Critical Review:
The effects of rate reduction on speech intelligibility in individuals with hypokinetic dysarthria

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This critical review examined the effects of rate reduction on speech intelligibility in individuals with hypokinetic dysarthria. A search of electronic databases yielded ten studies that met selection criteria for this critical review. Study designs included: one systematic review, four experimental single subject studies, and five group studies, including an alternating treatments time series study, a non-randomized controlled before and after study, a within groups repeated measures study, a case-control study, and a single group pre-post test study. Overall, the evidence indicates that individuals with hypokinetic dysarthria can reduce their rate of speech and this contributes to improved speech intelligibility. Further research should be conducted with larger sample sizes, further statistical analyses, more naturalistic speech tasks, and comparisons between treatments for rate and treatments for other speech characteristics.

Introduction

Individuals with hypokinetic dysarthria often possess many abnormal speech characteristics that affect speech intelligibility, including monopitch, monoloudness, imprecise consonants, changes in voice quality, and variable rate (Darley, Aronson, & Brown, 1969). Rate of speech abnormalities typically involve an overall rapid speech rate and short rushes of speech or increased rate within speech segments (Duffy, 2005). In addition, individuals with hypokinetic dysarthria may have altered self-perception of their speech loudness and rate, which could contribute to difficulty with monitoring their speech output (Duffy, 2005).

In the literature, studies of treatment methods for individuals with hypokinetic dysarthria most often focus on increasing vocal loudness in treatment programs such as Lee Silverman Voice Treatment (LSVT). Such treatment methods have provided the strongest evidence for improvements in communication for individuals with hypokinetic dysarthria to date (Yorkston, Hakel, Beukelman, & Fager, 2007).

The impact of speech rate reduction on speech intelligibility in these individuals has received less attention and most studies are at the phase of research that involves testing potential benefits of intervention (Yorkston et al., 2007). However, subjective evidence from clinicians has suggested that treatments for loudness may be more appropriate for clients of mild severity due to the physical and cognitive demands of intensive treatment programs like LSVT (Lowit, Dobinson, Timmins, Howell, & Kroger, 2010). Therefore, it is necessary to further investigate and evaluate other methods of treatment for communication in individuals with hypokinetic dysarthria that could be effective, while less fatiguing and possibly more feasible. Although a systematic review of the literature was published in 2007 by Yorkston et al. addressing the treatment of loudness, rate, and prosody in dysarthria, it addressed all types of dysarthria and many outcome measures, and therefore it was necessary to review the literature with more specific selection criteria. There have also been more recent studies published on the effects of rate reduction treatment on the intelligibility of speakers with hypokinetic dysarthria that were included in the present review.

Objectives

The primary objective of this paper was to outline and critically evaluate the existing literature that has examined the effects of rate reduction on speech intelligibility in individuals with hypokinetic dysarthria. The secondary objective was to propose evidence-based recommendations for the clinical use of rate reduction methods with individuals with hypokinetic dysarthria.

Methods

Search Strategy

Computerized databases including Scopus, PubMed, and Google Scholar were searched and the following key term searches were initially targeted: dysarthria AND "rate reduction," "speech rate" AND intelligibility AND dysarthria, speech AND rate AND intelligibility AND dysarthria. This search was limited to studies in English that were published before February 2013.

Selection Criteria

Studies selected for inclusion in this critical review paper were required to investigate the effects of rate reduction methods on intelligibility in speakers with hypokinetic dysarthria. These papers presented outcome measures for at least one adult patient that was stated to have hypokinetic dysarthria, and no other limits were set on the demographics of research participants (e.g. gender, culture, socioeconomic status, etc.) Papers included were required to have clear outcome measures for speech intelligibility.

Data Collection

Results of the literature search yielded ten articles consistent with the selection criteria: one systematic review, four experimental single subject studies, and five group studies, including an alternating treatments time series study, a non-randomized controlled before and after study, a within groups repeated measures study, a case-control study, and a single group pre-post test study. For the purpose of this review, outcomes of rate and intelligibility are primarily discussed, despite the inclusion of other measures in the studies.

Results

Systematic review: Yorkston et al. (2007) conducted a systematic review (level 1+ evidence) that focused on 51 intervention studies that looked at the effectiveness of treatment for global aspects of speech (loudness, rate, prosody, and general instructions) in people with dysarthria. Of these studies, 19 articles reported outcomes of treatment that focused on rate of speech manipulation. This is the only group of studies of particular interest for the purpose of the present review. The authors present the outcomes of these rate treatment studies in a table and comment that most of them are phase I studies (testing potential benefits of intervention) and some are phase II studies (preliminary investigation of intervention protocols). A variety of techniques were used to modify speaking rate. The authors evaluated these studies based on descriptions of participants and found that 21% of the studies provided comprehensive descriptions, 63% detailed, and 16% brief. Many medical diagnoses and dysarthria types were included in the studies they evaluated. In these studies, perceptual ratings of variables such as intelligibility were common. In general, this group of studies supported the relationship between decreasing rate of speech and improved speech intelligibility. The authors discussed that the literature suggests benefit of rate control in dysarthria, but this benefit is dependent on many factors that require further research.

This recent review effectively and thoroughly evaluated the literature on rate treatment across all individuals with dysarthria. Their results suggest that further investigation of the topic is required. Only a fraction of the studies evaluated in the Yorkston et al. (2007) review were included in the present review due to more restricted selection criteria.

Single subject study #1: Dagenais, Southwood, and Lee (1998) conducted a single subject multiple baseline study of three individuals (level 1 evidence) with diagnoses of Parkinson's disease (PD) and hypokinetic dysarthria. The authors of the study provided a detailed description of the study participants. The purpose of this study was to determine the impact of rate reduction treatments on speech intelligibility, and to determine the effects of incorporating delayed auditory feedback (DAF) into speech training protocols.

Measures obtained for speech rate were in syllables per minute (SPM) during reading, picture description, and spontaneous speech tasks. Intelligibility measures were obtained through online ratings and results from the Assessment of Intelligibility of Dysarthric Speech (AIDS) sentence subtest taken pre- and post-therapy. These measures were described in detail in the study and values for intrajudge reliability (97-100%) and interjudge reliability (79-98%) were reported.

Methods were described in enough detail for this study to be replicated. Speaker 1's treatment was an AiBCDAii design with the following conditions: Ai was baseline; B was different levels of delayed auditory feedback (DAF); C was DAF plus traditional clinician-directed rate therapy with oral-motor exercises, verbal feedback, and drills; D was DAF plus prolonged speech; Aii was a baseline phase to determine maintenance without intervention. Phase D was most effective for rate reduction in this speaker (rate reduction from 160 SPM at baseline to 60-80 SPM in reading and 75-130 SPM in picture description). Post-therapy intelligibility scores were significantly greater than pre-therapy scores ($p<.01$; pre-therapy M=87.5%, post-therapy M=95.4% and 4 months post-therapy M=95.5%). Speaker 2's treatment was an AiBDAii design. His rate was unstable with the various treatments and gains in intelligibility were minimal. Speaker 3's treatment followed the original AiBCDAii design, but the D phase did not contain DAF. Speaker 3 did not have a significant response to DAF at any delay setting or in prolonged speech without DAF. Despite the lack of rate change, Speaker 3 made gains in intelligibility with treatment (pre-therapy M=74.6% and post-therapy M=93.1%).

The authors noted that Speaker 1's change in rate and intelligibility were likely due to the prolonged speech treatment in the D phase, rather than DAF, since DAF was ineffective for this speaker in other phases. They also commented that Speaker 1 may have responded to prolonged speech while the others did not due to his earlier age of onset of PD. The results of this study suggest that prolonged speech can successfully improve rate control and consequently, speech intelligibility. This evidence is equivocal and should be interpreted with caution since this method was effective for only one of three speakers.

Single subject study #2: Hanson and Metter (1983) conducted a single subject time series study of two individuals (level 1 evidence) with diagnoses of PD and hypokinetic dysarthria. These authors provided

comprehensive descriptions of their participants. The purpose of this study was to determine the effects of DAF on these patients' rate of speech, vocal intensity, fundamental frequency, and speech intelligibility. Patients wore their DAF device daily for three months. Measurements were made from recorded samples with and without DAF during reading, conversation, and maximum phonation tasks. Conversation measurements were not taken for Patient A. Recordings were taken at the beginning of treatment and at one-month intervals for three months. Measurements of rate were in words per minute (WPM) and measures of speech intelligibility were from listener ratings by three speech-language pathologists (SLP) on 7-point equal-appearing intervals scales. The authors reported high interrater reliability for intelligibility (97%) and a correlation of r=.96 between ratings of identical samples.

Results showed that both speakers experienced a significant reduction in speech rate with DAF (Patient A for reading: t=9.49; df=3; p<.01 and Patient B for reading and conversation, respectively: t=4.67; p<.05 and t=3.29; p<.05). Comparisons of tracings of a phrase spoken normally and with DAF indicate the extent of increases in articulation and pause time with DAF, as well as increased physiological effort, which may assist with rate reduction. Mean intelligibility scores improved significantly over the four recording sessions (Patient A: t=12.99; p<.01 and slightly for Patient B) and between normal and DAF (Patient A: t=12.12; p<.01 and Patient B in conversation: t=4.99; p<.05).

These results indicate that speech rate can be significantly reduced in individuals with hypokinetic dysarthria and can result in significant improvements in speech intelligibility. However, these results should be interpreted with caution due to small sample size.

Single subject study #3: Hanson and Metter (1980) reported on a time series study of one patient (level 1 evidence) with progressive supranuclear palsy (PSP) and hypokinetic dysarthria. A detailed description of the patient was provided. The authors noted that this patient demonstrated many parkinsonian symptoms and speech characteristics and he originally received a diagnosis of PD. The purpose of this study was to examine the effects of wearing a DAF device as a permanent speech prosthesis. This patient wore a DAF device with 100 ms delay for three months. Time series measurements of speaking rate, vocal intensity, and speech intelligibility were made from recorded speech samples made with and without DAF. Speech samples were from reading and counting aloud. Rate was measured in WPM and intelligibility was judged by seven SLPs on a 7-point equal-appearing intervals scale. The authors reported high interrater (89%) and intrarater (98%) reliability.

Results of this study indicate that DAF was effective for reducing speech rate. The speech rate in trials measured without DAF was usually more than double the rate from trials with DAF. Ratings of speech intelligibility suggest an improvement in speech intelligibility with DAF. The mean of median ratings for samples without DAF was 6.43 and the mean of median ratings for samples with DAF was 1.00 (where 1 represents normal speech intelligibility and 7 represents severe deviation).

Overall, positive effects for use of DAF as a permanent speech prosthesis were seen and maintained. Data tables were included in this report but no statistical analysis of the data was reported. Impressive gains in intelligibility were presented, but this data should be interpreted carefully because of this lack of analysis and study of only one patient.

Single subject study #4: This study by Le Dorze, Dionne, Ryalls, Julien, and Ouellet (1992) is a single subject multiple baseline study of one woman (level 1 evidence) with PD and accompanying hypokinetic dysarthria. The authors provided a comprehensive description of the patient. The purpose of this study was to investigate the effects of computer-assisted auditory and visual feedback in speech and language therapy for aspects of prosody in people with dysarthria and PD.

Measures obtained during therapy included fundamental frequency, total sentence duration in milliseconds (ms), and rate was calculated in syllables per second (SPS). These measures were taken in each therapy session while speaking sentences. Measures were adequately explained in the study. Intelligibility was measured by ten judges as the total number of words understood. Reliability measures for ratings were not reported.

The prosodic therapy in this study involved the treatment of three behaviours sequentially in phases: intonation, mean fundamental frequency, and rate of speech. Therapy phases continued until criteria were achieved (two or three sessions per week for nine weeks). Therapy involved visual and auditory biofeedback in a software program, SpeechViewer, as well as instruction and modeling from an SLP.

After three rate therapy sessions, there was a substantial decrease in rate to the rate criterion 3.8 SPS, which was 2 standard deviations (SD) below the mean (baseline mean=4.3 SPS, SD=0.24). Measures obtained ten weeks post-treatment demonstrated a rate of 3.9 SPS. Mean percentage of words correct pre-treatment was 86% and post-treatment was 96% (t=3.101; p<.01).

Results demonstrate improvements in rate and intelligibility. There was a significant improvement in speech intelligibility post-treatment, however it cannot

be determined if changes were due to one specific behaviour treatment or the whole treatment protocol for intonation, fundamental frequency, and rate of speech. This data should also be evaluated cautiously since there was only one patient in the study.

Group study #1: An alternating treatments time series study (level 2a evidence) by Lowit et al. (2010) compared the long-term effects of traditional rate control therapy and altered auditory feedback (AAF) on speaking rate and intelligibility, and to evaluate the use of AAF as an everyday treatment device in ten speakers with PD. The authors presented detailed information about their study participants. The study used an alternating treatment design and each patient received both types of therapy (AAF and traditional therapy) for six weeks each, separated by a six-week break. Intervention was delivered once weekly in their own home. Traditional therapy involved pause insertion techniques with phrasing exercises, and performance feedback. Homework was encouraged. AAF was delivered with a choice of two devices. AAF sessions involved determining the best feedback types and settings, and practicing with the device in sessions and at home. Tasks for measurement included reading and monologues. Speech rate was measured in SPS in reading only and intelligibility was rated by ten SLP students using magnitude estimation for reading and a 9-point Likert scale for monologue. Agreement between listeners was good ($r=.89$, $p<.01$).

A mixed ANOVA was performed to evaluate changes in speech rate and intelligibility over time. Many statistical analyses were presented including Wilk's Lambda, Partial Eta Squared, Wilcoxon Signed Rank Tests, and Bonferroni post-hoc tests. These results suggested that AAF significantly reduced speech rate, but no significant changes in intelligibility occurred within each group. Individual profiles suggested that some participants had experienced changes over time, but no significant difference was found, suggesting that AAF and traditional therapy did not affect speech differentially. Despite this statistical insignificance, four of ten participants had higher intelligibility ratings without AAF after the first phrase of therapy and after six months. Three speakers showed improved intelligibility with AAF but not without AAF, and three speakers showed no change over time.

Overall, these results do not suggest that rate reduction techniques have long-term effects on intelligibility, however individual patients benefited from these treatments, providing equivocal evidence. This study did not clearly report on short-term effects of rate reduction treatment.

Group study #2: Van Nuffelen, De Bodt, Wuyts, and Van De Heyning (2009) conducted a non-randomized controlled before and after study (level 2a evidence) that investigated the effect of seven different rate control methods on speaking rate (SR), articulation rate (AR), and intelligibility in individuals with dysarthria. There were 19 participants described with sufficient detail, (six of whom demonstrated hypokinetic dysarthria and the others demonstrated unilateral upper motor neuron dysarthria, flaccid dysarthria, and ataxic dysarthria). SRs and ARs of this group were compared to a healthy control group. Rate reduction methods included: speaking slower on demand, alphabet board, hand tapping, pacing board, and DAF with three different delay times (50ms, 100ms, and 150ms). Individuals were given instructions for how to use the rate reduction methods. Reading samples of two minutes were collected from individuals using habitual speech and each of the seven rate control methods. Intelligibility was rated by five SLPs using a 100mm visual analogue scale. Strong interrater reliability was reported (intraclass correlation coefficient=.85). SR was calculated in SPS, pauses included and AR was calculated in SPS, pauses excluded.

Statistical analyses of the results using repeated-measures ANOVA and post hoc pairwise comparisons with the Bonferroni correction determined that each of the rate control methods resulted in significant SR reductions in comparison to the habitual SR ($p<.05$; $p<.001$ for alphabet board, hand tapping, and pacing board). Each rate control method significantly reduced AR compared to the habitual AR ($p<.001$) except for speaking slower on demand. The rate control methods unexpectedly resulted in significant decreases in intelligibility ($p<.001$). Statistical analysis of the mean percentage error demonstrated that changes in intelligibility of more than 8% were meaningful. An increase of more than 8% only occurred in five speakers, and of interest to this review, two of these were speakers with hypokinetic dysarthria. In addition, the rate control methods that were responsible for increases of greater than 8% in intelligibility were voluntary rate control, alphabet board, hand tapping, and pacing board.

This study provides evidence that rate reduction methods used in clinical practice are effective for rate reduction in speakers with dysarthria. However, these reductions in rate did not necessarily result in increased intelligibility. The application of these results to the population of interest to this review, speakers with hypokinetic dysarthria, should be carefully considered, as this study looked at overall group data and did not present data for specific dysarthria types individually.

Group study #3: Tjaden and Wilding (2004) conducted a within groups repeated measures study with condition comparisons (level 2b evidence) with 15 individuals with multiple sclerosis (MS) and spastic/ataxic dyarthria, 12 individuals with PD and hypokinetic dysarthria, and 15 neurologically healthy speakers in order to examine the effects of articulatory rate reduction and vocal loudness on acoustic output and intelligibility. The authors described their participants comprehensively. The participants read passages in habitual, loud, and slow conditions using magnitude production (e.g. their habitual rate corresponded to 10 and they were instructed to speak at half of this rate, corresponding to 5). Speech samples were recorded. Rate was calculated in SPS. Intelligibility was rated by ten listeners using magnitude estimation with a free-modulus paradigm (listeners create their own rating scales) and then converted to a common scale.

For data analysis, a mixed linear model was fit to each dependent variable. A significant condition effect ($F_{(2,38)}$=67.58, p<.0001) and a significant group X condition interaction ($F_{(4,38)}$=4.21, p<.0065) and an insignificant group effect were found for rate. These results suggested that individuals were able to slow their rate using magnitude production. The rate in the slow condition was 23-58% slower than the habitual condition. A significant condition effect ($F_{(2,24)}$=3.79, p<.0372) and condition X group interaction ($F_{(2,24)}$=8.33, p<.0018) were found for intelligibility. These results suggested that the PD group was most intelligible in the loud condition and more intelligible in the slow condition than in the habitual condition.

These results demonstrated that speakers with PD and hypokinetic dysarthria are able to reduce their speech rate voluntarily with resulting improvement in intelligibility. A methodological strength of this study is the inclusion of a control group. These results must be examined carefully with respect to clinical application because results were obtained due to voluntary changes in one speech task, rather than treatment changes.

Group study #4: Yorkston, Hammen, Beukelman, and Traynor (1990) conducted a case-control study (level 2b evidence) with eight individuals with dysarthria (four with hypokinetic dysarthria and four with ataxic dysarthria), and four healthy controls that were matched to particular individuals with dysarthria in the study. The authors provided detailed descriptions of the individuals in the study. The purpose of this study was to explore the effect of speaking rate control on perceptual aspects of speech, including intelligibility. Sentence intelligibility was calculated as percentage of words correct using transcriptions by three graduate students of sentences from the Computerized Assessment of Intelligibility of Dysarthric Speech (CAIDS). Phoneme intelligibility was calculated using percentage of vowels and consonants correctly identified in a Phoneme Identification Task completed by these judges. Mean scores were calculated and reliability measures were not presented. Speaking rates for participants were recorded at habitual rate, 80% of habitual rate, and 60% of habitual rate. Four rate control strategies were used: additive metered (AM) (words appear on the screen at the rate they should be spoken with equal duration), additive rhythmic (AR) (same as AM but with timing patterns of normal speech), cued metered (CM) (entire passage appears on the screen and words are underlined at the rate they should be spoken in equal duration), and cued rhythmic (CR) (same as CM but with timing patterns of normal speech). Both actual and target rates were measured and calculated as WPM.

All of the controls and six of the individuals with dysarthria were able to achieve the desired rates with the pacing tasks. A closer look at the data suggested that in all cases, speaking rates achieved were within 10% of the target rates in the sentence intelligibility task. For individuals with hypokinetic dysarthria in the phoneme intelligibility task, actual speaking rates were even slightly slower than the target rates.

Results indicated that in the group with hypokinetic dysarthria, mean sentence intelligibility improved from 60.7% at the habitual rate to 81.2% at the 60% of habitual rate. The individual data suggested that all individuals improved sentence intelligibility with decreases in rate. When looking across specific rate control methods, the CM strategy resulted in the highest sentence intelligibility score over half of the time (54%). Mean phoneme intelligibility scores demonstrated minimal change with decreased rate, and scores between the habitual rate and 60% of habitual rate conditions were no more than 5% different in any case.

This study provides evidence for the beneficial effect of rate reduction methods that caused improvements in intelligibility and could be used in clinical practice. A strength of this study is the matched control group. Due to small sample size, and therefore lack of statistical analyses, the applicability of this evidence should be considered with caution.

Group study #5: A single group pre-post test study (level 3 evidence) by Van Nuffelen, De Bodt, Vanderwegen, Van De Heyning, and Wuyts (2010) examined the effect of seven rate control methods on speech intelligibility, speaking rate (SR), articulation rate (AR), and pause characteristics in 27 individuals

with dysarthria described with sufficient detail (nine of whom demonstrated hypokinetic dysarthria, and the others demonstrated unilateral upper motor neuron dysarthria, flaccid dysarthria, ataxic dysarthria, spastic dysarthria, and mixed dysarthria). Rate reduction methods were the same as in the study by Van Nuffelen et al. (2009). Some information about measures obtained in this study was not presented, however, the authors' previous study used similar methods and measures. Two-minute reading samples were collected from individuals using habitual speech and each of the seven rate control methods. Intelligibility was rated by three SLPs using a 100mm visual analogue scale. Strong interrater reliability was reported (intraclass correlation coefficient=.85).

Each of the rate control methods resulted in significant SR reductions in comparison to the habitual SR and AR ($p<.001$) except for speaking slower on demand. SR and AR were reduced by an average of 9.3% and 3.7% respectively. Statistical analysis showed that rate reduction unexpectedly caused significant decreases in intelligibility ($p<.05$), however further analysis demonstrated that rate control significantly improved intelligibility for at least one rate control method in almost half of the participants. There were not enough participants with each type of dysarthria to complete statistical analyses by dysarthria type, however significant improvements in intelligibility were made for 13 patients; five of whom were people with hypokinetic dysarthria. The authors' report of significant results was not entirely clear and required some interpretation.

This study provides evidence that rate reduction methods used in clinical practice are effective for rate reduction in speakers with dysarthria, but methods that produce maximum decreases in SR do not necessarily produce maximum increases in intelligibility. This is important to consider when choosing methods of SR treatment. The evidence provided is equivocal because improvements in intelligibility were only noted when participants were considered individually.

Discussion

Overall, the evidence in the literature suggests that it is possible to reduce the rate of speech in individuals with hypokinetic dysarthria, and this typically results in improved speech intelligibility.

Despite this fairly consistent trend, the evidence from these ten studies needs to be interpreted carefully because the studies that were included have fairly small sample sizes. Four of these studies were single subject study designs with one to three participants. The sample sizes of the five group studies ranged from 10 to 42 participants. Of these group studies, two included groups of several dysarthria types and did not evaluate participants by dysarthria type, and two studies included comparison groups of individuals with other dysarthria types that were not of interest to this review. Due in part to these small sample sizes, statistical analyses and significance were not presented for all studies, making it more difficult to evaluate some of the data. While most of these studies described their participants in great detail and mentioned that they were regularly taking medications, most of them failed to mention the time of day that treatments and measurements were taken, relative to the ingestion of medication. This is relevant because medications used to minimize parkinsonian side effects can either increase or decrease the severity of dysarthria experienced (Duffy, 2005). The severity level of dysarthria was also noted in many studies, but the participants were not grouped or studied by severity level. This may be of importance because rate reduction treatment could have more impact on individuals of a certain severity level.

Furthermore, these studies were all very different methodologically, which makes it difficult to compare outcomes across studies. Some of these studies evaluated treatment techniques, while others assessed one-time voluntary changes in speech rate, and others focused on long-term effects of treatment. In addition, the single subject study by Le Dorze et al. (1992) used multiple treatment methods and only one of the treatments focused specifically on speech rate reduction. Since measures were taken at the end of the entire treatment protocol, it is difficult to determine whether improvements in intelligibility were due to rate reduction, another treatment, or the entire protocol.

Another important consideration is the type of speech tasks used for evaluating speech rate and intelligibility. Speech tasks varied across studies, and even across participants within some studies. While all of the studies evaluated speech rate and intelligibility in reading, only three studies took measures during conversation. Tasks such as reading and counting are much more controlled and therefore easier methods to study these individuals, however they are very contrived. One's ability to reduce rate and improve intelligibility in these tasks does not necessarily reflect their ability to do so in conversation, which is a more naturalistic task. Trends from conversation tasks would likely be more applicable to real life speaking situations for individuals with hypokinetic dysarthria.

Measurements used for determining intelligibility are rather subjective in nature and a variety of methods and scales were used for its measurement in these studies, also making comparisons across studies difficult.

Despite these inconsistencies, six of the nine studies presented good reliability measures for ratings of intelligibility.

In conclusion, the literature provides suggestive evidence that rate reduction can improve intelligibility in individuals with hypokinetic dysarthria. However, this literature should be interpreted carefully and the topic warrants further research. Further research would ideally include studies of larger groups of individuals with hypokinetic dysarthria and not include individuals with other dysarthria diagnoses in order to determine the effects of rate reduction on intelligibility specifically in individuals with hypokinetic dysarthria. It may also be of interest to group individuals based on severity level of dysarthria. With larger group sample sizes, it would also be possible to conduct more statistical analyses, which would help to evaluate the strength of evidence provided. Studies should also look at rate of speech and intelligibility measures from conversational samples in addition to reading samples to more adequately reflect natural speaking situations experienced by individuals with hypokinetic dysarthria. While it is difficult to determine the most effective protocol for measuring speech intelligibility, it would be ideal for studies to employ a standardized measure that is less subjective in nature. It would also be interesting to study intelligibility ratings by familiar listeners in addition to unknown listeners because their ability to understand these individuals may be different and it is most important that people are understood in their daily lives by those who they spend the majority of their time with. Research should also focus on the comparison of rate reduction treatment to treatments of other speech characteristics, such as loudness and prosody, in order to determine the most effective methods of treatment for individuals with decreased speech intelligibility associated with hypokinetic dysarthria. It is evident that further research with more consistent methods and tasks that are more applicable to daily living must be conducted in order to determine the strength of the relationship between rate reduction and speech intelligibility in individuals with hypokinetic dysarthria.

Clinical Implications

The results of these studies indicate that rate reduction in individuals with hypokinetic dysarthria is associated with improvements in speech intelligibility. This has important clinical implications, as improved intelligibility is often a major goal in speech therapy for individuals with hypokinetic dysarthria. Rate reduction treatment can be used in speech therapy as an effective method for making gains in intelligibility that may be less fatiguing and possibly more feasible than other treatment protocols. Future studies are necessary to determine the strength of this relationship and research should focus on the recommendations indicated above.

References

Dagenais, P.A., Southwood, M.H., & Lee, T.L. (1998). Rate reduction methods for improving speech intelligibility of dysarthric speakers with Parkinson's disease. *Journal of Medical Speech-Language Pathology, 6*(3), 143-157.

Darley, F.L., Aronson, A.E., & Brown, J.R. (1969). Differential diagnostic patterns of dysarthria. *Journal of Speech and Hearing Research, 12*, 246-269.

Duffy, J. R. (2005). Hypokinetic dysarthria. In *Motor speech disorders: Substrates, differential diagnosis, and management* (2nd ed.) (pp. 187-215). St. Louis, Missouri: Elsevier Mosby.

Hanson, W., & Metter, E. (1983). DAF speech rate modification in Parkinson's disease: A report of two cases. In W. Berry (Ed.), *Clinical dysarthria* (pp. 231-254). Austin, TX: Pro-Ed.

Hanson, W., & Metter, E. J. (1980). DAF as instrumental treatment for dysarthria in progressive supranuclear palsy: A case report. *Journal of Speech & Hearing Disorders, 45*, 268-276.

Le Dorze, G., Dionne, L., Ryalls, J., Julien, M., & Ouellet, L. (1992). The effects of speech and language therapy for a case of dysarthria associated with Parkinson's disease. *European Journal of Disorders of Communication, 27*(4), 313-324.

Lowit, A., Dobinson, C., Timmins, C., Howell, P., & Kroger, B. (2010). The effectiveness of traditional methods and altered auditory feedback in improving speech rate and intelligibility in speakers with Parkinson's disease. *International Journal of Speech-Language Pathology, 12*(5), 426-436.

Tjaden, K., & Wilding, G. E. (2004). Rate and loudness manipulations in dysarthria: Acoustic and perceptual findings. *Journal of Speech, Language, and Hearing Research, 47*(4), 766-783.

Van Nuffelen, G., De Bodt, M., Vanderwegen, J., Van De Heyning, P., & Wuyts, F. (2010). Effect of rate control on speech production and intelligibility in dysarthria. *Folia Phoniatrica Et Logopaedica, 62*(3), 110-119.

Van Nuffelen, G., De Bodt, M., Wuyts, F., & Van De Heyning, P. (2009). The effect of rate control on speech rate and intelligibility of dysarthric speech. *Folia Phoniatrica Et Logopaedica, 61*(2), 69-75.

Yorkston, K. M., Hakel, M., Beukelman, D. R., & Fager, S. (2007). Evidence for effectiveness of treatment of loudness, rate or prosody in dysarthria: A systematic review. *Journal of Medical Speech-Language Pathology, 15*(2), xi-xxxvi.

Yorkston, K. M., Hammen, V. L., Beukelman, D. R., & Traynor, C. D. (1990). The effect of rate control on the intelligibility and naturalness of dysarthric speech. *Journal of Speech and Hearing Disorders, 55*(3), 550-560.