately described in **Chaper 6**. SMTA is designed for non-speaking patients and non-fluent speaking patients suffering from AoS and aphasia. For each patient, the aims are personalised, but the general aim for non-speaking patients is 'de-blocking. For non-fluent speaking patients, the SMTA treatment is aimed at improving speech motor programming and planning. This means improvement in: accuracy, consistency and fluency (i.e., the flow and melody of speech) of articulation. Furthermore, the speech-therapy line of treatment and the music-therapy line of treatment in SMTA are described in this chapter.

Various factors play a role in the recovery from non-fluent aphasia and Apraxia of Speech (AoS). In **Chapter 7**, eleven factors are related to the therapy outcomes. Using measures of language impairment (AAT) and functional communication (ANELT), this retrospective study evaluates the outcome data of 41 patients with non-fluent aphasia and AoS, in relation to eleven prognostic factors. All patients are treated

with SMTA in parallel with speech and language therapy. The results demonstrate significant improvement on all AAT subtest scores and the comprehensibility measure of the ANELT. In this study, SMTA candidates are homogeneous: patients with a lesion in the left hemisphere in the medial cerebral artery, diagnosed as aphasic patients with AoS and impaired cognitive functions. Two factors influence therapy outcome; first, the severity of the aphasia decreases with long therapy duration, and second, non-fluent speakers with aphasia and AoS respond better to the therapy than non-speaking patients.

**Chapter 8** presents the evaluation of the newly developed Modified Diadochokinesis Test (MDT), a task to assess the effects of rate and rhythm therapies for AoS. The consistency, accuracy and fluency of speech of 24 adults with AoS and twelve unaffected speakers matched for age, gender and educational level are assessed using the MDT. The reliability and validity of the instrument are considered and outcomes are compared with those obtained with existing tests. The results show that the MDT has a strong internal consistency. Syllable structure complexity influence scores, while distinctive features of articulation have no measurable effect. The test-retest and intra- and inter-rater reliabilities are adequate as well as the discriminant validity. For convergent validity different outcomes are found: apart from one correlation, the scores on tests assessing functional communication and AoS correlate significantly with the MDT outcome measures. The spontaneous speech phonology measure of the AAT correlates significantly with the MDT outcome measures but no correlations were found for the repetition subtest and the spontaneous speech articulation/prosody measure of the AAT. The study shows that the MDT has adequate psychometric properties, implying that it can be used to measure changes in speech motor performance after AoS treatment. The results demonstrate the validity and utility of the instrument as a supplement to speech tasks in assessing speech improvement aimed at the level of speech motor programming and planning.

**Chapter 9** reports the final study in this thesis, which examines the effectiveness of SMTA. Five patients with AoS and aphasia are studied in a case-series design with multiple measurements. The main research question is whether verbal communication in daily life improves after SMTA therapy. Related questions are (1) whether accuracy, consistency and fluency of articulation improve; (2) whether improvement is the result of the therapy or spontaneous recovery; (3) whether the severity of aphasia decreases; and (4) whether the improvement remains stable. All patients receive 24 SMTA treatment sessions. They are tested before and after this treatment period and 3 months after therapy stops (follow-up). Various outcome measures are used: ANELT, DIAS and AAT. During the treatment period the patients are tested weekly with the MDT and a control test (PALPA 12). Intelligibility of verbal communication for all participating individuals, as well as comprehensibility in four out of five participants, improves after 24 SMTA treatment sessions. All measures of MDT and repetition of AAT show significant improvement for all participants. Four participants also improve on the test for articulation of phonemes and the diadochokinesis test of the DIAS. Furthermore, two participants improve on the articulation of words (DIAS). The improvement remains stable after treatment ends (follow-up). For three out of the five participants no improvement is found on the control tests. Two participants also show improvement on almost all outcome measures, but also improve on the control tests. SMTA not only affects articulation but also the severity of the aphasia decreased in four out of five participants.

**Chapter 10** discusses the main findings of the review and the three experimental studies related to the aim of this thesis, and elaborates on three issues. The first issue refers to the relation between speech motor control and musical parameters. It is suggested in this thesis that SMTA provides an external *musical* frame directed to the dynamic process of speech motor control. To explain the working mechanism of this musical frame, the musical parameters melody, rhythm, meter, tempo and

dynamics are related to process of speech motor planning. The second issue concerns the evaluation of AoS treatment in rate and rhythm control strategies. DIAS can be used as an evaluation instrument to measure improvement of speech motor programming by evaluating a change in articulation of phonemes, diadochokinesis (DDK) and articulation of words after therapy. Additionally, MDT can be used to evaluate accuracy, consistency and fluency of articulation. The final issue addresses the effectiveness of SMTA patients with AoS and aphasia. An efficacy study has been performed to examine empirical evidence on the effect of SMTA in a group of five patients, as a 'proof of principle' and the results show a positive effect in three of the five participants. Methodological issues concerning the quality of the study and sample size are described. Furthermore, the use of SMTA and MIT in clinical practice is discussed and an outlook for future research is described.