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# Acoustic and perceptual correlates of faster-than-habitual speech produced by speakers with Parkinson's disease and multiple sclerosis

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ABSTRACT

Acoustic-perceptual characteristics of a faster-than-habitual rate (Fast condition) were examined for speakers with Parkinson's disease (PD) and multiple sclerosis (MS). Judgments of intelligibility for sentences produced at a habitual rate (Habitual condition) and at a faster-than-habitual rate (Fast condition) by 46 speakers with PD or MS as well as a group of 32 healthy speakers revealed that the Fast condition was, on average, associated with decreased intelligibility. However, some speakers' intelligibility did not decline. To further understand the acoustic characteristics of varied intelligibility in the Fast condition for speakers with dysarthria, a subgroup of speakers with PD or MS whose intelligibility did not decline in the Fast condition (*no decline* group, $n = 8$) and a subgroup of speakers with significantly declined intelligibility (*decline* group, $n = 8$) were compared. Acoustic measures of global speech timing, suprasegmental characteristics, and utterance-level segmental characteristics for vocalics were examined for the two subgroups. Results suggest acoustic contributions to intelligibility under rate modulation are complex. Potential clinical relevance and implications for the acoustic bases of intelligibility are discussed.

**Learning outcomes:** Readers will be able to (1) discuss existing evidence for the use of rate change to facilitate intelligibility, (2) describe acoustic-perceptual characteristics of a faster-than-habitual rate among speakers with mild dysarthria, (3) discuss the relationships between rate, intelligibility, suprasegmental variables, and segmental variables, (4) identify the need to further investigate the acoustic basis for intelligibility and its potential theoretical and clinical implications.



## 1. Introduction

Rate change has been shown to affect the spectral characteristics of speech (see also review in Tsao, Weismer, & Iqbal, 2006). For healthy speakers, for example, a faster-than-habitual rate has been associated with a decrease in vowel acoustic contrast and vowel acoustic working space (e.g., Lindblom, 1963, 1990; Perkell et al., 2004; Tsao et al., 2006) although other studies have demonstrated a variable relationship between a faster-than-habitual rate and vowel spectral characteristics (e.g., Fourakis, 1991; Gay, 1978; Van Son & Pols, 1990). In comparison, a slower-than-habitual rate has been associated with

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enhanced vowel spectral characteristics (e.g., Ferguson & Kewley-Port, 2007; Tjaden & Wilding, 2004). For speakers with dysarthria, similarly, a faster-than-habitual rate has been associated with a decrease in vowel acoustic contrast and vowel space (e.g., Hustad & Lee, 2008; McRae, Tjaden, & Schoonings, 2002; Tjaden, Rivera, Wilding, & Turner, 2005; Turner, Tjaden, & Weismer, 1995; Weismer, Laures, Jeng, Kent, & Kent, 2000), and a slower-than-habitual rate has been associated with an increase in the size of the acoustic vowel space (e.g. McRae et al., 2002; Tjaden et al., 2005; Tjaden & Wilding, 2004; Weismer et al., 2000).

Evidence of enhanced segmental acoustic contrast for a slower-than-habitual rate would seem to support improved intelligibility for healthy speakers and speakers with dysarthria alike, but slower-than-habitual rate has been shown to variably impact intelligibility for speakers with dysarthria despite an increase in vowel space area (McRae et al., 2002; Turner et al., 1995; Weismer et al., 2000). Nonetheless, rate control, usually in the form of a slower-than-habitual rate, is commonly recommended as a therapeutic technique to improve intelligibility for speakers with dysarthria (Duffy, 2013; Yorkston, Hakel, Beukelman, & Fager, 2007).

On the other hand, evidence of degraded segmental articulation in the form of reduced acoustic contrast at a faster-than-habitual rate would seem to suggest that a faster-than-habitual rate would likely contribute to compromised speech intelligibility (e.g., Tsao et al., 2006). However, studies have shown that a faster-than-habitual rate is not always accompanied by a reduction in intelligibility despite a decrease in vowel acoustic working space (e.g., McRae et al., 2002; Weismer et al., 2000). In addition, Turner et al. (1995) reported variable effects of a faster-than-habitual rate on intelligibility and vowel space area for speakers with dysarthria secondary to amyotrophic lateral sclerosis (ALS). Thus, the disparate findings to date suggest the relationship between segmental acoustic changes accompanying rate manipulation and intelligibility warrants further attention.

It is noteworthy that a faster-than-habitual rate has been shown to facilitate speech naturalness or speech acceptability at least for some speakers, with or without dysarthria (Dagenais, Brown, & Moore, 2006; Logan, Roberts, Pretto, & Morey, 2002), and these perceptual constructs are strongly associated with intelligibility (see also discussion in Sussman & Tjaden, 2012). The perceptual constructs of speech naturalness or acceptability are further thought to reflect global, suprasegmental aspects of speech (Sussman & Tjaden, 2012). Wingfield's (1975) study on time-compressed speech also demonstrated the importance of prosody to intelligibility. Much of what is known about the suprasegmental contributions to intelligibility comes from the normal speech literature (e.g., Bradlow, Toretta, & Pisoni, 1996; Bunton, Kent, Kent, & Duffy, 2001; Krause & Braida, 2004; Laures & Bunton, 2003; Laures & Weismer, 1999; Miller, Schlauch & Watson, 2010; Spitzer, Liss & Mattys, 2007), and there is a scarcity of dysarthria studies investigating the contribution of suprasegmental variables to intelligibility (Weismer, 2008). Even more limited are studies of rate manipulation reporting suprasegmental measures such as fundamental frequency (F0) or vocal intensity. One study by D'Innocenzo, Tjaden, and Greenman (2006) reported measures of mean sound pressure level (SPL) for sentences produced at a faster-than-habitual rate by a speaker with dysarthria secondary to traumatic brain injury. Intelligibility for this speaker did not decline at a faster-than-habitual rate. D'Innocenzo and colleagues further reported that a faster-than-habitual rate was associated with an increase in vocal intensity. The finding of an increased SPL at a faster-than-habitual rate has also been reported for healthy speakers (Dromey & Ramig, 1998; Wohlert & Hammen, 2000). Relatedly, an increase in mean SPL has been reported to be beneficial for intelligibility in studies investigating speaking strategies other than rate manipulation, such as studies investigating an increased vocal intensity as well as clear speech (Ferguson & Kewley-Port, 2007; Sapir, Spielman, Ramig, Story, & Fox, 2007; Smiljanić & Bradlow, 2009).

Rate manipulation also may impact utterance level F0 characteristics. One study has reported an increase in utterance-level F0 variability for a faster-than-habitual rate (Dromey & Ramig, 1998). Conversely, Tjaden and Wilding (2011) found that a slower-than-habitual rate for speakers with multiple sclerosis (MS) and PD was associated with reduced F0 modulation (e.g., F0 range and F0 rate of change). Similar associations between a slower-than-habitual rate and reduced F0 modulation have also been reported for neurologically normal speakers (Cooper & Sorensen, 1981; Ladd, Faulkner, Faulkner & Schepman, 1999). Given that a decrease in utterance-level F0 variability has been shown to be detrimental to intelligibility (e.g., Bunton et al., 2001; Laures & Weismer, 1999; Watson & Schlauch, 2008), one implication is that increased F0 modulation for a faster-than-habitual rate may have the potential to facilitate intelligibility.

In summary, the acoustic consequences of rate modulation for speakers with dysarthria and their relationship to intelligibility warrant further investigation, as this knowledge has potential clinical implications and theoretical importance (Kim, Kent, & Weismer, 2011; Smiljanić & Bradlow, 2009; Weismer, 2008; Weismer et al., 2008). Dysarthria studies to date have largely focused on the contribution of segmental variables to intelligibility. How segmental and suprasegmental variables interact to impact intelligibility is only beginning to be understood (e.g., Bunton, 2006; Spitzer et al., 2007). Importantly, rate modulation affords the opportunity for an examination of segmental and suprasegmental characteristics associated with variations in intelligibility (e.g. Turner et al., 1995; Weismer et al., 2000; McRae et al., 2002; D'Innocenzo et al., 2006) and therefore can help to advance conceptual understanding of intelligibility.

### 1.1. Purpose and design

The goal of the current study was to investigate acoustic variables associated with variations in intelligibility at a faster-than-habitual rate for speakers with mild dysarthria. The interest in a faster-than-habitual rate was motivated by two primary findings that emerged from the above review. First, a slower-than-habitual rate has yielded variable intelligibility outcomes despite its wide acceptance as a therapeutic technique, and there does not appear to be strong evidence that a