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Phonological markers of sentence stress in ataxic dysarthria and their relationship to perceptual cues

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ABSTRACT

A wide range of literature is available on the features of ataxic dysarthria, investigating segmental and prosodic characteristics by acoustic and perceptual means. However, very few studies have been published that look closely at the relationship between the observed phonetic disturbances and their perceptual sequelae, particularly in the area of prosody. The aim of the current study was therefore to examine the stress production of eight individuals with ataxic dysarthria and matched healthy controls, and to relate the results of phonological and perceptual evaluations to phonetic performances to better understand the relationship between these three components for speech outcomes.

Speakers performed a sentence stress task which was analysed phonologically in terms of inventory, distribution, implementation and function of pitch accentuation. These data were then evaluated in relation to previously published phonetic and perceptual results on the same speaker group by the authors. Results indicated that the speakers with ataxia used a wide range of pitch patterns, but pitch-accented a higher number of words, and produced shorter phrases. The increased number of pitch accents per phrase was furthermore reflected in a reduced percentage of de-accented words in post-focal position. Perceptual results established this pattern as the main cause for listener errors in identifying the intended stressed item in an utterance. In addition, the performances of two speakers are discussed in greater detail. Although they were unable to de-accent, they nevertheless marked stress appropriately through phonetic compensatory strategies.

Learning outcomes: After reading this article the reader will be able to (1) explain the relevance of phonology and phonetics in the perception of stress production in ataxic dysarthria; (2) describe the different levels of intonational analysis; and (3) understand the observed intonation patterns in ataxic dysarthria as well as the compensatory mechanisms speakers may adopt to produce stress.

1. Introduction

Ataxic dysarthria is a speech disorder caused by disturbances in cerebellar functioning. It can have a number of underlying causes, ranging from cerebellar degeneration (cerebellar/spino-cerebellar ataxia (CA/SCA), Friedreich's ataxia (FDA)) to cerebellar damage by stroke or toxicity. Darley, Aronson, and Brown (1969a, 1969b) identified predominantly

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articulatory, prosodic and phonatory problems in their group of patients with cerebellar disease. They list the most deviant speech dimensions, in order of their severity, as imprecise consonants, excess and equal stress, irregular articulatory breakdown, vowel distortions, harsh voice, phoneme prolongations, monopitch and monoloudness, slow rate, excess loudness variations and voice tremor.

Subsequent research has confirmed Darley et al.'s (1969a, 1969b) observations with a range of perceptual as well as instrumental methods. Studies focusing on segmental aspects report a range of impairments in vowel and consonant production in speakers with CA as well as FDA. More specifically, a reduction in vowel space contrasts has been reported (Baudelle, Vaissiere, Renard, Roubeau, & Chevrie-Muller, 2003; Chiu, Chen, & Tseng, 1996). In addition, segmental timing difficulties are frequently identified, such as a loss of distinction between voiced and voiceless plosives (Ackermann, Graber, Hertrich, & Daum, 1999; Ackermann & Hertrich, 1997; Blaney & Hewlett, 2007), as well as difficulties with vowel length (Ackermann et al., 1999; Blaney & Hewlett, 2007; Gentil, 1990).

Timing problems also feature strongly at the suprasegmental level. Ataxic dysarthria is generally associated with a slow speech rate, both in alternating/sequential movement rates as well as connected speech. This has been reported across FDA and CA (Ackermann & Hertrich, 1994; Folker et al., 2012; Gentil, 1990; Hartelius, Runmarker, Andersen, & Nord, 2000; Schalling, Hammarberg, & Hartelius, 2008; Wang, Kent, Duffy, & Thomas, 2009; Ziegler & Wessel, 1996). Probably the most distinctive symptom of impaired speech timing in ataxic dysarthria are the rhythmic disturbances experienced by many speakers, also referred to as scanning speech or syllable-timed rhythm. Acoustic-phonetic studies have identified a tendency towards more equalised vowel durations as one of the main contributors to this perceptual phenomenon, although other factors such as the reduced speech rate as well as altered loudness and pitch manipulations can also play a role (Hartelius et al., 2000; Henrich, Lowit, Schalling, & Mennen, 2006; Liss et al., 2009; Schalling et al., 2008).

Further prosodic disturbances are associated with phonation. Boutsen, Duffy, Dimassi, and Christman (2011), Schalling et al. (2008) and Kent et al. (2000) report phonatory problems for CA, including vocal tremor, and disturbances in periodicity and loudness and pitch variability. Similarly, Gentil (1990) reports sudden variations in pitch and loudness for speakers with FDA. Folker et al. (2012) furthermore observed strained-strangled or rough voice quality, combined with changes in signal-to-noise ratio in FDA speakers. Although a number of researchers noted that their participants presented with a highly variable profiles, possibly reflecting different underlying neurological symptom complexes, it can probably be argued that the majority of speakers with ataxia will experience phonatory disturbances at some stage of their disease progression. Combined with the timing difficulties described above, such problems can impact on the speaker's ability to use prosody in a linguistically meaningful way, such as focusing on important information in utterances, or signalling grammatical or pragmatic distinctions. Ataxic dysarthria can thus result in significant communication issues despite relatively unaffected segmental articulation patterns.

The above investigations are based on a variety of methodologies, including perceptual and acoustic analysis methods, structured versus more naturalistic speech tasks and detailed instrumental investigations as opposed to more global judgements on speech quality. The collation of results from this wide range of investigations has allowed researchers to establish what the main characterising features of ataxic dysarthria are. What is still lacking though is a good understanding of how exactly disturbances at the acoustic-phonetic level relate to perceived problems of expressing linguistic meaning and vice versa. Although a number of studies have incorporated several analysis levels, data have not necessarily been able to elucidate this relationship. Of the above studies into articulatory difficulties, only Blaney and Hewlett (2007) compared the results of segmental error analysis with overall intelligibility ratings of the same speakers, thus being able to indicate which segmental errors correlated most with the observed intelligibility deficit. Prosodic investigations present with similar methodological issues. Although Schalling et al. (2008) provide both perceptual and acoustic data, these were not correlated to aid the characterisation of their participants' speech performances. Similarly, Lowit, Kuschmann, MacLeod, Schaeffler, and Mennen (2010) evaluated the phonetic characteristics of stress production in their speakers in the context of how well these contrasts had been perceived by listeners, but did not directly correlate the results with each other. There is thus a significant lack of research into the relationship between acoustic-phonetic measures and their perceptual correlates in ataxia dysarthria.

One area that has recently seen some progress in bridging this gap is research on intonation, where the application of the autosegmental-metrical (AM) framework (Pierrehumbert, 1980) has allowed researchers to investigate intonation from a phonological perspective and to relate these phonological representations to their phonetic correlates in order to make statements about the linguistic meaning. The AM framework interprets intonation contours as a sequence of meaningful local events around stressed syllables and phrase boundaries. This categorisation of intonation patterns allows researchers to systematically investigate the relationship between phonetic speech characteristics such as duration, intensity, and F0 modulations and their phonological manifestations. Kent and Kim (2003) highlight the value of this dual approach for the investigation of intonation deficits in motor speech. However, to date, only Kuschmann and Lowit (2012) have investigated this relationship in a systematic way in a small sample of speakers with Foreign Accent Syndrome (FAS). The study was able to establish differences between impaired speakers and healthy controls at both the phonetic and phonological level. More importantly though, it highlighted variations across the disordered population in the relationship between the two levels, which had distinct perceptual outcomes and warranted different treatment approaches. Kuschmann and Lowit (2012) were thus able to confirm the clinical value of such investigations in addition to contributing to our understanding of the disorders.

The current investigation aims to apply a similar approach to speakers with ataxic dysarthria. Lowit et al. (2010) had performed an acoustic-phonetic analysis of stress production tasks with speakers with CA and SCA, with one of the