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Effect of Rate Control on Speech Production and Intelligibility in Dysarthria

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Key Words

Rate control methods · Speaking rate · Articulation rate · Intelligibility · Pause characteristics

Abstract

The reported study investigated the effect of 7 rate control methods (RCM) on running speech intelligibility, speaking rate (SR), articulation rate (AR) and pause characteristics in 27 individuals with dysarthria. The data reveal that with the exception of slower on demand, each RCM resulted in lower mean SRs and ARs ($p < 0.05$). Clinically significant improvements in intelligibility were found in half of the participants with different types of dysarthria. The majority of them had normal or decreased ARs and SRs. The most effective methods were: alphabet board, hand tapping and pacing board. For the majority of speakers, the maximal decrease in speech rate was not associated with the maximal increase in intelligibility.

Introduction

Speech rate is often considered as a powerful modifiable variable for improving the intelligibility of dysarthric speech [1–3]. The correlation between rate and intelligibility, however, is not straightforward and depends on several (unknown) variables. Whereas several studies have demonstrated a positive effect of a specific rate control method (RCM) on intelligibility in dysarthria, others did not find such an effect, and 2 studies even found the opposite effect. When clustering all the data provided in these papers, there is an indication that pacing is a more effective method than delayed auditory feedback and speaking slower on demand. However, since all studies used different patients and methods, this has no scientific value. In their 2007 systematic review of evidence on the effectiveness of treatment of loudness, rate and prosody in dysarthria, Yorkston et al. [4] indicated that treatment studies comparing various RCMs would be necessary in the future. In 2008, Van Nuffelen et al. [5] published a study that compared the effect of 7 RCMs on articulation rate (AR), speaking rate (SR) and intelligibility in dysarthria. The 7 methods were: speaking slower on demand, pacing board, alphabet board, hand tapping, delayed auditory feedback with delays of 50 ms (DAF50), 100 ms (DAF100) and 150 ms (DAF150). The

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authors found that, with exception of speaking slower on demand, all methods significantly reduced AR and SR. Strikingly, all reduced the mean intelligibility of the whole dysarthric population. In cases of DAF100 and DAF150, the decrease was even significant. However, analysis of the individual data showed a clinically significant increase in intelligibility in 5 out of 19 participants. The methods that led to a clinically significant increase were hand tapping, speaking slower on demand, alphabet board and pacing board. At the 28th International IALP Congress, held in August 2010 in Athens, the authors discussed their data (which had been extended) more thoroughly, including information on method-specific pause characteristics and determination of ideal speech rate. These data are presented in this paper.

The following research questions were addressed:

(1) What is the effect of various RCMs on AR and SR?
(2) What is the effect of various RCMs on total pause duration, mean pause duration and pause frequency?
(3) What is the effect of various RCMs on intelligibility?
(4) Does the effect of rate control on intelligibility depend on habitual speech rate, type of dysarthria and/or severity of dysarthria?
(5) Does the maximal decrease in speech rate result in a maximal increase in intelligibility and can we define an ideal speech rate?

Methods

The methods used in the current study are in accordance with the methods used in the previous study [5].

Participants

The presented data are based on 27 participants (22 men, 5 women, mean age: 64 years, range: 17–88 years). Individuals with a habitual intelligibility level above 90% were excluded. All participants reported adequate language, hearing and visual abilities. The etiology of dysarthria varied among the participants. Detailed information for each patient concerning age, gender, type, etiology of dysarthria, severity of dysarthria, habitual SR and habitual AR is presented in table 1.

Rate Control Methods

The mutually compared RCMs were speaking slower on demand, alphabet board, hand tapping, pacing board, DAF50, DAF100 and DAF150. Prior to each method, the participants were given clear instructions. In case of speaking slower on demand, the participants were asked to speak half as fast as they were used to. In case of the alphabet board, the participants were instructed to indicate the first grapheme of each word on the board before uttering the word. Using the pacing board, the participants had to touch one square for each pronounced word (uttering word per word) and in case of hand tapping they were asked to tap once for each syllable (uttering syllable per syllable).

Text Passages

For this task, 20 different passages with simple sentence constructions and without any difficult word choices or reading level [6] were used. Seven (mean sentence length: 9 words; mean word length: 1.34–1.39 syllables) or 8 (mean sentence length: 10 words; mean word length: 1.38–1.44 syllables) were selected. For each method, the participants were asked to read a randomly selected reading passage for at least 2 min.

Speech Samples

Two-minute samples were recorded in each of the 8 assessed conditions. Each subject started with habitual SR, followed by the 7 RCMs. The sequence of the RCMs was randomized and differed between participants. The speech samples were recorded in a quiet environment by means of a notebook and a freely available wave editor (Audacity®). The mouth to microphone (Sony ECM-717) distance measured 300 mm. The digital speech samples had a sampling frequency of 44 kHz. Each sample was saved as a separate wave file.

Intelligibility Ratings

The intelligibility of the speech samples was rated by 3 speech language pathologists with experience in dysarthria. They were not familiar with the reading passages. Accordingly to a previously used definition of intelligibility [7–10], the listeners were instructed to indicate the degree to which they understood the utterances produced by the speaker on a 100-mm visual analogue scale. The listeners were asked to exclude perceptual judgments of naturalness, voice quality, pitch and so forth from the intelligibility rating. The extremities of the scale were respectively labeled as completely unintelligible and completely intelligible. Listeners reported normal hearing, and were native speakers of Dutch.

The 216 samples (27 participants × 8 conditions) were randomly played back by means of Windows Media Player, installed on a notebook (HP pavilion ze4600). As the samples were judged by all the listeners simultaneously, speakers (Logitech) were used to present the samples at a sound pressure level of 75–80 dB.

Inter-Rater Reliability for the Intelligibility Ratings

The inter-rater reliability for the intelligibility ratings was determined for all 216 samples by means of an intraclass correlation coefficient. Strong inter-rater reliability was found (0.85). The mean error rate was 8%, meaning that an increase in intelligibility of >8% can be interpreted as clinically significant.

Total Pause Duration, Mean Pause Duration and Pause Frequency

The samples were analyzed by means of the freely available wave-editor Audacity. Calculations of total pause duration, mean pause duration and pause frequency were based on silent pauses (a silent pause is defined as a silent fragment of at least 200 ms). Filled pauses were not included.

The total pause duration, expressed in milliseconds, is the sum of the duration of all silent pauses occurring in the 1-min sample.

Table 1. Participants' characteristics, habitual SR and AR

Participant No.	Gender	Age years	Etiology	Subtype	Severity of dysarthria	Habitual SR syllables/s	Habitual AR syllables/s
1	M	24	MD	flaccid	mild	2.48	3.73
2	F	17	trauma	UUMN	mild	3.52	5.54
3	F	34	trauma	flaccid	moderate	0.93[2]	2.51[2]
4	M	54	stroke	ataxic	mild	3.27	4.24
5	M	58	stroke	hypokinetic	mild	2.73	5.86
6	M	61	PD	hypokinetic	mild	3.00	8.96[1]
7	F	52	stroke	ataxic	moderate	1.42[2]	2.02[2]
8	M	57	stroke	UUMN	mild	3.10	4.53
9	M	72	stroke	UUMN	mild	3.47	4.99
10	M	72	stroke	UUMN	mild	2.62	3.68
11	F	78	stroke	UUMN	moderate	2.30	3.50
12	M	88	PD	hypokinetic	mild	2.88	4.37
13	M	78	PD	hypokinetic	mild	3.43	6.14[1]
14	M	86	PD	hypokinetic	severe	2.43	5.32
15	M	82	stroke	UUMN	mild	2.10[2]	2.92[2]
16	M	78	PD	hypokinetic	severe	4.97[1]	5.08
17	M	62	stroke	spastic	moderate	2.30	3.39[2]
18	M	63	PD	hypokinetic	moderate	4.73[1]	5.39
19	M	61	stroke	UUMN	moderate	4.20	4.83
20	F	83	stroke	UUMN	moderate	4.26	4.80
21	M	60	stroke	UUMN	moderate	3.63	3.98
22	M	59	ALS	mixed	moderate	1.93[2]	3.18[2]
23	M	77	stroke	mixed	severe	4.01	4.30
24	M	82	stroke	hypokinetic	moderate	3.34	3.57
25	M	69	stroke	UUMN	mild	2.28[2]	3.93
26	M	69	PSP	hypokinetic	moderate	1.66[2]	2.19[2]
27	M	55	stroke	ataxic	moderate	4.17	4.22

MD = Myotonic dystrophy; UUMN = unilateral upper motor neuron; PD = Parkinson's disease; ALS = amyotrophic lateral sclerosis; PSP = progressive supranuclear palsy.

[1] Exceeds the upper boundary of the 95% prediction interval of the control group.

[2] Lower than the lower boundary of the 95% prediction interval of the control group.

Pause frequency is defined as the number of pauses per minute.

The mean pause duration, also expressed in milliseconds, was obtained by dividing the total pause duration by the pause frequency.

Results

Effect of Rate Control on SR

Figure 1 shows the mean SRs of the dysarthric group for the 7 examined speech RCMs. A significant effect of methods was found ($p < 0.001$). Pairwise comparison showed that each RCM, with the exception of speaking slower on demand, resulted in significantly lower mean SRs when compared with the habitual rate ($p < 0.001$; $p < 0.05$ for DAF100). It should be noted that although the participants were instructed to speak half as fast as they were used to, mean SR was only reduced by 9.3%.

The slowest mean SRs were obtained by hand tapping, alphabet board and pacing board.

Effect of Rate Control on AR

Figure 1 also presents the mean ARs of the dysarthric population for habitual reading and the 7 RCMs. The effect of methods was highly significant ($p < 0.001$). Pairwise comparison pointed out that each RCM significantly reduced AR ($p < 0.001$) with the exception of speaking slower on demand.

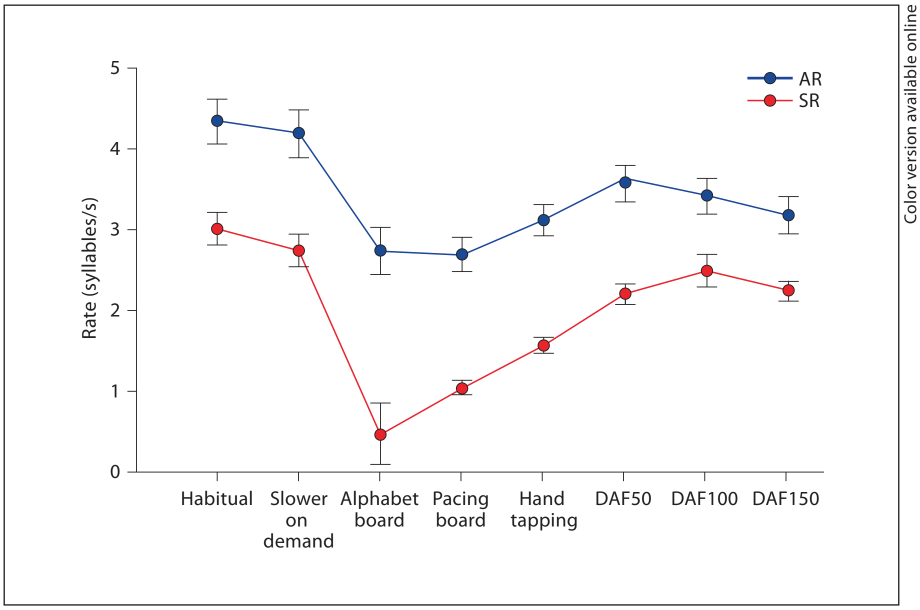

Fig. 1. Habitual and modified ARs and SRs of the dysarthric population. Data presented as means ± SE.

Table 2. Effect of the investigated RCMs on total pause duration, mean pause duration and pause frequency

	Total pause duration, ms	Mean pause duration, ms	Pause frequency
Habitual	21,907.12	1,012.02	22.63
Demand	24,511.13	1,042.06	24.74
Alphabet board	46,829.96	3,016.97	17.04
Pacing board	34,573.07	1,345.87	29.54
Hand tapping	25,476.22	873.33	33.00
DAF50	20,771.15	916.66	23.04
DAF100	22,540.75	994.14	23.74
DAF150	21,473.70	842.04	25.93

Table 3. Visualization of the effect of the investigated RCMs on articulation rate, total pause duration, mean pause duration and number of pauses

	Articulation rate	Total pause duration	Mean pause duration	Pause frequency
Demand				
Alphabet board	↓**	↑**	↑**	↓*
Pacing board	↓**	↑**		↑*
Hand tapping	↓**			↑*
DAF50	↓**			
DAF100	↓**			
DAF150	↓**			

* $p < 0.05$; ** $p < 0.001$.

Speaking slower on demand only reduced AR by 3.7% on average.

AR was most effectively reduced by the following methods: hand tapping, alphabet board and pacing board.

Effect on Total Pause Duration, Mean Pause Duration and Pause Frequency

Tables 2 and 3 summarize the effect of the 7 RCMs on total pause duration, mean pause duration and pause frequency. Total pause duration was only significantly increased when using an alphabet board or pacing board ($p < 0.001$) and only the use of the former resulted in a significantly increased mean pause duration ($p < 0.001$). Finally, only pacing board and hand tapping significantly increased the number of pauses ($p < 0.05$). Note that when using an alphabet board, the number of pauses decreased significantly ($p < 0.05$).

Intelligibility

Statistical analysis showed that rate reduction had a significant effect on intelligibility ($p < 0.05$), as illustrated in figure 2. The figure clearly shows that the mean intelligibility of the dysarthric population decreased due to each RCM. Although each RCM resulted in lower mean intelligibility ratings, pairwise comparison showed that

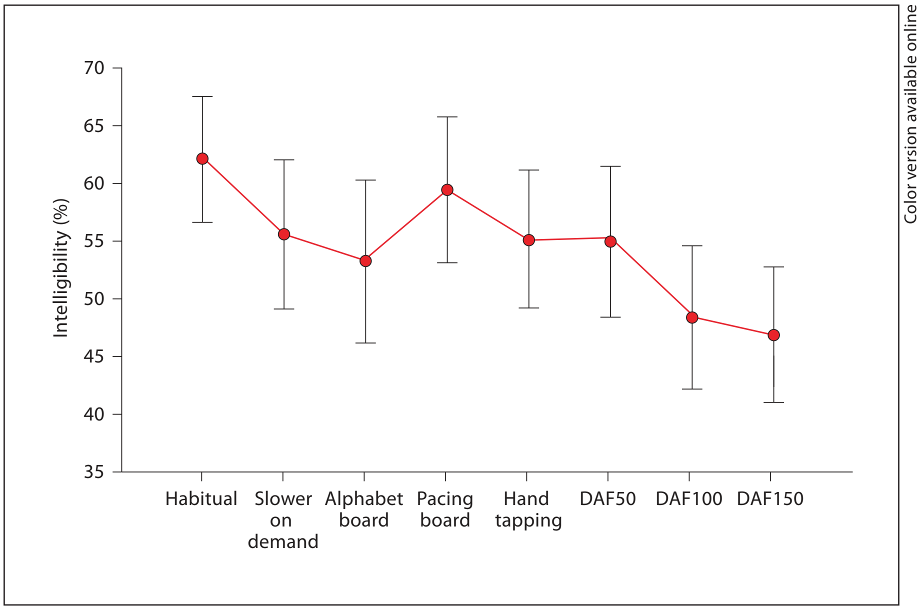

Fig. 2. Effect of RCMs on the intelligibility of dysarthric speakers. Data presented as means ± SE.

the mutual difference with habitual intelligibility was only significant in case of DAF100 and DAF150 ($p < 0.05$).

Analysis of the individual data (table 4) reveals that rate control did not decrease the intelligibility of every participant. In fact, in almost 50% of the participants (namely participants 4, 5, 9, 10, 11, 13, 15, 16, 18, 22, 25, 26 and 27), a clinically significant increase (i.e. >8%) was noted secondary to one or more RCMs. Each RCM led to a clinically significant increase in at least 1 participant. Alphabet board, pacing board and hand tapping were the most effective methods with a clinically significant increase in 6, 6 and 8 participants, respectively. Speaking slower on demand increased the intelligibility of 5 participants with more than 8%, both DAF50 and DAF100 did the same in 4 participants and DAF150 in 1 participant.

In 4 participants, intelligibility even improved by more than 20%, with a maximal increase of 59%.

Ideal Speech Rate

A very important question regarding rate control and its application in clinical practice is: to what extent should we decrease the rate to obtain maximal improvement in intelligibility? In other words, does the phrase 'the slower, the better' apply?

Although the most effective methods, namely hand tapping, pacing board and alphabet board were also the most effective in reducing mean AR and mean SR, the individual data reveal that in general an individual's maximal intelligibility level was not obtained by the method that reduced SR or AR most effectively. A maximal improvement in intelligibility was only associated with maximal decrease in SR or AR in 6 of the 27 participants.

Table 5 presents the habitual ARs and SRs, as well as the ARs and SRs associated with maximal improvement in intelligibility, of the 13 participants whose intelligibility significantly improved. SR associated with an individual's maximal intelligibility ranged from 0.35 to 3.12 syllables/s and the percentage decrease in SR leading to maximal intelligibility varied considerably (4–82%).

Furthermore, the range of ARs associated with maximal improvement in intelligibility is considerable (1.57–4.74 syllables/s) and the percentage decreases in AR leading to maximal intelligibility ranged from 3 to 55%.

Characteristics of the Patients Who Benefited from Rate Control

In order to gain further insight into which type of dysarthric speaker may benefit from rate control, the individual data (table 1) obtained from the 13 participants who showed a clinically significant increase in intelligibility were analyzed.

Habitual Speech Rate

The data in table 1 reveal that rate control is not only beneficial for individuals with increased habitual SR

Table 4. Speech intelligibility ratings (%) according to RCM

Participant	Habitual	Slower on demand	Alphabet board	Hand tapping	Pacing board	DAF50	DAF100	DAF150
1	89.33	89.67	78.67	89.67	79.67	80.67	74.00	62.67
2	83.33	90.01	85.00	85.67	88.33	72.33	72.33	79.33
3	79.67	76.33	47.00	65.00	33.00	63.00	64.00	51.67
4	74.33	93.67	91.00	87.00	80.33	70.33	84.33	62.33
5	55.33	66.00	26.67	51.00	47.00	65.33	64.33	55.00
6	69.67	51.00	6.00	2.33	0.33	17.00	57.33	5.67
7	45.33	8.67	8.67	24.33	1.00	10.00	8.33	2.00
8	88.00	75.33	90.67	74.00	84.33	73.00	80.00	85.67
9	45.33	49.00	10.00	56.67	58.00	54.00	37.33	32.67
10	88.00	96.33	27.67	79.00	67.33	89.67	82.00	63.00
11	51.33	39.00	83.67	53.00	60.67	47.33	36.33	43.00
12	85.67	71.00	80.67	91.67	77.33	87.33	62.67	59.67
13	81.33	73.67	54.00	49.33	88.00	91.00	84.00	81.00
14	19.67	17.33	–	6.00	–	14.67	1.67	1.67
15	67.33	96.33	100.00	92.00	99.33	96.00	90.67	61.67
16	2.33	0.00	0.00	13.33	0.00	1.00	0.00	0.00
17	51.67	32.33	28.00	26.00	53.33	14.00	32.00	50.00
18	55.00	13.67	6.67	68.67	87.33	1.33	5.33	3.67
19	87.33	86.00	68.33	88.33	78.33	70.67	57.33	70.33
20	82.67	46.00	83.67	69.67	61.00	87.00	79.67	84.33
21	87.67	44.33	92.33	65.67	77.67	86.67	52.00	62.00
22	79.00	68.67	92.33	65.33	60.67	84.00	35.33	86.67
23	3.00	0.00	5.67	0.00	0.00	1.67	0.00	0.00
24	84.00	87.67	57.67	11.00	75.33	74.67	31.00	36.33
25	84.33	95.00	94.33	93.33	96.67	90.33	98.00	83.33
26	11.33	7.33	3.33	21.00	8.67	18.00	5.33	20.33
27	22.67	26.33	62.67	60.00	81.67	23.33	9.67	21.67

Table 5. SR and AR (habitual/maximal intelligibility) and decrease in AR and SR leading to the maximal intelligibility of the 13 subjects with significantly improved intelligibility

Participant No.	SR habitual, syllables/s	SR max. intelligibility, syllables/s	Decrease, %	AR habitual, syllables/s	AR max. intelligibility, syllables/s	Decrease, %
4	3.27	2.85	13	4.24	4.09	5.5
5	2.73	2.62	4	5.86	5.67	3
9	3.47	1.13	68	4.99	3.31	34
10	2.62	2.70	–	3.68	3.86	–
11	2.30	0.43	81	3.49	1.92	45
13	3.43	3.12	9	6.14	4.74	23
15	2.1	0.42	80	2.92	1.92	34
16	4.97	1.66	67	5.08	3.83	25
18	4.73	1.12	76	5.39	3.42	36.5
22	1.93	0.35	82	3.18	1.93	40
25	2.28	1.97	14	3.93	2.84	28
26	1.66	0.75	55	2.19	1.57	28
27	4.17	1.1	74	4.22	1.9	55

and/or AR. Only 2 of the 13 participants with significantly improved intelligibility had increased SRs and only 1 had an increased AR. Thus, the majority of these participants had either normal or decreased SRs and ARs. Moreover, for 4 of the 6 participants with decreased SR, a further decrease in intelligibility was beneficial. The same was true for 3 out of 6 participants with decreased AR.

Type of Dysarthria

The limited number of participants per subtype of dysarthria does not allow for statistical analysis. However, analysis of table 1 shows that significant improvements in intelligibility were found in 5 participants with hypokinetic dysarthria, 5 with UUMND, 2 with ataxic dysarthria and 1 with mixed dysarthria.

Severity of Dysarthria and Degree of Intelligibility

To investigate whether the effect of rate control on intelligibility depends on the severity of dysarthria, the effect of the 7 RCMs on the intelligibility of participants with mildly impaired speech (n = 12) was compared with their effect on the intelligibility of participants with moderately or severely impaired speech (n = 15) by means of separate independent-sample t tests. A significant difference ($p < 0.05$) between both groups was only found for slower on demand and DAF100. Both methods were more beneficial for individuals with mildly impaired speech when compared to individuals with moderately or severely impaired speech.

Seven of the 13 participants with significantly improved intelligibility were judged as mildly, 5 as moderately and 1 as severely impaired dysarthric speakers. Their intelligibility ranged from 11 to 88%.

Discussion

Effect of Rate Control on AR and SR

This study revealed that – with exception of speaking slower on demand – each investigated RCM significantly decreased the mean AR and mean SR of the dysarthric population. These results are in accordance with those of other studies [11–20] and our previous study [5], and confirm that most RCMs applied in clinical practice to reduce speech rate are effective. The RCMs that most effectively reduced AR and SR were pacing board, hand tapping and alphabet board.

Table 3 clearly visualizes in which way each of the investigated RCMs affects SR. Three categories of RCMs can be distinguished. Category 1 only contains speaking slower on demand and does not significantly change AR, pause duration or pause frequency. The effect of DAF on SR is obviously the result of its effect on AR. The last category consists of those methods that affect both AR and pause duration and/or pause frequency, namely alphabet board, pacing board and hand tapping. Note that these methods do not change SR in exactly the same way. Whereas using an alphabet board increases total pause duration and mean pause duration, the use of a pacing board increases total pause duration and pause frequency and hand tapping only increases pause frequency.

Some attention should be paid to the limited effect that speaking slower on demand has on AR and SR. Although the participants were asked to speak half as fast as they were used to, on average, they only reduced their SR by 9% and their AR by nearly 4%. Two other studies that investigated the effect of speaking slower on demand on speech rate and intelligibility, using the same methods as the current study, revealed greater changes in AR and SR. Turner et al. [12] registered a decrease in SR of 21%, but noted that the percentage decrease in the dysarthric population was only half the decrease registered for the neurologically intact group. Tjaden and Wilding [11] found decreases in AR of 23 and 31% for individuals with dysarthria due to multiple sclerosis and Parkinson's disease, respectively. Although the decreases in AR and SR observed in those studies are obviously greater, the dysarthric populations did not reduce their rates by 50% and only reduced their rates half as much as neurologically intact speakers. Thus, the question is whether the limited effect of speaking slower on demand on AR and SR in the current study is due to the study design (i.e. no modeling and limited feedback) rather than to the skills of the dysarthric speaker. Yorkston et al. [21] stated that few speakers with dysarthria can reduce their SR and maintain a slowed rate after simply being instructed to 'slow down'. Since speaking slower on demand is the most natural RCM, this issue deserves further investigation.

Finally, little is known about the ideal delay for DAF. Regarding AR, although the mean AR decreased with increasing delay (fig. 1), no significant differences between DAF50, DAF100 and DAF150 were found. Moreover, no significant effect of delay on SR was found.

Effect of Rate Control on Intelligibility

For the whole study group, each RCM resulted in significantly lower mean levels of intelligibility ($p < 0.05$). These group results are clearly reflected in the individual data, revealing that rate control may have the opposite effect on intelligibility. Rate control significantly decreased intelligibility in 22 of the 27 participants. When using a pacing board, alphabet board and hand tapping, this effect may be explained by the fact that these methods require a certain degree of attention and coordination. The influence of these actions may be high since the subjects were not familiar with the methods. The same may be true for DAF [16, 20]. These presumptions obviously need further investigation in order to verify them.

As discussed in the previous paragraphs, rate control can have the opposite effect on the intelligibility of dysarthric speech. However, analysis of the individual data showed that a clinically significant improvement in intelligibility was registered in almost 50% of the individuals with dysarthria. Strikingly, the most effective methods (hand tapping, pacing board and alphabet board) all affect SR by reducing AR and increasing pause duration and/or pause frequency and these methods all set boundaries (i.e. word or syllable boundaries). As a consequence, these methods facilitate the 3 speech perception processes of the listener, namely lexical activation (activation of certain words based on segmental information provided by the acoustic signal), lexical competition (which word matches best with the perceived acoustic signal?) and lexical segmentation (dividing the stream of acoustic information into separate words) [22].

Whereas only slower on demand, alphabet board, pacing board and hand tapping led to significantly increased intelligibility in the initial study [5], the extended data reveal that each of the investigated RCMs is able to significantly improve intelligibility of dysarthric speech.

As mentioned previously, little is known about the ideal delay for DAF. Figure 2 shows that the mean intelligibility of the dysarthric population further decreased with increasing delay. At the individual level, DAF50 and DAF100 both significantly increased (+ >8%) the intelligibility of 4 participants, whereas DAF150 only significantly increased intelligibility in 1 individual. These results indicate that in general DAF50 and DAF100 are more effective, but when considering an individual patient a higher delay might sometimes be more effective.

Ideal Speech Rate

Little is known about the ideal SR or AR with regard to intelligibility. Yorkston et al. [23] found in 4 individuals with ataxic dysarthria and 4 individuals with hypokinetic dysarthria that a decrease in SR (down to 60% of the habitual SR) resulted in higher intelligibility levels than speaking at 80% of the habitual SR. However, does this imply that maximal intelligibility is achieved by maximally decreasing SR and/or AR? The individual data of the current study indicate that this does not hold true. Only in 6 of the 27 participants was the highest degree of intelligibility obtained as a result of the RCM that most effectively reduced SR and/or AR.

Liss [22] even argued that speaking too slowly can have an adverse effect on intelligibility. Speaking too slow may negatively influence the listener's speech perception strategies by affecting prosody and demanding too much of the listener's short-term memory. However, whereas the individual data do not reveal a critical upper boundary for AR and SR, they also do not reveal a critical lower boundary. In addition, it is not possible to withdraw a reference for an ideal speech rate, neither in terms of a concrete number nor in terms of percentage decrease in AR or SR.

Characteristics of Patients Who May Benefit from Rate Control

Although the number of participants in the various subgroups is rather limited and thus insufficient for statistical analysis, the individual data do reveal some interesting information regarding the type of dysarthric patient that may benefit from rate control.

First, the results point out that the beneficial effect of rate control is not limited to patients who speak too fast. The majority of the participants with significantly improved intelligibility had SRs and ARs within normal boundaries or even decreased rates. These results add credence to the results of the initial study [5] and the findings of Jaeger et al. [24] who found that individuals with dysarthria tend to speak near the upper limit of their SR.

When it comes to the type of dysarthria, the literature has mainly reported on individuals with a hypokinetic dysarthria [11, 14–17, 20, 23, 25–28] and to a lesser extent ataxic dysarthria [6, 14, 23]. This is probably due to the fact that hypokinetic dysarthria is associated with increased speech rate, and the fact that modifying rate and prosody is described as one of the most important aspects of behavioral therapy in ataxic dysarthria [1]. This study revealed that apart from individuals with a hypokinetic and ataxic dysarthria, individuals with UUMND and mixed dysarthria may also benefit from rate control. Two other studies reported a positive effect of rate control in a total of 6 individuals with mixed dysarthria [12, 18]. These results suggest that the positive effect of rate control is not restricted to hypokinetic and ataxic dysarthria and that various types of dysarthria may benefit from rate control. This obviously requires further investigation.

Finally, the results show that the effect of rate control is not greater in individuals with moderately or severely impaired speech compared to individuals with mild dysarthria.

Implications for Clinical Practice

The data of this study and the data available in literature reveal some important implications for clinical practice. First of all, rate control should be considered as a therapeutic method in each individual with dysarthria, independently of the habitual speech rate, severity of dysarthria and type of dysarthria. Secondly, clinicians should keep in mind that each RCM has the potential to improve intelligibility, but pacing, hand tapping and alphabet board were found to be the most effective methods. And finally, a maximal decrease in speech rate does not always lead to maximal improvement of intelligibility. Based on the current knowledge, it is recommended to judge the effect of rate control for a specific individual with dysarthria during a trial session, trying out different methods and different rates.

Conclusions

The results of the current study reveal that each of the investigated RCMs decrease both SR and AR. However, in the case of speaking slower on demand, this decrease is limited and not significant.

When it comes to speech intelligibility, the results show that each RCM can establish a significant improvement in intelligibility. The most effective methods were hand tapping, pacing board and alphabet board. It is striking that these methods all affect SR by reducing AR and increasing pause duration and/or pause frequency, and that the methods all set boundaries at the word or syllable level. The results of this study also indicate that the effect of rate control on intelligibility does not depend on the habitual speech rate or severity of dysarthria. Based on the current results and some data in literature, it can also be suggested that rate control may be beneficial for various types of dysarthria. Furthermore, it is not possible to conclude upon an ideal speech rate. However, this study does reveal that maximally decreased rate is not always associated with maximally improved intelligibility. Finally, it should be mentioned that although rate control may improve intelligibility in dysarthria, it may also have the opposite effect on intelligibility in some cases.

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