Case Report

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Audiovisual production therapy associated with transcranial current stimulation improves naming in a patient with Broca's aphasia and Parkinson's disease

Terapia de produção audiovisual associada a estimulação por corrente contínua melhora nomeação em paciente com afasia de Broca e doença de Parkinson

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ABSTRACT

Parkinson's disease (PD) is a neurodegenerative disorder characterized by motor and nonmotor symptoms. PD patients may present language problems, including deficits in confrontation naming. Naming deficits are also an important feature of Broca's aphasia, a condition associated with post-stroke damage to the left inferior prefrontal cortex (Broca's area). We present the case of a 79-year old, male patient diagnosed with both PD (stage 4 in Hoehn and Yahr's scale) and chronic post-stroke, non-fluent aphasia. The patient, with particularly severe naming deficits, was treated with a novel combination of audiovisual production therapy and transcranial direct current stimulation (tDCS), a noninvasive neuromodulatory technique that has been increasingly used to potentiate speech therapy. Anodal tDCS (2 mA) was applied to the left inferior prefrontal cortex (F7 in the 10/20 system) in nine 20-min sessions over two weeks while the patient tried to name pictures of common objects aided by short videos of an articulating mouth (audiovisual cue). We found significant pre- to post-training naming improvement for treated items and for untreated, phonemically similar items (generalization). The results provide initial indication that audiovisual production therapy combined with anodal tDCS over Broca's area may represent a viable treatment alternative for patients with severe naming deficits.

Keywords: Parkinson Disease; Aphasia, Broca; Transcranial Direct Current Stimulation; Boston Diagnostic Aphasia Examination; Rehabilitation

RESUMO

A doença de Parkinson (DP) é uma doença neurodegenerativa, caracterizada por disfunções motoras e não motoras. Pacientes com DP também podem apresentar problemas de linguagem, incluindo deficit em tarefas de nomeação. Dificuldade em tarefas de nomeação é uma característica importante da afasia de Broca, transtorno de linguagem associado a lesões pós-acidente vascular cerebral (AVC) no córtex pré-frontal inferior esquerdo (área de Broca). Aqui, apresenta-se o caso de um paciente de 79 anos diagnosticado com DP (estágio 4 na escala de Hoehn e Yahr) e afasia crônica não fluente pós-AVC, com deficit de nomeação severos. O paciente foi tratado com uma nova combinação de terapia audiovisual de produção e estimulação transcraniana por corrente contínua (ETCC), técnica neuromodulatória não invasiva, que tem sido cada vez mais adotada para potencializar terapias fonoaudiológicas. ETCC anodal (2 mA) foi aplicada sobre o córtex pré-frontal inferior esquerdo (F7 no sistema 10/20), durante nove sessões de 20 minutos, ao longo de duas semanas, enquanto o paciente tentava nomear imagens de objetos comuns com o auxílio de vídeos curtos mostrando uma boca articulando os sons do nome do objeto (pista audiovisual). Observou-se aumento significativo nos escores de nomeação entre o pré e o pós-tratamento, tanto para imagens treinadas, quanto para não treinadas, mas fonemicamente similares (generalização). Os resultados apresentam indícios iniciais de que terapia audiovisual de produção associada à ETCC anodal sobre a área de Broca pode representar uma alternativa viável para pacientes com deficits de nomeação severos.

Palavras-chave: Doença de Parkinson; Afasia de Broca; Estimulação Transcraniana por Corrente Contínua; Teste de Boston para o Diagnóstico das Afasias; Reabilitação

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INTRODUCTION

Parkinson's disease (PD) is a complex neurodegenerative disorder characterized by motor and nonmotor symptoms. Motor symptoms include bradykinesia, rest tremor and muscular rigidity. Non-motor features can include psychiatric (e.g., depression) and cognitive disorders (e.g., dementia)[(1)]. Language problems are also observed in PD patients, including deficits in sentence comprehension, verbal fluency and object naming[(2)]. Naming impairment is an important feature of Broca's aphasia, a condition associated with post-stroke damage to the left inferior prefrontal cortex[(3)]. Thus, both PD and Broca's aphasia can independently impair naming abilities, and patients with both conditions may present with particularly severe naming deficits. In this study, we present an initial indication that a particular naming treatment (audiovisual production therapy) associated with transcranial direct current stimulation (tDCS) can improve naming performance in a patient diagnosed with both advanced PD and severe post-stroke aphasia.

In audiovisual production therapy, the patient's task is to name familiar objects aided by cues with increasing phonemic and visual information about the target words[(4)]. Object naming is facilitated when the patient looks at a speaker saying the object's name out loud relative to when the patient only listens to the speaker[(4,5)]. Audiovisual production therapy leverages on the tight relationship between audiovisual speech production and perception[(6)]. Perception of speech-related, mouth motion engages brain areas essential both for speech perception and production[(7)].

Consistent with this view, it has been shown that the related audiovisual perceptual therapy, which involves matching auditorily presented names to visually presented pictures, can also improve subsequent naming production both for trained and untrained words in patients with aphasia[(8)]. This therapy-related naming improvement can be potentiated when tDCS is concurrently applied to the left prefrontal cortex[(9)].

TDCS has been extensively investigated in clinical trials, including trials with PD and post-stroke aphasia patients[(10)]. It is a neuromodulatory technique that relies on the stimulation of cortical tissue with an electrical current generated by two electrodes placed over the scalp. A positive electrode (anode) increases cortical excitability, whereas a negative electrode (cathode) decreases excitability. In PD studies, the anode has been traditionally placed over M1 (motor cortex) to address motor symptoms and over F3 (left dorsolateral prefrontal cortex in the 10/20 International System) to address non-motor symptoms (e.g., working memory). In aphasia studies, the anode has been mostly placed over F7 (left inferior prefrontal cortex; Broca's area) to stimulate residual cortical areas.

Despite the distributed nature of the brain networks involved in speech production (e.g., Broca's area, left anterior insula, left putamen, supplementary motor area), several lines of evidence point to Broca's area (F7) as a particularly promising stimulation site in patients with aphasia. Increased activation in preserved areas in the left frontal cortex is associated with increased naming accuracy in patients with aphasia, suggesting that preserved perilesional cortex may play an important role in aphasia recovery[(11)]. Moreover, a treatment akin to audiovisual production therapy (*speech entrainment*) improved speech production and increased activation in preserved areas in left inferior frontal cortex in patients with Broca's aphasia, suggesting that the recovery mechanism in this class of therapies involves recruitment of perilesional areas of the left frontal cortex[(5)]. These results suggest that stimulation of Broca's area (F7) and neighbouring tissues may provide an effective therapeutic strategy for patients with Broca's aphasia. Here, tDCS was applied over F7 while the participant performed an audiovisual production training task known to engage Broca's area.

Audiovisual *production* therapy has been shown to improve naming performance in patients with aphasia[(4, 5)]. Similarly, the closely related audiovisual *perceptual* therapy, when coupled with tDCS, has also been shown to improve naming performance in patients with aphasia[(9)]. No previous study, however, has reported the concurrent application of *audiovisual production therapy with tDCS*. Thus, the first aim of this study was to present preliminary evidence on the feasibility of this novel treatment combination. In addition, the protocol presented here was tested on a patient with both PD and chronic aphasia. The treatment was focused on the patient's naming deficits, not on the patient's PD-related, motor impairments. The case is of interest because both PD and aphasia may affect complementary aspects of speech, resulting in particularly severe deficits that may prove resistant to traditional speech-language therapies. Thus, the second aim of this study was to assess the potential benefit of this novel treatment on naming accuracy in a patient with severe naming disability (PD and aphasia).

CLINICAL CASE PRESENTATION

Case history

A 79-year-old, right-handed, college-educated man with no previous psychiatric history took part in this study. The patient presented with PD, stage 4 on Hoehn and Yahr's scale, and chronic (eight months) ischaemic stroke in the left middle cerebral artery, confirmed with an MRI scan (left frontotemporal cortico-subcortical encephalomalacia). According to the patient's wife, the patient worked as a civil engineer and was able to communicate orally before the stroke. After the stroke, the patient developed severe, non-fluent aphasia. The non-fluent nature of the aphasia was assessed with a selection of subtests (e.g., word discrimination, commands, visual confrontation naming, naming fluency) from the Boston Diagnostic Aphasia Examination (BDAE; Table 1). The classification of Broca's aphasia was determined with Helm-Estabrooks, Albert and Nicholas' criteria[(12)], since the patient had relatively preserved auditory comprehension (based on BDAE subtest scores) but severely impaired repetition (based on word and phrase repetition tasks from Martins and Ortiz' verbal apraxia protocol). The patient was on medication (levodopa and donepezil HCl) throughout the data collection period. Donepezil was introduced six months prior the current study to treat memory problems, as reported by the patient's wife. He was not clinically depressed, according to his geriatrician. Nor did he show auditory deficits (correct responses for tonal stimuli below 70 dB on 500 Hz, 1 kHz, 2 kHz e 4 kHz), visual deficits (correct responses beyond the third line on the Snellen scale), or severe cognitive impairments (scored 14 on the Mini-Mental State Examination, mostly due to oral and written communication deficits; e.g., he was able to point to target objects but not to name them). However, the patient did show PD-related speech symptoms, such as soft

Table 1. Patient characteristics and initial assessment results

Variable	Score
Age (years)	79
Sex	Male
Education (years)	18
Time post-stroke (months)	8
MMSE	14
BDAE subtests	
Fluency (%)	0
Melodic line (1–7)	1
Phrase length (1–7)	1
Articulatory agility (1–7)	1
Grammatical form (1–7)	1
Paraphasia in running speech repetition (1–7)	1
Word finding (1–7)	1
Auditory Comprehension (%)	43
Word discrimination (0–72)	35
Commands (0–15)	5
Naming (%)	0
Visual confrontation naming	0
C score (0–100)	20
Aphasia severity (0–5)	1
Type of aphasia	non-fluent
Non-verbal apraxia (0–200)	80 (mild)
Verbal apraxia	Patient could not repeat words or phrases
Dysarthria	Abnormalities of resonance, articulation, and prosody
Lesion extension (cortical and subcortical)	left frontal, temporal and parietal lesion, including left inferior frontal gyrus

Note: Number in parentheses represents the range of the scores; C score = lower score indicates poorer overall performance; Aphasia severity = lower score indicates more severe aphasia; Verbal and non-verbal apraxia were assessed with the apraxia protocol proposed by Martins and Ortiz
Subtitle: MMSE = Mini-Mental State Examination; BDAE = subtests from the Boston Diagnostic Aphasia Examination

voice, slow speech and reduced verbal fluency. Importantly, the patient presented with mild non-verbal apraxia (score 80 in the non-verbal apraxia protocol proposed by Martins and Ortiz[13]) and with dysarthria (presence of clear abnormalities of resonance, articulation, and prosody). The patient underwent physical rehabilitation prior to the study, but not speech-language therapy. The study was approved by the Human Research Ethics Committee of the Faculty of Health Sciences at the University of Brasília (CAAE: 57633316.0.0000.0030). The patient's caregiver signed an Informed Consent Form and authorized the use of sound recordings from the test sessions.

Procedure

The experiment took place in 10 sessions over the course of two weeks. Patient assessment was conducted in the first session and patient treatment took place in the following nine sessions. The number of sessions was chosen based on the findings that picture naming can be improved with as few as five sessions of audiovisual perceptual therapy (with or without tDCS)[8,9], and with as many as 20 sessions of audiovisual production therapy (without tDCS)[4]. In the first session, the patient was assessed by a trained speech therapist (CAP) after referral by the patient's neurologist. At the end of the first session, the patient completed a 20-minute *pre-treatment test*. In this test, the patient was presented with 36 pictures and was asked to name the object depicted in each picture. The pictures were displayed for 20 s, with a 2 s intertrial interval. Participant's utterances were recorded for later scoring by judges. Pictures were black-and-white line drawings of common objects selected from a widely used data set[14]. The objects in the pictures corresponded to one-, two-, and three-syllable words in Brazilian Portuguese with low naming variability. Of the 36 pictures, 18 were subsequently trained in the treatment sessions (*trained list*; e.g., “carro” −*car*) and 18 were not trained but shared the first phoneme with a corresponding word in the trained list (*similar list;* e.g., “casa” − *house*; Figure 1a). The similar list was included to assess whether the potential effects of audiovisual therapy together with tDCS would generalize to untrained, but similar items. Trained and similar items were presented in a randomized order.

The patient underwent nine 20-minute sessions of combined tDCS and audiovisual therapy, four sessions in the first week (Tue-Fri), and five in the second week (Mon-Fri). tDCS was delivered with a battery-driven, direct-current stimulator (DC-STIMULATOR, neuroConn GmbH, Ilmenau, Germany) consisting of two electrodes enclosed in saline-soaked sponges (35 cm^2). To stimulate Broca's area (BA 44, 45), the anode was placed over F7, on the left hemisphere, according to the 10/20 system of electrode placement (Figure 1b). The cathode was placed over the contralateral supraorbital area. A constant current of 2 mA was applied for 20 minutes, following a protocol used in previous studies in patients with Broca's aphasia[15]. The stimulator was switched on 1 minute before the beginning of the audiovisual therapy task and switched off 1 minute after the end of the task. Audiovisual therapy consisted of a naming task aided by audiovisual cues (Figure 1c). Each of the 18 pre-tested pictures (trained list) were displayed on a computer screen for 60 s. During the first 5 s, the patient was encouraged to name the displayed object. Then, a small video screen appeared showing a moving mouth. The mouth said out loud the name of the depicted object four times, with a 2-s interval between repetitions (mean video presentation time = 26 s). After video offset, the picture remained on the screen for the remaining time (mean = 29 s). The participant was encouraged to name the object at any time during the trial and to imitate the moving mouth when it was on the screen. The trained list was repeated across sessions, with different picture sequences used in each session. At the end of the last session, 5 minutes after the stimulator was switched off, the patient took a 20-minute *post-treatment test*. The post-treatment test was identical to the pre-treatment test, except that the sequence of pictures was randomized anew. Treatment adherence and tolerance were both high, as the patient attended all the sessions at the expected times and did not report any major discomfort. According to the patient's wife, his mood improved markedly over the course of treatment. The patient himself had difficulty sharing his perspective due to his severe language deficits.

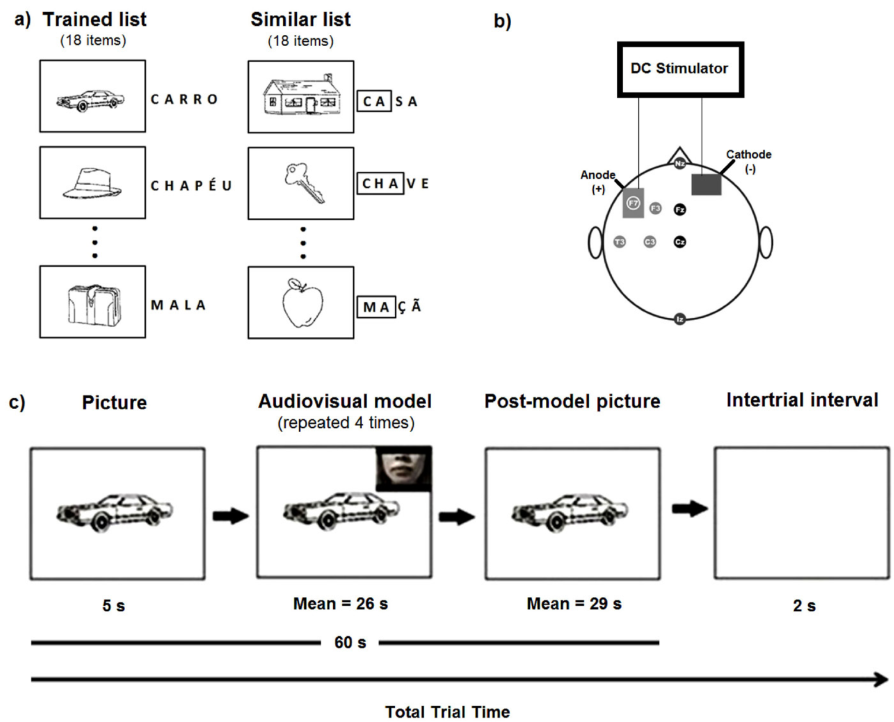

Figure 1. (a) Examples of trained and similar items. Similar items were not trained but shared the first phoneme with a corresponding trained item. Trained and untrained items were assessed pre- and post-treatment; (b) Schematic representation of tDCS montage; (c) Trial during audiovisual treatment and concurrent tDCS. DC = direct current

Scoring

Naming performance was scored with a modified version of the Porch Index of Communicative Ability scoring system[(4)], which is sensitive to small changes in naming ability. In the original scoring system, scores ranged from 1 (no response) to 16 (accurate response without cues or delay). In the modified version used here, scores ranged from 0 (no response) to 9 (correct, target name produced without cues or delay). Intermediate scores represent increasing levels of similarity between verbal response and target word (1-4 points), production of target word with cue support (5-6 points) or spontaneous production of target word (7-9 points). The scoring range was shorter here compared to previous studies[(4)] because our protocol does not involve hierarchical cueing (e.g., our scoring system does not have a score for "correct response when the target's first phoneme is given as a cue" because no first-phoneme cue was provided). Table 2 presents the adapted version of the Porch Index of Communicative Ability scoring system. The patient's recorded utterances were transcribed and assessed independently by four judges (RMGR, JSD, MFRL, and BAC). Pre- to post-treatment inter-rater reliability was assessed with an absolute-agreement, two-way, random-effect model: intra-class correlation r = .99 [.98, .99]. Given the high inter-rater reliability, item scores were computed as the average of all raters.

RESULTS

Paired-sample t-tests (pre- vs. post-treatment) for each list based on the individual word scores revealed a significant naming improvement both for trained words, $t(17) = 2.34$, $p = .03$ (two-tailed), and similar, untrained words, $t(17) = 3.95$, $p = .001$ (two-tailed). For trained words, mean naming scores increased from 1.39 (pre-treatment) to 2.38 (post-treatment). For untrained words, scores increased from 1.11 (pre-treatment) to 1.94 (post-treatment). Most responses consisted of non-words, some of which contained phonemes belonging to the target word. One of the few target words correctly produced upon presentation of its picture was "taça" (wine glass). Table 3 summarizes the results.

Additional inspection of the patient's scores indicated that the naming improvement in both trained and untrained lists may be attributable to an increase in communicative intention. That is because the number of responses with score 2 (which indicates production of non-target phonemes) rose from 33.33% to 90.28% (trained list) and from 45.83% to 91.67% (similar list). Moreover, the number of items scored 0 (no responses) or 1 (stereotypical utterances) dropped from 56.95% to 2.78% (trained list) and from 54.16% to 5.56% (similar list). Finally, the number of responses with the maximum score of 9 (e.g., correctly said /tasa/ to "taça") rose from 0% to 5.56% in the trained list, but remained at 0% in the similar list. By contrast, the number of approximations (score 4; when the patient utters incorrect responses phonologically related to the target; e.g. /cado/ to "gato") rose from 0% to 2.78% in the similar list, and dropped from 2.78% to 0% in the trained list.

DISCUSSION

To our knowledge, this is the first study to assess the potential benefit of concurrent audiovisual speech therapy and

Table 2. Porch Index of Communicative Ability scoring system (adapted version)

Score	Response type	Category	Description and example
9	Complete	Spontaneous	Correctly says the target word without any cue within 3 seconds (e.g., "gato" for target "gato")
8	Phonemic error	Spontaneous	Incorrect phonemes are pronounced but spontaneously corrected (e.g., "cato, gato" for target "gato")
7	Self-corrected	Spontaneous	Responds with a wrong word and then self-corrects (e.g., "cachorro, gato" for target "gato")
6	Repeated presentation	Modelling	Correctly produces the target word at least 3 seconds after the watching the audiovisual cue (e.g., says "dedo" 3 seconds after watching audiovisual model for target "dedo")
5	Simultaneous production	Modelling	Correctly produces the target word during the presentation of the audiovisual cues (e.g., says "dedo" during the presentation of mouth uttering target "dedo")
4	Incomplete	Related	Produces an approximation, but cannot completely produce the word (e.g., "cado" for target "gato")
3	Semantic similarity	Related	Produces word semantically related to target (e.g.., "tigre" for target "gato")
2	Incorrect	Communicative Intention	Produces none of the phonemes in a target word, but produces unrelated words or non-words (e.g., "bola" and "teaz" for target "gato")
1	No Response	Communicative Intention	Produces unrelated response, such as jargon or stereotypic utterance (e.g., "bustiganda" for target "gato")
0	No Response	Not Produced	Produces no response or unrelated sounds (e.g., "eeeh" for target "gato")

Note: Scores 5 and 6 do not apply to pre-treatment and post-treatment, as they refer to the audiovisual therapy under consideration

Table 3. Porch Index of Communicative Ability on picture naming task

Word type	Pre-treatment		Post-treatment		t	p	d
	M	*SD*	*M*	*SD*			
Trained	1.39	0.94	2.38	1.66	2.34	.032	0.55
Similar	1.11	0.89	1.94	0.51	3.95	.001	0.93

Note: Similar = Untrained, phonemically similar words; *d* = Cohen's effect size

Subtitle: *M* = Mean; *SD* = Standard deviation; *t* = paired-sample *t* test; *p* = *p* value; *d* = Cohen's *d*, a measure of effect size

transcranial direct current stimulation over Broca's area in a patient presenting with both Parkinson's disease (stage 4) and chronic post-stroke, non-fluent Broca's aphasia. Both conditions can impair naming abilities[2,3], and thus patients with both conditions may suffer from severe naming deficits. In fact, the patient in this study scored 0 on the naming component of the assessment test. Any improvement in naming performance would thus be notable in this case. We found that the patient's ability to name common visual objects improved after treatment. The improvement was observed for both practiced items and unpracticed items. The results are promising insofar as the prognosis for speech improvement in patients with this particular combination is quite poor. The results also provide initial evidence that the concurrent application of two theory-driven, intervention techniques – audiovisual speech therapy[4,5] and tDCS over Broca's area[8,9] – can improve naming abilities in a chronic patient and, therefore, warrant further research.

The magnitude of the naming improvement was relatively small. Although the patient's naming behaviour changed from producing almost no responses to producing correct target words, there were very few correct responses. The modified Porch Index of Communicative Ability scoring system[4] used here was able to capture small changes in speech production. Had we used a binary response scale (e.g., proportion of correct responses), we would have obtained a floor effect on both pre-treatment and post-treatment tests. The naming improvement was partly attributable to an increase in communicative intention (fewer cases of "no response" and stereotypical utterances; increased production of non-target phonemes). Thus, the treatment seems to affect not only speech-related processes (e.g., more approximations and correct responses) but also motivational and non-speech-related processes (e.g., less hesitation and more naming attempts by the patient).

There are several limitations in the present study. First, this is a case study in which a speech-language intervention was coupled with transcranial direct stimulation in a patient with both PD and Broca's aphasia. Given the number of variables involved, it is hard to determine which factor was responsible for the observed naming improvement (therapy vs. tDCS vs. both) and which medical condition was most sensitive to the treatment (PD vs. Broca's aphasia vs. both). It is possible that the naming therapy itself, without tDCS, was responsible for the naming benefit. In addition, it is possible (although unlikely) that the observed naming improvement would occur naturally without any treatment. Randomized clinical trials would allow disentangling the unique contributions of audiovisual production therapy and tDCS on naming performance on separate groups of PD patients (without left frontal cortex stroke), patients with Broca's aphasia (without PD) and patients with both conditions.

Second, there are other possible reasons for the patient's severely compromised naming ability. Memory deficits, for example, could partly account for the naming impairment. The patient's score on the Mini-Mental test was low for his age and education level, and he was taking donepezil at the time of testing, indicating pre-existing memory problems. We note, however, that the patient's scores on the Mini-Mental test were greatly affected by his communication disabilities, and were thus not directly attributable to memory deficits. He followed instructions correctly, by pointing to target objects when required, but he was not able to name those objects when prompted to do so, which considerably lowered his test scores. Although the Mini-Mental test is not indicated for non-fluent patients, it was used here mostly as a screening tool (for example, the Mini-Mental allowed us to check whether the patient was able to follow simple instructions). Motor impairments (e.g., dysarthria) and deficits with motor planning and sequencing (e.g., non-verbal apraxia) were also probably not the main reason for his naming impairments. The treatment focused exclusively on naming, not on oral-motor exercises, which are traditionally used to strengthen the musculature of tongue and lips. Although the treatment sessions did represent an opportunity for oral-motor exercise, it was the communicative nature of his improvement that stood out in the pre- to post-treatment comparisons (e.g., more naming attempts and increased production of target and similar-to-target phonemes as opposed to unrelated phonemes). Thus, although memory, motor and planning/sequencing deficits may have affected the patient's naming abilities, they were probably not the main reason for the severity of his naming impairment.

A third limitation of the study concerns the generalization manipulation. Half of the test items were repeatedly tested during the practice sessions (trained items); the other half were not (untrained items). Both trained and untrained items benefited from treatment[9]. What they had in common was the first phoneme (e.g., "carro" and "casa"). It is thus possible that untrained items benefited from treatment due to the practice of the phoneme they shared with trained items (e.g., /ka/). However, as this is a case study, alternative accounts are possible. An informative future study may include a third type of item (e.g., untrained and without shared phonemes with a target) so that it would be possible to determine if what was responsible for the naming improvement found for untrained items was the shared nature of their first phonemes. Previous studies with speech-language therapy coupled with tDCS have found mixed results with respect to generalization[8,9]. Fridriksson et al.[8] found that patients treated with an audiovisual perceptual therapy showed naming improvement for both trained and untrained items, whereas Baker et al.[9] used the same therapy and found naming improvements only for trained items. Thus, future research is needed to assess whether the effects of speech-language therapies coupled with tDCS will generalize to new, untrained stimuli. Moreover, the names in both trained and untrained lists contained a wide range of phonemes (e.g. /bo/ in "boca", /de/ in "dedo", /ka/ in "carro"), the pronunciation of which were not all equally difficult to the patient. This is a limitation, as a personalized stimulus set, more closely tied to the patient's linguistic needs, may have yielded a better outcome.

Finally, a fourth limitation of the present study refers to treatment dosage (the number of sessions was small) and follow-up testing (which was not conducted here). The choice of 10 sessions (nine training sessions) was motivated by previous studies using similar interventions and showing significant naming improvement[4,9]. Future studies with more sessions may produce better results in patients with aphasia.

Future studies should also assess the long-term impact of the intervention. Here, testing was conducted shortly after the last training session. Follow-up studies with longer intervals (e.g., two weeks, one month) would allow establishing whether the treatment benefits on naming are long lasting.

FINAL COMMENTS

In this study we present a proof-of-concept treatment – audiovisual speech therapy coupled with transcranial direct current stimulation over Broca's area – that may improve naming performance in a patient with severe naming deficits. Naming performance improved for both practiced and unpracticed items in a patient presenting with both Broca's aphasia and Parkinson's disease.

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