Case Report

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# Effects of transcranial direct current stimulation (tDCS) on voice and speech in Parkinson's disease: a case report

## Efeitos da estimulação transcraniana por corrente contínua (ETCC) na voz e fala na doença de Parkinson: relato de caso

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## ABSTRACT

This study describes the results of two different interventions for dysarthria in Parkinson's disease (PD). It concerns two male patients with PD and hypokinetic dysarthria who underwent speech and voice assessment. The first (S1) received ten 20-minute sessions of transcranial direct current stimulation (tDCS), while the second (S2) received ten 20-minute sessions of tDCS as well as speech therapy. The patients were re-evaluated immediately after the intervention and again after 30 days. Improvements in phonation time, velar movement, and other measures of dysarthria were more significant in S1. According to the acoustic analysis source parameters, improvements in the frequency measurements and Jitter, Shimmer, and noise measurements were greater in S2 in both the immediate post-intervention and 30-day postintervention assessments, followed by S1 in the immediate post-intervention assessment. S1 showed better results in the auditory-perceptual evaluation of speech and voice, whereas S2 obtained better scores in acoustic analysis. These findings suggest that conventional speech therapy combined with tDCS has a more significant impact on speech and voice than tDCS alone, demonstrating the potential of tDCS as an adjuvant treatment for patients with PD.

**Keywords:** Dysarthria; Parkinson; Speech therapy; Electrical stimulation; Voice

## RESUMO

Este estudo descreve os resultados de duas intervenções diferentes para a disartria na doença de Parkinson (DP). Trata-se de dois pacientes do sexo masculino com DP e disartria hipocinética que foram submetidos à avaliação fonoaudiológica. O primeiro (S1) recebeu dez sessões de 20 minutos de estimulação transcraniana por corrente contínua (ETCC), enquanto o segundo (S2) recebeu dez sessões de 20 minutos de ETCC e terapia fonoaudiológica. Os pacientes foram reavaliados imediatamente após a intervenção e novamente após 30 dias. A melhora no tempo de fonação, movimento velar e outras medidas de disartria foram mais significativas no S1. De acordo com os parâmetros da análise acústica de fonte glótica, a melhora nas medidas de frequência e Jitter, Shimmer e ruído foi maior no S2 tanto na avaliação pós-intervenção imediata quanto na avaliação 30 dias pós-intervenção, seguida por S1 na avaliação pós-intervenção imediata. S1 apresentou melhores resultados na avaliação perceptivo-auditiva de fala e voz, enquanto S2 obteve melhores escores na análise acústica. Esses achados sugerem que a terapia fonoaudiológica convencional associada à ETCC tem um impacto mais significativo na fala e voz do que a ETCC isolada, demonstrando o potencial da ETCC como tratamento complementar para pacientes com DP.

**Palavras-chave:** Disartria; Parkinson; Terapia de fala; Estimulação elétrica; Voz

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## INTRODUCTION

Dysarthria is a speech disorder that affects the ability to articulate sounds and verbal fluency[1]. This condition is caused by damage to the central nervous system that controls speech production, affecting the coordination of the muscles in the mouth, tongue, and throat[2]. As a result, speech may become difficult to understand, with problems of articulation, volume, speed, and intonation[1]. In PD, dysarthria is a common symptom, affecting about 90% of patients in the advanced stages of the disease[2].

This motor speech disorder can significantly affect the quality of life and the ability to communicate and socialize of patients with PD[1]. Additionally, dysarthria can lead to problems with speech comprehension, which can be particularly difficult in social situations or noisy environments[1,2]. Therapeutic strategies for treating dysarthria in PD include speech and language therapy, muscle strengthening exercises, and techniques to enhance articulation and speech comprehensibility[3].

Transcranial direct current stimulation (tDCS) is a non-invasive neuromodulation technique investigated as a potential therapy to improve speech and communication in patients with PD[4]. tDCS involves the application of a low electrical current through the scalp to modify the brain's electrical activity[5].

The hypothesis was that combining conventional speech therapy and tDCS would result in more significant improvements in speech and voice compared to using tDCS alone. This study sought to explore this hypothesis by examining the outcomes of different treatments for dysarthria in two individuals with PD. Specifically, the study aimed to compare the effectiveness of conventional speech therapy combined with tDCS and tDCS alone.

## CASE PRESENTATION

This study was registered and approved by the Human Research Ethics Committee of the institution under protocol number 4.642116. The subjects signed the Informed Consent Term for the research.

### Subject 1 (S1)

A.L.O., male, 69 years, was diagnosed with PD four years ago. He was treated with levodopa during recruitment and was instructed not to interrupt his treatment during the study. In the initial assessment, it was detected hearing loss at 4 kHz frequency. The subject was also evaluated regarding auditory perceptual characteristics and through acoustic analysis of glottal source parameters. The results of the evaluations will be available after the presentation of the second subject.

In this study, we used three assessment protocols: the Consensus Auditory Perceptual Evaluation – Voice[6], Speech Intelligibility Assessment Protocol (Protocolo de Avaliação da Inteligibilidade da Fala-PAIF)[7], and Dysarthria Assessment Protocol[8].

The CAPE-V[6] and PAIF[7] were audio-recorded using an H4n Zoom digital recorder placed in front of the participants' mouths (at distances of 4 cm during vowel production and 10 cm during sentence production). We used the using the Audacity® software, version 2.3.2, to edit the recordings with a sampling rate of 44.1 kHz and a 16-bit analog-to-digital converter.

CAPE-V allows auditory-perceptual evaluation of voice disorder severity and was analyzed the analysis according to the recommendations of the American Speech-Language-Hearing Association[6].

In the PAIF[7], we evaluated speech intelligibility through repetition. This instrument contains 25 high-, medium-, and low-predictability sentences and a list of 60 words. Eleven blind listeners transcribed the recorded tasks. Each listener heard a single recording for transcription to avoid any learning effects due to repeated exposure to test stimuli. The transcriptions determined the correspondence between the stimulus words and the listeners' comprehension.

The Dysarthria Assessment Protocol[8] determines the degree of dysarthria by using tasks that evaluate different components of speech (respiration, phonation, resonance, articulation, and prosody).

Acoustic analysis was performed to complement auditory-perceptual assessment and involved recording the vowel/a/'s maximum phonation time (MPT) of the vowel /a/. The MPT was recorded and analyzed using the KayPENTAX® Multi-Dimensional Voice Program (MDVP) with a sampling rate of 44 kHz and 16-bit analog-to-digital conversion. Participants were asked to stay seated for the recordings because of motor impairments and to sustain the vowel /a/ at habitual loudness and pitch[9].

All recordings of MPT made at different assessment points were edited to exclude vocal attacks and the end of the emission due to instability. In addition, the analysis window duration for all recordings was standardized to 7 s. The recordings were analyzed to evaluate the acoustic measurements, as proposed in another study[9].

These variables allowed for the analysis of periodicity/noise, frequency, and stability of vocal signals. The $f_o$ was analyzed using a reference range of 80-150 Hz for male subjects[10]. In addition, normative references in MDVP software were used[9].

The first author of this study performed all assessments. S1 was assessed at three time points: pre-intervention, immediate post-intervention, and 30 days post-intervention.

tDCS protocol was applied by ten consecutive days, separated by a weekend. Each tDCS session lasted 20 minutes and was conducted in a silent room, with the patient remaining still. The treatment was administered through two rubber electrodes inserted into 7 × 5-cm sponges dipped in 0.7% saline solution and secured to the scalp using elastic bands. The procedure was conducted using an NKL Microestim Foco tDCS Fix 8 device.

The protocol involved an anodic stimulation of the primary motor cortex (M1), aiming at the positive effects of this stimulation on the global motor symptoms of PD[5]. The 10-20 EEG electrode positioning system placed the anode over C3 and the cathode over the contralateral supraorbital region (Fp2).

### Subject 2 (S2)

F.J.R., male, 79 years, was diagnosed with PD eight years ago. This subject were also treated with levodopa during recruitment and were instructed not to interrupt his treatment during the study. In the screening test, hearing loss was detected. In addition to the tDCS intervention, S2 received speech therapy in 20-minute intervention sessions, structured based on the

motor speech treatment hierarchy, for each speech component. The resulting protocol consisted of two sessions for respiration, followed by two sessions for phonation, two for resonance, two for articulation, and two for prosody. The sessions were performed during tDCS administration.

A speech pathologist with training and experience in tDCS and conventional speech therapy for dysarthria performed the intervention.

Table 1 shows the results of the Dysarthria Assessment Protocol[8] at each of the three time points: pre-intervention, immediate post-intervention, and 30 days post-intervention. Global improvements were observed across speech components in S1 and S2, with S1 demonstrating the most considerable progress, as evidenced by performance on both post-intervention assessments. However, there was no reduction in the severity of dysarthria.

Table 2 shows the results of PAIF. We observed that patients who received the intervention showed improved intelligibility in the immediate post-intervention assessment and 30 days post-intervention.

Table 3 shows the results of the acoustic voice analysis using the MDVP at three-time points: pre-intervention, immediate post-intervention, and 30 days post-intervention. S2 showed better results in STD, fhi, Jitter, Shimmer, and noise immediately post-intervention and after 30 days. However, S1 showed improvement after the intervention.

**Table 1.** Descriptive results of the Dysarthria Evaluation Protocol tasks

| | S1 | | | S2[1] | | |
|---|---|---|---|---|---|---|
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** |
| *Respiration* | | | | | | |
| MPT /a/ (s) | 8 | 10.3 | 10.5 | 13.5 | 9.5 | 7.4 |
| MPT /i/ (s) | 8.5 | 10.3 | 10.1 | 14.5 | 10.6 | 6.6 |
| MPT /s/ (s) | 6.5 | 9 | 9 | 1.2 | NA | NA |
| MPT /z/ (s) | 4 | 6.6 | 8.61 | NA | NA | NA |
| S/Z ratio | 1.62 | 1.36 | 1.05 | NA | NA | NA |
| Disturbance degree | 5 | 4 | 3 | 3 | 3 | 4 |
| *Phonation* | | | | | | |
| Vocal attack | isochronic | isochronic | isochronic | abrupt | abrupt | abrupt |
| Loudness | low | low | low | high | high | high |
| Pitch | acute | acute | acute | bass | bass | bass |
| Vocal quality variation | unstable | unstable | unstable | stable | stable | stable |
| Disturbance degree | 5 | 4 | 5 | 6 | 5 | 6 |
| *Resonance* | | | | | | |
| Velar movement | minimum | minimum | minimum | appropriate | appropriate | appropriate |
| Pharyngeal wall movement | minimum | minimum | minimum | minimum | appropriate | appropriate |
| Nasal emission | appropriate | appropriate | appropriate | mild | mild | mild |
| Disturbance degree | 2 | 1 | 2 | 6 | 5 | 6 |
| *Articulation* | | | | | | |
| Accuracy | 3 | 4 | 4 | 5 | 3 | 3 |
| Diadocokinesia | disturbed | normal | normal | disturbed | disturbed | disturbed |
| Disturbance degree | 4 | 5 | 4 | 4 | 4 | 3 |
| *Prosody* | | | | | | |
| Intonation | normal | normal | normal | disturbed | normal | disturbed |
| Speech speed | disturbed | normal | normal | disturbed | disturbed | disturbed |
| Pauses in speech | 4 | 2 | 3 | 6 | 5 | 4 |
| Disturbance degree | 2 | 1 | 2 | 5 | 4 | 4 |
| **TOTAL** | 18 | 15 | 18 | 24 | 21 | 23 |

[1]We could not collect the maximum phonation time of /s/ and /z/ because S3 did not perform the task correctly, probably due to hearing loss

**Subtitle:** S1 = subject 1; S2 = subject 2; E1 = pre-intervention evaluation; E2 = immediate post-intervention evaluation; E3 = evaluation after 30 days; MPT = maximum phonation time; NA = not applicable

**Table 2.** Results of the Speech Intelligibility Assessment Protocol

| | S1 | | | S2 | | |
|---|---|---|---|---|---|---|
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** |
| Words (%) | 78.3 | 75 | 66.6 | 50 | 45 | 50 |
| Sentences (%) | 91.2 | 93.6 | 98.4 | 80.8 | 85.6 | 90.1 |

**Subtitle:** S1 = subject 1; S2 = subject 2; E1 = pre-intervention evaluation; E2 = immediate post-intervention evaluation; E3 = evaluation after 30 days

**Table 3.** Comparison of the results of the Glottic Source Acoustic Vocal Analysis by *the Multi-Dimensional Voice Program Advanced* in the different subjects and moments

| | S1 | | | S2 | | | Threshold |
|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E1 | E2 | E3 | |
| $f_o$ (Hz) | 164.351 | 166.050 | 172.457 | 112.242 | 123.158 | 105.494 | 145.223 |
| fhi (Hz) | 287.725 | 205.205 | 358.113 | 212.500 | 145.479 | 131.154 | 150.080 |
| flo (Hz) | 67.143 | 133.029 | 68.332 | 86.607 | 103.803 | 87.765 | 140.418 |
| STD (Hz) | 60.965 | 9.099 | 45.027 | 8.433 | 3.920 | 4.992 | 1.349 |
| PFR | 26 | 8 | 30 | 17 | 7 | 8 | 2.095 |
| Jita (s) | 295.212 | 268.180 | 353.695 | 234.241 | 129.877 | 246.975 | 41.663 |
| Jitt (%) | 4.415 | 4.440 | 5.775 | 2.610 | 1.598 | 2.600 | 0.589 |
| RAP (%) | 2.560 | 2.695 | 3.116 | 1.502 | 0.951 | 1.520 | 0.345 |
| PPQ (%) | 3.084 | 2.428 | 4.138 | 1.562 | 1.004 | 1.607 | 0.338 |
| sPPQ (%) | 7.288 | 3.481 | 15.136 | 3.881 | 1.429 | 1.910 | 0.561 |
| $vf_o$ (%) | 37.094 | 5.480 | 26.109 | 7.513 | 3.183 | 4.732 | 0.939 |
| ShdB (dB) | 1.029 | 0.869 | 1.629 | 0.998 | 0.503 | 0.693 | 0.219 |
| Shim (%) | 10.278 | 8.613 | 15.533 | 11.849 | 5.588 | 7.844 | 2.523 |
| APQ (%) | 9.343 | 8.487 | 14.429 | 8.895 | 4.360 | 5.771 | 1.986 |
| sAPQ (%) | 12.770 | 12.408 | 23.324 | 17.635 | 5.647 | 7.251 | 3.055 |
| vAm (%) | 26.598 | 29.811 | 29.781 | 51.968 | 39.277 | 38.795 | 7.712 |
| NHR (%) | 0.268 | 0.195 | 0.420 | 0.363 | 0.155 | 0.164 | 0.122 |
| VTI | 0.043 | 0.029 | 0.050 | 0.093 | 0.053 | 0.062 | 0.052 |
| SPI | 9.422 | 34.620 | 17.576 | 5.596 | 11.194 | 31.933 | 6.770 |
| DVB (%) | 8.907 | 1.238 | 18.844 | 22.023 | 0 | 0 | 0.200 |
| DSH (%) | 4.188 | 7.798 | 6.164 | 0 | 0 | 0 | 0.200 |
| DUV (%) | 18.026 | 6.438 | 37.339 | 37.339 | 0 | 7.296 | 0.200 |
| NVB (%) | 7 | 3 | 15 | 12 | 0 | 0 | 0.200 |
| NSH (%) | 8 | 17 | 9 | 0 | 0 | 0 | 0.200 |
| NUV (%) | 42 | 15 | 87 | 87 | 0 | 17 | 0.200 |
| Fatr (Hz) | 8.696 | 5.333 | 2.963 | 2.286 | 2.721 | 2.649 | 3.655 |
| Fftr (Hz) | 4.301 | 4.819 | 2.235 | 2.083 | 2.395 | 5.479 | 2.728 |
| FTRI | 6.405 | 1.928 | 4.688 | 0.901 | 0.833 | 1.113 | 0.311 |
| ATRI | 9.293 | 11.234 | 7.344 | 0.418 | 7.785 | 7.000 | 2.133 |

**Subtitle:** S1 = subject 1; S2 = subject 2; E1 = pre-intervention evaluation; E2 = immediate post-intervention evaluation; E3 = evaluation after 30 days; $f_o$ = fundamental frequency (Hz); fhi = highest fundamental frequency (Hz); flo = lowest fundamental frequency (Hz); STD = fundamental frequency standard deviation (Hz); PFR = fundamental frequency semitone variability; Jita = Absolute Jitter ($\mu$s); Jitt =Percentage or relative jitter (%); RAP = relative mean of pitch disturbance (%); PPQ = fundamental frequency perturbation quotient (%); sPPQ = smoothed fundamental frequency perturbation quotient (%); $vf_o$ = fundamental frequency variation (%); ShdB = Absolute shimmer or in decibels; Shim = percentage or relative shimmer (%); APQ = amplitude perturbation quotient (%); sAPQ = smoothed amplitude perturbation quotient (%); vAm = amplitude variation (%); NHR = noise-harmonic ratio (%); VTI = vocal turbulence index; SPI = soft phonation index; DVB = degree of vocal breaks (%); DSH = degree of subharmonic components (%); DUV = degree of unvoiced segments (%); NVB = number of vocal breaks (%); NSH = number of subharmonic segments (%); NUV = number of unvoiced segments (%); Fatr = tremor amplitude frequency; Fftr = frequency of the tremor fundamental frequency; FTRI = tremor frequency intensity index; ATRI = tremor amplitude intensity index; NA = not applicable

## DISCUSSION

This study compared the two treatments for dysarthria in patients with PD to investigate using tDCS as a complementary resource to conventional speech therapy. We hypothesized that tDCS would amplify the results of traditional speech therapy, as confirmed by a descriptive analysis of each subject's performance.

According to the literature, the MPT in healthy older adult males ranges from 13.3 to 18.11 s for the phoneme /a/; 14.7 to 19.22 for the phoneme /i/; 13.3 to 15.22 s for the phoneme /s/, and 14.3 to 15.61 s the phoneme /z/[11]. The MPT of patients with PD in the present study was less than half that observed in healthy adults across all phonemes evaluated (Table 3). This agrees with the literature[11], which states that the MPT is reduced in older adults with PD.

S1 showed improvements in all measures of MPT in the immediate post-intervention assessment and after 30 days (Table 1), which suggests a superior effect of tDCS alone despite the unstable vocal quality in A3. Interestingly, S2 showed worsening MPT performance over time, despite receiving tDCS. This finding contrasts with the literature on the benefits of speech therapy in patients with PD.

Conventional therapy had some benefits in the present study, but only tDCS alone led to consistent improvements in MPT. Additionally, there were improvements in velar movements in S1 (Table 1). These results, like those obtained in the MPT, favor using tDCS alone, although the unstable vocal quality of the S1 in the assessment was performed 30 days after the intervention.

Analysis of the overall performance of the Dysarthria Assessment Protocol[8] showed that both S1 and S2 benefited from respective treatments. However, S1 improved on more indicators in the immediate and 30-day post-intervention assessments than S2 (Table 1). These findings suggest that our intervention may be more beneficial to patients with PD than anodic tDCS over the inferior frontal gyrus, as examined

in a previous study [4], who found that this intervention only produced improvements in articulatory performance. A possible explanation for this difference is that the inferior frontal gyrus is more associated with language processing tasks[12], whereas M1 is related to alterations observed in dysarthria.

The PAIF (Table 2) showed that all interventions improved this measure. This was observed in the immediate post-intervention assessment, as well as a, with the highest percentages occurring in S2. According to a previous study, one-hour sessions of intensive speech therapy over a month improved speech intelligibility in patients with PD, as assessed by blinded listeners[3].

Acoustic voice analysis (Table 3) showed improvements in STD, fhi, Jitter, Shimmer, and noise in both post-treatment assessments, with the most significant changes occurring in S2, followed by S1. These findings demonstrate an improvement in acoustic voice parameters of the subjects studied following tDCS, particularly when combined with conventional therapy.

The limitations of this study include its case study design, which involved few subjects and no case-control matching, and the inclusion of only male participants. Future studies should be conducted with larger sample sizes, including female participants. Additionally, these studies could include healthy control groups or patients matched for age and disease stage to account for confounding factors.

## FINAL COMMENTS

Finally, we observed that tDCS, both alone and in combination with speech therapy, impacted speech and voice and may be used as an adjuvant treatment in cases such as those involved in this study. In S1, tDCS alone led to improvements in all components of speech, whereas in S2, improvements were observed in the vocal and acoustic analysis of glottal source parameters.

## Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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