Testing a rhythm-based intervention for dysarthria: Evidence from two case studies

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Abstract

Dysarthria is characterized by disruptions in motor control necessary for producing speech and other verbal sounds. These motor impairments often extend to reading, impacting both speed and accuracy due to the articulatory challenges inherent in speech production. Most dysarthria treatments traditionally focus on improving oral production. However, a novel approach involves targeting anticipatory processes through rhythmic stimulation combined with verbal fluency exercises. In this study, a remote intervention was delivered via an online platform, incorporating rhythm-based reading exercises for two patients (A and B) diagnosed with dysarthria. Following a two-week period of daily intervention, patients were assessed on reading and language fluency. Both patients showed considerable improvements in reading skills. Additionally, Patient B exhibited improvements in functions commonly impaired in dysarthria, including respiratory and articulatory abilities. In conclusion, this remote rhythm-based intervention resulted in notable enhancements in reading and language parameters in dysarthria. These preliminary findings suggest that this approach holds promise and warrants further investigation in future studies on dysarthria.

Keywords: dysarthria, language fluency, rehabilitation, reading, rhythm, music therapy

Introduction

Dysarthria is a clinical condition characterized by speech disorders of neurological base which reflect abnormalities in the strength, speed, range, steadiness, tone, or accuracy of movements required for breathing, phonatory, resonatory, articulatory, or prosodic aspects of speech production (Duffy, 2013). Dysarthria can arise from acquired neurological disorders (e.g., Parkinson's disease (PD), acute ischemic stroke, amyotrophic lateral sclerosis (ALS)) and is caused by lesions in various locations (Darley et al., 1969). Although a common feature is a decreased speech intelligibility, the clinical manifestation may vary greatly and several dysarthria types have been described based on salient features (i.e., flaccid, spastic, hypokinetic, hyperkinetic, ataxic, and mixed) (Duffy, 2013). Traditional language treatments for dysarthria addresses communication skills through speech therapy, providing strategies, and optionally assistive communication support (Chiaramonte & Vecchio, 2020).

Process-based alternative treatments include the use of musical and / or rhythmic strategies for the facilitation of speech in various motor speech disorders, dysarthria included. Instead of focusing rehabilitation on the direct practice of impaired skills, as in traditional methods, process-based alternative treatments aim to modulate and stimulate the cognitive and motor processes underlying articulatory and vocal abilities. For example, rhythmic and musical training provide multisensory stimulation, engage alternative neural networks, facilitate prosodic modulation, and, by increasing motivation and emotional involvement, contribute to more solid and lasting learning (Magee et al., 2017). Zumbansen and Tremblay (2019) conducted a systematic review on the effect of Melodic Intonation Therapy (MIT) – a music-based technique for oral language production recovery – focusing on motor-speech impairments. Results revealed that music-based interventions are indeed effective in significantly improving the quality of speech in patients with motor-speech disorders, thus suggesting that rhythmic-cued and melodic activities facilitate the effective stimulation of the motor-speech system.

In this regard, Mainka and Mallien (2014) designed the Rhythmic Speech Cueing (RSC), an intervention protocol aimed at improving several speech parameters, such as articulatory rate, pause, time, and intelligibility of speech in patients with fluency disorders. In RCS, patients are presented with a metronome pulsed signal or a rhythmic pattern to acoustically cueing their speech production. In the rehabilitation procedure, the rhythmic stimulation serves as a stable time anchor to which the patients try to adjust their speech, with pulse regularity leading to better coordination of the articulatory muscles by facilitating a more accurate motor anticipation during speaking.

Furthermore, the tempo of the rhythmic stimulation is set to slow down syllable duration during speech production, an effective strategy to improve articulation in dysarthric patients, as suggested by other dysarthria studies (e.g., Stahl et al., 2011; Mainka & Mallien, 2014). The RSC has been shown to be effective in patients with various types of dysarthria, such as hypokinetic ataxic, spastic, and mixed, improving intelligibility, sharpness of articulation, and speech fluency. The treatment does not vary by dysarthria type, but hypokinetic dysarthria (e.g., in Parkinson's) requires more frequent sessions than other types.

Another music-based intervention for speech fluency was developed by Kim and Jo (2013), namely, the Accent-based Music Speech Protocol. The training protocol consists in facilitating the production of accentuated melodic chanting through slow and exaggerated oral articulatory movements, following a regulated timing of inhaling and exhaling. Empirical evidence showed that the protocol leads to improvements in voice intensity and in a better coordination of the respiratory and vocalization movements in post-stroke patients with mixed dysarthria.

As a result of the articulatory disfunctions, reading skills are typically negatively impacted in dysarthria. Given the established results of rhythm-based intervention on speech articulation fluency, embedding the rhythmic activities in written verbal material appear to be a feasible and promising approach for dysarthria intervention. To do that, a rhythm-based intervention that was originally designed for improving reading skills in dyslexia, the Rhythmic Reading Training (RRT; Cancer et al., 2016), was selected. As RSC (Mainka & Mallien, 2014), RRT relies on the facilitatory effect of the rhythmic stimulation, which provides a regular structure that helps patients organize temporal cues of speech sounds. Similarly to Accent-based Music Speech Protocol (Kim & Jo, 2013), RRT is administered daily for 10 days, over the course of two weeks.

The primary aim of this multiple case-study is to investigate whether RRT is feasible and effective in improving the reading intelligibility (Mackenzie & Lowit, 2012, Lowit et al., 2023) in dysarthric patients. As a secondary aim, the study investigated whether a training addressing reading processes leads to amelioration in articulatory sharpness, breathing, phonation, diadochokinesis, and prosody of oral speech.

Methods

Participants

Two patients with dysarthria were selected among the patients with a diagnosis of dysarthria who had completed a speech therapy rehabilitation at the Neurorehabilitation Unit of the Fondazione Poliambulanza Hospital in Brescia, Italy. Specifically, patients were recruited by meeting the following inclusion criteria: absence of history of neuropsychological or psychiatric disorders preceding the diagnosis; age less than 80 years; absence of hearing deficits; time elapsed since the acute event ≥ 6 months. Participation was voluntary. Both patients provided their informed consent to participate in the study prior to enrollment. The study was approved by the Ethics Committee of the Università Cattolica del Sacro Cuore in Milan, Italy (approval code: 22-19) and by the Fondazione Poliambulanza Hospital's General Management (approval code: 13-07-20) and it was conducted according to the standards of the Helsinki Declaration (World Medical Association, 2013).

Patient A. The patient, a 47-year-old man, in 2015 was diagnosed with large B-cell lymphoma with subsequent autotransplant complicated by encephalitis. Ataxia of the march and cognitive deficits were reported. In 2017 he was hospitalized for cerebellar syndrome, dysarthria, and dysphagia and received the diagnosis with progressive multifocal leukoencephalopathy associated with a cerebellar syndrome JC virus-related. The focal event was dated June 2017. In 2020 the patient was diagnosed with dysarthria characterized by high/clavicular respiration in phonation and diaphragmatic respiration at rest; nasal quality of voice; loss of articulatory clarity as speed and complexity of movements increases; altered diadochokinesis; normal prosody and intelligibility. Therefore, he received speech and language rehabilitation program during the first semester of 2020. Patient A did not have other linguistic deficits, was right-handed, reported having normal hearing and corrected-to-normal vision. He had a normal cognitive level and he did not have any brain injuries.

Patient B. The patient, a 33-years-old woman, suffered the outcomes of traumatic brain injury. The focal event occurred in 2014 and caused a hemorrhage that involved the left temporo-frontal and fronto-parietal areas and the right frontal area. The patient was diagnosed with non-fluent aphasia and dysarthria. In 2019 she received the last speech and language rehabilitation treatment. The linguistic functions mostly compromised were oral expression and oral comprehension (especially for longer and complex sentences; Token test: 26/36). Oral communication was influenced by articulatory difficulties and agrammatism. She was right-handed and has normal hearing and corrected-to-normal vision. The cognitive level was normal (Raven test: 34/36; MMSE: 27/30; LCF: 8). Patient B did not have any other brain injuries.

Training intervention

The RRT is a computerized, rhythm-based intervention program which integrates reading exercises with rhythmic stimulation that gradually increases in speed, providing a temporal structure to help readers better organize the timing of speech sounds. The software comprises several reading exercises categorized into three sections: “Syllables”, “Words”, and “Pseudo-words”.

In the “Syllables” section, exercises focus on training rapid syllable recognition. The “Words” and “Pseudo-words” sections include exercises that challenge patients to read words and pseudo-words of varying lengths. All reading tasks are synchronized with a customizable rhythmic accompaniment, which can be adjusted in speed according to the reader’s individual characteristics. The RRT also allows for increasing levels of difficulty within the same exercise by offering various speed settings for the rhythmic component. Patients are instructed to read each stimulus – whether syllables, words, pseudo-words – in synchrony with the rhythmic beat. Additionally, each stimulus can be highlighted by a colored visual mask at the precise moment it should be read, creating a multimodal stimulation experience that combines visual (color changes) and auditory (rhythmic beat) cues in synchronization. The visual cue is recommended in the initial phases of training to support synchronization during reading; In later stages, the therapist discontinues it once the participant can accurately align their reading with the beat without visual assistance. The difficulty of the exercises also escalates with the complexity of the verbal stimuli (e.g., syllables with more complex orthography, longer words, or pseudo-words) and through a gradual reduction in font size. This structured approach aims to enhance reading skills by engaging both auditory and visual processing in a coordinated manner.

The training was previously tested in rehabilitation programs of 10-20 sessions, supervised by experienced practitioners, aimed at children, adolescents, and adults with developmental dyslexia (Bonacina et al., 2015; Cancer, Monti & Antonietti, 2016; Cancer et al., 2016; 2017; 2019; 2020; 2021; 2022; 2023). The effectiveness of the intervention is confirmed by several experimental controlled studies with a test-training-retest design, which showed significant reading skills improvement, compared to spontaneous reading development (Bonacina et al., 2015) and to alternative validated treatments (Cancer et al., 2020; 2023). In a recent pilot study, the training was applied to patients with post-stroke aphasia, showing its feasibility and acceptability in acquired language disorders (Cancer et al., 2025).

Assessment measures

The pre- and post-training assessment included measures of language, reading, and verbal memory. Reading, language, and verbal memory skills were assessed using the VALS test battery ("Assessment of reading and writing difficulties in adulthood" [Valutazione delle difficoltà di lettura e scrittura in età adulta]; George &Pech-Georgel, 2017). Specifically, spelling, rapid automatized naming, text, word, and pseudo-word reading, forward digit span, backwards digit span subtests were administered. Patients were additionally tested with a specific test for language fluency, namely, "Dysarthria assessment profile" ([Profilo di valutazione della disartria]; Robertson, 1982; Fussi & Cantagallo, 1997), which includes scores for respiratory function, phonatory function, diadochokinesis, articulatory function and prosodic aspects. This test provides two therapy outcome measure (TOM) scores: (1) level of impairment and (2) level of disability. Finally, participants answered, after each training session, to five self-report questions on the training experience (three 5-point Likert scales: "difficult", "boring", "how much they liked it") and assessment of achieved progress (two 10-point Likert scales: "progress in reading" and "progress in language fluency").

Procedure

The study consisted of a test-treatment-retest procedure. In the pre-training and post-training testing sessions, participants completed the battery of tests (average completion time: 2 hours). Following the pre-training testing session, both patients received 10 training sessions, one per day from Monday to Friday, over the course of two weeks. The training sessions were of 30 minutes each and were supervised by a specialized speech therapist.
The sessions were personalized based on the patient's needs and relied on baseline reading skills assessed in the pre-training phase. All sessions involved training at the three different levels of reading: syllables, words, and non-words. In the initial sessions, equal time was typically allocated to each level (10 minutes). As the treatment progressed, the therapist could determine whether it was appropriate to reduce the time spent on syllable reading and increase the time dedicated to word and non-word reading. To

gradually increase the tempo of the rhythmic accompaniment, the therapist monitored reading accuracy, advancing to a faster tempo in the next trial only if accuracy reached 95%.
At the end of each training session, patients answered the questions of the self-report assessment questionnaire.

Participants were tested and treated remotely through a video-conference software (Skype), which supports screen sharing.

Results

Pre- and post-training performance in the primary (reading, language) and secondary outcome (spelling, verbal memory) measures were compared for each patient.

Additionally, self-report measures on training experience and on perceived improvement over the course of the 10 training sessions were analyzed for each patient.

Patient A

Patient A's pre- and post-RRT test scores are reported in Tab. 1. The patient improved in almost all skill domains directly and indirectly trained by RRT, with the only exception of text reading speed. Patient A also improved in domains not directly trained by the intervention program (e.g., digit span).

In the Dysarthria assessment profile assessment, patient A obtained a score of 4 (mild dysarthria) on both the impairment and disability TOM scales in the pre-RRT phase, representing an intelligible oral expression most of the times. After RRT, the scores remained unchanged, therefore suggesting that 10 RRT sessions did not have a significant impact on respiratory, phonatory, articulatory prosody, or diadochokinesis functions.

As for the self-report evaluation (see Tab. 2), the trends for the perceived improvements in reading and speech fluency was rather stable, with a tendency to report high improvement scores in both parameters. The trends for the 3 questions investigating judgements on the proposed exercises were more variable, with a tendency to consider the activities less difficult and boring by the end of the 10-session training and a stable high level of reported pleasantness.

Tab. 1- *Patient A's test scores from the VALS battery pre- and post-RRT intervention program*

Test measure	**Pre RRT (t0)**	**Post RRT (t6)**
Words reading accuracy (correct items)	19/20	20/20
Words reading speed (syllable/second)	3.36	3.50
Pseudo-words reading accuracy (correct items)	11/20	18/20
Pseudo-words reading speed (syllable/second)	1.70	2.43
Text reading accuracy (errors)	19	6.5
Text reading speed (syllable/second)	4.16	3.64
Spelling accuracy (correct items)	2/10	9/10
Spelling speed (seconds)	124	119
Rapid automized naming accuracy (errors)	0	0
Rapid automized naming speed (seconds)	50	53
Digit span forward (correct items)	6/8	8/8
Digit span backwards (correct items)	3/6	6/6

Tab. 2 - *Patient A's training experience (5-point Likert) and perceived improvement (10-point Likert) self-report measures over the course of 10 training sessions*

	Training experience			**Perceived improvement**	
Session	Difficult	Boring	Liked	Reading	Speech fluency
1	4	2	4	6	5
2	1	4	2	6	6
3	2	2	3	6	6
4	2	2	4	6	6
5	2	2	3	6	6
6	2	2	4	6	6
7	3	2	4	7	6
8	3	3	3	6	6
9	2	2	4	6	6
10	2	2	4	6	6

Patient B

Patient B's pre- and post-RRT test scores are reported in Tab. 3. The patient improved in several test domains directly and indirectly trained by RRT. Most of the improvements were related to the accuracy parameter, however text reading speed was significant improved.

Tab. 3 - *Patient B's test scores from the VALS battery pre- and post-RRT intervention program*

Test measure	Pre RRT (t0)	Post RRT (t6)
Words reading accuracy (correct items)	15/20	18/20
Words reading speed (syllable/second)	1.17	0.90
Pseudo-words reading accuracy (correct items)	9/20	15/20
Pseudo-words reading speed (syllable/second)	0.87	0.51
Text reading accuracy (errors)	87.5	38.5
Text reading speed (syllable/second)	1.15	1.20
Spelling accuracy (correct items)	Not applicable	Not applicable
Spelling speed (seconds)	Not applicable	Not applicable
Rapid automized naming accuracy (errors)	1	0
Rapid automized naming speed (seconds)	121	130
Digit span forward (correct items)	0/8	0/8
Digit span backwards (correct items)	0/6	0/6

Tab. 4 - *Patient B's training experience (5-point Likert) and perceived improvement (10-point Likert) self-report measures over the course of 10 training sessions*

	Training experience			Perceived improvement	
Session	Difficult	Boring	Liked	Reading	Speech fluency
1	3	1	5	10	10
2	4	1	5	10	9
3	3	1	5	10	9
4	3	1	5	10	9
5	4	1	5	10	9
6	4	1	5	10	10
7	3	1	5	10	10
8	4	1	5	10	9
9	4	1	5	10	9
10	3	1	5	10	10

In the Dysarthria profile assessment, patient B obtained a score of 3 (mild/moderate dysarthria) on the impairment scale and a score of 4 on the disability scale in the pre-RRT phase. After RRT, while the disability scores remained unchanged, patient B scored 4 (mild dysarthria) in the impairment scale, suggesting a significant improvement in speech fluency parameters, specifically respiratory and articulatory functions.

Considering the self-report assessment (see Tab. 4), patient B reported to perceive a high level of improvement in both reading and speech fluency after each training session. No score variation was observed for the experience judgments, in which patient B reported to always have liked the activities and to consider them not boring at all, and rather difficult.

Discussion

Results presented in this study showed that RRT is a feasible intervention for improving language fluency, as well as intelligibility in both speech and reading, in individuals with dysarthria. By "reading intelligibility" we refer to the intelligibility of speech during reading as a parameter that directly influences the listener's oral comprehension (Mackenzie & Lowit, 2012, Lowit et al., 2023).

Patient A demonstrated significant benefits from RRT, particularly in reading-related tasks. Notably, there was an improvement in reading speed and accuracy for words, as well as in the speed and accuracy for pseudo-words. Additionally, text reading accuracy improved markedly. However, it is important to note that text reading speed decreased by the end of the training. This decline in speed may be attributed to the nature of the RRT exercises, which primarily focused on reading words and pseudo-words, rather than continuous text. Despite the reduction in text reading speed, Patient A achieved a substantial reduction in text reading errors (from 19 to 6.5), indicating improved reading precision, likely facilitated by a more deliberate pace. Other significant improvements in Patient A included enhanced speed and accuracy in spelling tasks, as well as an increased number of items correctly recalled in both forward and backward digit span tests. However, Patient A did not show improvement in respiratory, phonatory, diadochokinetic, articulatory, and prosodic functions. In fact, the patient's dysarthria severity, as measured by the Dysarthria assessment profile, shifted from mild to mild/moderate by the end of the training.

Patient B also exhibited significant improvements following RRT, particularly in reading accuracy for words, pseudo-words, and text. Although there was a reduction in reading speed for words and pseudo-words, text reading improved in both speed and accuracy, which was a surprising and favorable outcome. Additionally, Patient B demonstrated a reduction in errors on the rapid automatized naming task and the rhythmic pattern discrimination test. Importantly, Patient B also showed significant improvements in respiratory and articulatory functions, with dysarthria severity improving from mild/moderate to mild by the end of the training.

This suggests that RRT may have broader therapeutic potential beyond reading tasks, albeit cautiously.

Self-reported outcomes provided additional insights into the patient's perceived communicative function. Patient A perceived moderate improvements in both reading and speech fluency, which only partially aligned with the objective data. While his reading improvements were substantial, his speech fluency did not show a corresponding significant enhancement. The feedback from the training difficulty questions was valuable for adjusting RRT parameters in subsequent sessions. Conversely, Patient B reported remarkable perceived improvements in both reading and speech fluency. Although these subjective ratings were highly positive, quantitative data suggested there was still room for further improvement. Nonetheless, the patient's positive feedback regarding the training's pleasantness, non-monotony, and challenging yet achievable difficulty levels was encouraging.

These findings suggest that RRT may exert a positive influence on reading and language parameters in patients with dysarthria, and thus underscore its potential as a targeted intervention for speech fluency in patients with dysarthria, with variability in outcomes that warrant further investigation. Although it is clear that the different outcomes may be due to the distinct clinical characteristics of dysarthria in the two patients, other factors may also come into play. The clinical histories of the two patients were very different, both in terms of the number of acute brain events they experienced and the time interval between these events and the start of the rehabilitation training. Another factor that plays a fundamental role in determining rehabilitation-related changes is the patient's interest and motivation toward the proposed training (Colombi et al., in press). The two patients, in fact, showed different levels of satisfaction and interest in the treatment provided.

This rehabilitation approach can be framed within the ICF (International Classification of Functioning, Disability and Health; Della Sanità, 2002) model, as it addresses not only impairments in body functions (e.g., phonological and articulatory processes) but also activity limitations (e.g., reading skills) and participation restrictions (e.g., communication and social interaction). The training is personalized to individual needs, adaptable to different environments (also remote settings) and includes self-report measures, aligning with the ICF's biopsychosocial and person-centered approach.

Conclusion

In conclusion, this case-study showed that Patient B demonstrated improvement in intelligibility across both reading tasks (in terms of speed and accuracy) and spontaneous speech, while Patient A exhibited improvements exclusively in reading intelligibility. Clarity during spontaneous oral production, however, involves additional cognitive processes, including reasoning processing and the engagement of motor areas, which may also impact overall communication effectiveness.

From the observations of these two cases, we can hypothesize that RRT could be effective in enhancing reading-specific intelligibility but may not significantly improve overall speech intelligibility. It is important to note that both patients had previously undergone rehabilitation targeting oral production intelligibility, which may explain the lack of further significant improvements as measured by the assessment tools utilized in this study. It is possible to hypothesize that, to generalize reading-related speech intelligibility to spontaneous speech production, it would be beneficial to incorporate the repetition of words and short phrases (as in MIT), supported by a rhythmic and melodic base.

To better understand the broader efficacy of RRT, particularly in terms of its impact on overall intelligibility, it is recommended that this intervention be applied to a larger clinical sample. This would help determine whether the observed improvements in reading intelligibility are consistently replicable across a wider population of patients.

Among the limitations of this study is the lack of information regarding the type of dysarthria in the two patients. Regrettably, in both cases, the specific type of dysarthria was not described, as the clinicians who diagnosed the patients prior to their enrollment in our research did not make a distinction. Future studies could take into account the differences in the modifiability of reading abilities and verbal communication functions after RRT treatment based on dysarthria subtype.

Finally, it would be important to include pre- and post-treatment measures assessing the impact of communicative effort on quality of life, in order to capture more comprehensively the functional relevance of the intervention.

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