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Case Study

The clinical outcome of concurrent speech therapy and transcranial direct current stimulation in dysarthria and palilalia following traumatic brain injury: A case study

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Abstract

Purpose: Dysarthria, a neurological injury of the motor component of the speech circuitry, is of common consequences of traumatic brain injury (TBI). Palilalia is a speech disorder characterized by involuntary repetition of words, phrases, or sentences. Based on the evidence supporting the effectiveness of transcranial direct current stimulation (tDCS) in some speech and language disorders, we hypothesized that using tDCS would enhances the effectiveness of speech therapy in a client with chronic dysarthria following TBI.

Method: We applied the constructs of the "Be Clear" protocol, a relatively new approach in speech therapy in dysarthria, together with tDCS on a chronic subject who affected by dysarthria and palilalia after TBI. Since there was no research on the use of tDCS in such cases, regions of interest (ROIs) were identified based on deviant brain electrophysiological patterns in speech tasks and resting state compared with normal expected patterns using the Quantitative Electroencephalography (QEEG) analysis.

Results: Measures of perceptual assessments of intelligibility, an important index in the assessment of dysarthria, were superior to the primary protocol results immediately and 4 months after intervention. We did not find any factor other than the use of tDCS to justify this superiority. The percentage of repeated words, an index in palilalia assessment, had a remarkable improvement immediately after intervention but fell somewhat after 4 months. We justified this case with subcortical origins of palilalia.

Conclusion: Our present case-based findings suggested that applying tDCS together with speech therapy may improve intelligibility in similar case profiles as compared to traditional speech therapy.

To reconfirm the effectiveness of the above approach in cases with dysarthria following TBI, more investigation need to be pursued.
Keywords: traumatic brain injury (TBI), Dysarthria, transcranial direct current stimulation (tDCS), Quantitative Electroencephalography (QEEG), speech therapy

1 Introduction

Traumatic brain injury (TBI) is defined as an alteration in brain function and/or evidence of brain pathology caused by an external force (Menon et al., 2010). At a global scale in 2010, approximately 2.5 million people were reported to have sustained a TBI (CDC_ Centers for Disease Control and Prevention) (2017). According to a local observational research (2007-2008), the incidence of TBI was estimated at 53.3-144 per 100,000 in Tehran (Rahimi-Movaghar et al., 2011). TBI may have consequences in physical, sensory, cognitive, communicative, swallowing, and behavioral domains (ASHA_ American Speech, Language and Hearing Association) (2017). High-level cognitive functions, psychiatric disorders and impairment of social and leisure activities are among long term consequences of TBI (Stocchetti and Zanier, 2016). Dysarthria is a communicative deficit regarded as one of the consequences of TBI. The condition is an acquired speech disorder occurred following neurological injury of the motor component of the speech circuitry characterized by reducing the speech intelligibility due to poor, inaccurate, slow, and/or uncoordinated speech muscles (Mitchell et al., 2017). This may potentially affect speech-related functions including respiratory, articulation, phonation, and resonance mechanisms (Kwon et al., 2015).

The mainstay of behavioral treatment in cases with stable dysarthria remains to be speech therapy that is a time-consuming procedure with relative outcomes (Mitchell et al., 2017) . Speech therapy may focus on enhancement of particular speech subsystem by increasing the strength and range of movement of the musculature, implementing behavioral changes such as decreasing speaking rate and accurate pronunciation of speech phonemes by focusing on the kinetic, kinematic, and somatosensory aspects of speech production to improve intelligibility (Yorkston et al., 2007, Robertson, 2001) or providing assistive devices to enhance communicative interactions (Yakcoub et al., 2008). Researchers developed a program named "Be Clear" comprising a treatment plan based on Principles of Motor Learning (PML) which is a relatively new approach in treating motor disorders and believed to facilitate retention/transfer of skilled movement (Maas et al., 2008). The program typically scheduled for 16 one-hour sessions and 15 minutes' homework within 4 weeks. The base of this program is based on external attentional focus (instead of internal attentional focus, in spite of traditional approaches), intensive treatment, and well practice schedule emphasizing on meaningful speech production tasks (Park et al., 2016). According to their study on 8 participants of whom 6 were affected by dysarthria following TBI, increasing sentence intelligibility, the measure they consider the most relevant to evaluate the program outcomes, and decreasing in speech rate was documented immediately and three months after the intervention (Park et al., 2016). However, no significant improvement was observed in terms of word intelligibility and psychosocial impact of dysarthria from the perspective of the speaker (Park et al., 2016).

Although the incidence of dysarthria following TBI is estimated at almost 60% (Mitchell et al., 2017), to date, there are few investigations on neuro-rehabilitation approaches using the concurrent use of electrical or magnetic brain stimulation and speech therapy. To our knowledge, the effectiveness of such techniques in TBI- induced dysarthria has similarly not been focused. As such, further research is required to examine the effectiveness of these approaches associated with common behavioral treatments given the high incidence of TBI and sever communicative problems in people with TBI who suffer from dysarthria.

Palilalia is a type of motor perseveration involving speech, consisting of compulsive repetition of normally articulated phrases, words, or syllables often with increasing rapidity and decreasing volume. Palilalia has been described in several neurological disorders such as cerebrovascular and degenerative diseases, encephalitis or tic disorders (Landi et al., 2012). Basal ganglia involvement has been suggested as the culprit in some cases of palilalia. Palilalia can be seen in untreated schizophrenic patients, in paramedian thalamic damage, also in advanced stages of degenerative brain diseases such as Alzheimer's disease, and in cerebrovascular or traumatic lesions of the basal ganglia (Borsel et al., 2007, Azevedo et al., 2012) which the latter case is likely to be about our case.

Transcranial direct current stimulation (tDCS) is a noninvasive procedure in which brain cortices get potentiated for depolarization by an electrical field with a maximum 2 milliampere (mA) direct current and electrodes localized on definite area over the scalp. The effectiveness of using tDCS in chronic motor disorders (Chang et al., 2017), dysarthria (You et al., 2010), and language impairments (Devido-Santos et al., 2013) due to stroke has been substantiated through brain imaging (Stagg and Johansen-Berg, 2013). tDCS has been successfully applied in various conditions including memory problems, executive dysfunctions, as well as issues with cognitive agility in chronic and subacute conditions in TBI (Demirtas-Tatlidede et al., 2012). A review study has demonstrated that common protocols of tDCS have not associated with serious and irreversible side effects across over 33,200 sessions in 1000 subjects who underwent repeated sessions (Bikson et al., 2016).

The montage of tDCS electrodes is based on related studies finding or neuroimaging techniques such as fMRI, PET, or EEG. EEG is a method to record and measure brain's electrical activity. Electrical brain signals or electroencephalogram contained regular patterns that may be better understood by their spectral (frequency) content. Bursts of sinusoidal waves occurred and reoccurred in a predictable fashion are corresponded with mental states. The powerful computers of today have paved the way for new and faster analysis methods of digitally recorded signals, determining specific patterns in signals, displaying these patterns on screens, and saving the digital data. Quantitative EEG is a powerful and sensitive tool for identifying maladaptive brain activity patterns–that is, bad brain habits (Kaiser, 2007).

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Based on the above, we hypothesized that such a technique would potentially enhances the effectiveness of speech therapy in a client with chronic dysarthria following TBI. To test the hypothesis at least in a single case investigation, we applied the constructs of the "Be Clear" protocol in dysarthria together with tDCS. As such, an individualized therapy plan was formulated in Persian and applied on a chronic case who affected by dysarthria after TBI concurrently with tDCS. Because of the strong relationship between information transfer and speech intelligibility in dysarthria (Beukelman and Yorkston, 1979), this measure was applied as a primary index in speech assessment. In summary, the findings of the current study revealed tES concurrent with speech therapy may have more effectiveness compared to the standard practice of speech therapy in cases with TBI and may be a promising treatment plan in language problems of TBI patients in future. An overview of diagnostic and therapeutic procedures is illustrated in diagram 1.

Diagram 1

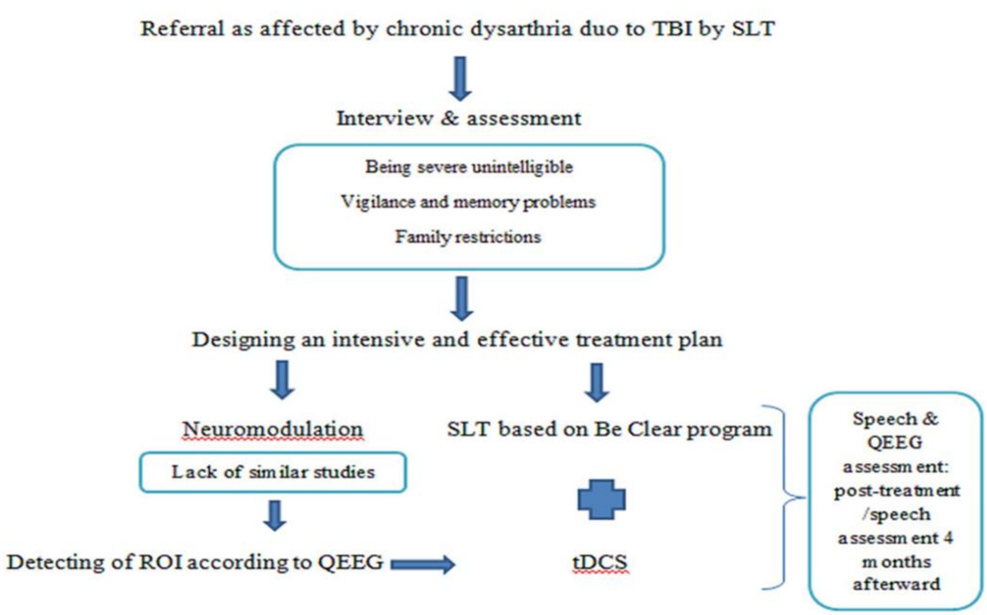

Diagram 1. Flow chart of the study.

2 Methods

2.1 Case presentation

MA was a 40-year-old male who had a car crash 5 years prior to presentation and experienced a closed head injury resulting in hospitalization whereby he survived 31 days of ICU admission in coma. He is a master's degree holder in geology and used to work in a state-owned company prior to the accident. He was diagnosed with diffused axonal injury in his medical history by neurologist. The case had lost his orientation, movement, speech, and efficient swallowing for 6 months after which started to gradually regain some functions following intensive rehabilitation. The case was referred as dysarthria following TBI because of no progress through traditional speech therapy over last 3 years by his speech language therapist.

All procedures were approved by the Ethics Committee of Shiraz University of Medical Sciences (IR.SUMS.REC.1397.799) and informed consent was obtained for experiments with subject.

2.1.1 Sensory-motor problems

According to our neuroscientist and speech language pathologist he has a mild left-sided hemiparesis, left mild facial paresis and oral apraxia, decreased frequency and amplitude of oral movements, hypoesthesia in left upper extremity, slight gait paresis, and left upper extremity hyper-reflexia. There was no hearing problem in his history as well as our observation.

2.1.2 Speech problems

The patient had significant communication problem where unintelligibility was the chief complain of the client and his family. The family was deeply concerned about his excessive repetition of his own words and sentences in conversations.

2.1.3 Cognitive problems

He was found to have notable problem in short-term and episodic memory upon cognitive profile that had potentially caused difficulty in his social functions. Apparently, he was unable to recall what the breakfast was or how he came to our neuroscience laboratory at the day of initial assessment.

Being cognitively incompetent resulting in dependency to his family for his speech homework and living with his elderly parents who were unable to follow speech therapist instructions, necessitate the case to improve the behavioral intervention efficacy.

2.2 Diagnostic assessments and interventions

2.2.1 Speech and language assessments

According to the speech language pathologist (SLP) of the study, the case was diagnosed with spastic dysarthria. Speech intelligibility index, diadochokinetic rate, maximum phonation time, speech rate, and the percentage of repeated words in all words were calculated. Strained-struggled phonation in open vowels and back consonants were diagnosed upon perceptual analyses.

For assessment of intelligibility, like the procedure of “Be Clear” protocole, 8 conversational speech samples (approximately 40 seconds), presented in 4 paired comparisons, on topics participant’s professional interests were rated by 4 native Persian listeners in terms of clarity or understandability. The speech samples were randomly presented to listeners in several different combinations including: a-pretreatment/post-treatment, b-pretreatment/follow up, c- post-treatment/pretreatment, and d-follow up/pretreatment. The listeners' task was to determine whether the first or the second sample of each pair was easier to understand, or whether there was no discernible difference. Listeners were blinded to the assessment intervals (i.e., pretreatment, post-treatment, follow up) and had no confrontation with dysarthric speech. They were 25-45 years old and have undergraduate degrees at least (their email address is available for further correspondence). Prior to task completion, the listeners were provided with the following instructions adopted from "Be Clear" protocol (Park et al., 2016):

"You are going to hear pairs of audio speech samples. You will be deciding which speech sample, the first or the second, is clearer or easier to understand. On your paper you will write the name of a sample is easier to understand. If you do not think there is any difference in how easy it is to understand the two samples, write the word same. Repeat this procedure after one week and date it. There is a training sample at the first to listen and judge (Park et al., 2016).

Each listener completed the ratings twice with a 1-week interval. A total of 32 ratings comparing the pretreatment and post-treatment/follow-up speech samples were also included in the analysis.

Speech intelligibility is of basic considerations in dysarthria intervention (Hustad, 2006) and some objective methods have been suggested for its measurement. Of basic objective measurement methods is transcription the words of speakers' sentences by the listeners and then dividing the words correctly discriminated by whole words. The percentage of intelligibility is obtained by multiplying the result by 100 (Miller, 2013). Formal assessment of intelligibility was accomplished with "Assessment of Intelligibility of Dysarthric Speech (ASSIDS) (Yorkston et al., 1984)" in "Be Clear" program. The subjects are required to repeat a list of words and sentences after examiner and percentage of intelligibility is estimated in ASSIDS by transcription of speakers' responses. There is no such reliable test in Persian so 6 samples of paired comparisons, 2 samples from each stage, were randomly chosen and transcribed by two independent SLPs. Then the SLP of the study calculated the percentage of words which were correctly transcribed. The final estimation was confirmed by the independent SLPs. Rate of speech was extracted in this way too. As the sample extraction method should be instant through investigation till the comparison is possible(Miller, 2013), the content of participant's monologues which were about his professional major(geology) were recorded in presence of a listener and the project SLP by a voice recorder android software one meter from his mouth and samples with 30-46 seconds connected speech with a coherent topic were selected and delivered to independent listeners for perceptual analyses and objective measurements.

The set of speech assessments which were adopted from the "Be Clear" protocol were carried out just before and after interventions as well as 4 months after interventions were

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completed to assess dysarthria. The index of percentage of repeated words was applied to assess palilalia. The percentage of repeated words in whole words characterizing palilalia was calculated in speech samples by the main SLP based on independent SLTs' transcriptions.

Diadochokinetic rate (DDR) and maximum phonation time (MPT) were evaluated by independent SLPs besides the items stated in main protocol since these two aspects are affected in dysarthria (Mitchell et al., 2017, Kwon et al., 2015, Portnoy and Aronson, 1982). DDR which is also known as alternative motion rate is an index used in clinical neurology and speech and language pathology to assess orofacial function and speech motor control and could be an indicator for rehabilitation efficacy(Yang et al., 2011). The rate is estimated by repetition of some nonsense syllables (/pe/, /te/, /ke/, each one 20 times and /pe,te,ke/ , 10 times) as fast as possible and dividing the number by the times which is known as Fletcher test (Fletcher, 1972). Respiration is another affected aspect in dysarthria since reduction or alteration in respiratory support influences the airstream needed for phonation and articulation (Speyer et al., 2010). The maximum phonation time has proven to be a noninvasive, economical, and highly reliable evaluation in voice assessment and provides an objective measure indicating respiratory system efficacy through phonation (Speyer et al., 2010). Subjects are required to sustain a vowel after a deep inhalation for as long as possible at a comfortable pitch and loudness on one exhalation, without straining in this evaluation. The samples of 3 stages of the study which been recorded in this way were delivered to independent SLPs to record the time in seconds up to two decimal places. Three subsequent trials would be averaged to give estimation.

Aphasia was ruled-out based on Persian Aphasia Battery (PAB) developed by Nilipour (Nilipour et al., 2016). There were no resonance problems according to speech pathologist.

2.2.2 Electrophysiological assessments and tDCS application

Since there was no research on the use of tDCS in dysarthria following TBI, regions of interest (ROIs) were identified based on deviant brain electrophysiological patterns in speech tasks and resting state compared with normal expected patterns using the Quantitative Electroencephalography (QEEG) analysis, inbuilt NrSign and Neuroguide softwares (NrSign, BC, Canada 2011 and Applied Neuroscience Inc. 2017; respectively).

EEG data was recorded in two conditions: recording while performing speech tasks (reading, monologue, and orofacial movements), and upon resting eyes-open state. A minimum of 5 minutes of continuous signal was recorded. Signals were recorded while the participant was sitting on a comfortable chair. The EEG data was recorded from 19 channels using NRsign amplifier (see methods) according the international 10-20 system. The impedance in the plug-in was set to a maximum of 5 KΩ. The sampling was performed at a frequency of at least 0.5 and a maximum of 40 Hz, and the sensitivity was adjusted to 70 Hz.

Based on clinical discretion of 2 neuroscientists on the QEEG report of the present case, the therapy plan using an individualized dual-channel montage for tES was defined. A 2 mA

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anodal current was applied on F7 and T5 areas (based on the 10-20 system) and a 2 mA cathodal current was applied on F6 and T4 areas during speech therapy sessions (Figure 1). tDCS was delivered by a calibrated DC-stimulator (Neurostim 2, Medina Teb Ltd, Tehran). The electrode pads (35x35 mm) were covered by equi-sized sponges soaked with 0.9% saline solution. A19-Channel QEEG signals were acquired and analyzed upon speech tasks immediately after intervention. Results have been illustrated in Figure 2.

Figure 1

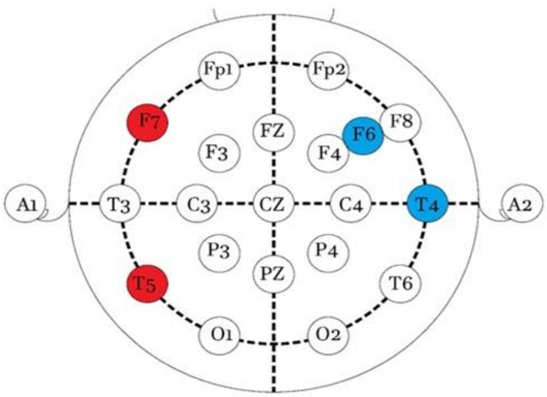

Figure 1. Regions of interest for tDCS. Red: Anodal tDCS, Blue: Cathodal tDCS

2. 2.3 Behavioral intervention based on Be Clear protocol

The plan of speech therapy was developed in Persian based on the “Be Clear” protocol with regard to participant’s needs and performed in 10 45- minute sessions within a 2-week period together with tDCS. Since the treatment design was not language dependent, we translated the instructions of the protocol and customized it based on our participant’ issues while clinging to instructions. The treatment comprised 2 phases including a prepractice and an intensive practice phase. All treatment sessions were delivered by the SLP in an individual face-to-face format. The one-hour prepractice phase aimed to establish the case’s understanding of the concept of clear speech and confirm a clear speech production. Speech models were produced in 2 forms of normal and exaggerated more intelligible articulation by SLP. The participant was required to identify which of the speech samples were clearest and then discuss the changes made by SLP (e.g., speech rate reduction, exaggerated articulation, and no repetition of words and phrases) which might have reflected in the observed improvements in speech clarity.

The knowledge of performance (KP) feedback on the client’s speaking technique (e.g., speaking with open mouth, controlling the speech rate using fingers, and soft contact of vocal folds to reduce strained/struggled voice due to dysarthria) was provided in this session to shape a clearer speech. Clear speech refers to a speaking style where talkers spontaneously modify their habitual speech to enhance intelligibility for a listener (Park et al., 2016). The intensive practice phase followed the prepractice phase and consisted of 45-minute therapy sessions, 5 times a week, for 2 weeks. Every session of this phase was initialized with providing an appropriate modeling and KP feedback by SLP to shape proper speech in the participant and then structured speech drilled once he was able to produce adequate clarity because the increasing the number of repetitions of the task has been shown to be vital in establishment of neural reorganization and maintaining behavioral improvements following the cessation of treatment (Ludlow et al., 2008).

Later during the sessions and consistent with the original protocol, “Be Clear” program, reading, picture description, and conversation were delivered in small blocks of trials since PML based small blocks of trials may result in superior retention and transfer of trained skills than either traditional blocked or random practice schedules (Park et al., 2016).

During the intensive practice sessions, treatment stimuli were created on the basis of participant’s interests and functional needs. The specific practice of meaningful speech production tasks was ensured to conform with the principles of specificity and saliency, potentially enhancing the effects of treatment on neuroplasticity (Wulf, 2013). Complete clarity during performing all tasks was ensured with encouraging the participant to focus on his acoustic speech features. The participant was asked to evaluate his speech to improve self-evaluation skills. During the practice phase of each session, the clinician provided general Knowledge of results (KR) feedback on speech clarity, labeling speech attempts as either clear or unclear since according to PML an external attentional focus (attentional focus on the external signals following a movement) promotes automaticity, retention, and transfer the outcomes(Hustad et al., 2007). According to the “Be Clear” protocol, ending part of intensive phase was delivering the homework that was not accomplished because of mentioned problems. “Be Clear” protocol had scheduled a 10-minute 3-5 times practice in follow up period that was not taken place by client.

A part of the present investigation was allocated to assess the participant’s palilalia because of family concerns. Due to the rare occurrence of this speech disorder, many specific characteristics of palilalia are still unknown (Akbari and Shollenbarger, 2016) so we planned an intervention program based on PML principles. Given SLP’s diagnosis of palilalia in the present case, in intensive practice phase, the participant was required to provide feedback based on his acoustic speech features (based on external attentional focus rule in PML) if there were repetitions. Then he had to discriminate the words which had been repeated and number of repetitions in upon his practice of productive speech.

3 Results

3.1 Speech analyses

Results of the perceptual analyses of intelligibility are compared with ones of original study, “Be Clear” program, developed by Park and colleagues (Park et al., 2016) in table 1. FU

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corresponds to samples of follow up assessment, PR to samples of pretreatment assessment and PT to samples of immediately post-treatment assessment.

Table 1. Results of comparative ratings for speech intelligibility.

	Pre better (%)	Post better (%)	FU better (%)	Same (%)
This study	0	46.875	46.875	6
Original study	14.6	36.5	33.3	15.6

Pre: pretreatment; post: post-treatment; FU: follow up

The paired comparison ratings of speech intelligibility reported from the "Be Clear" program, for better illustration, have averaged for 6 participants who experienced dysarthria following TBI and presented in terms of percentage. Post-treatment and follow up speech samples were rated better than pre-treatment 10 and 13 percent more than "Be Clear" program respectively.

Increasing the mean percentages of intelligibility in the "Be Clear" program was 8.36 and 6.99 whereas they were 38.3 and 24.7 in our study in post-treatment and follow up samples respectively according to 2 independent SLTs. Intra-class correlation coefficient (ICC) estimate and its 95% confident intervals was calculated using SPSS package (IBM SPSS statistics 22) based on the absolute-agreement, 2-way random-effects model. The ICC of two raters was 0.967(CI: 0.801-0.995, α=0.05) which was considered as significant. Results have been illustrated in tables 2 for pretreatment/post-treatment/follow up phases.

Results DDR and MPT for pretreatment/post-treatment/4 months after treatment are compared in table3. The only measures which increased with intervention and remain better than initial assessment were /ke/ and MPT that improved 1 second.

The percentage of repeated words in whole words decreased 16.17% in post-treatment assessment but increased 11.42% after 4 months (see table 4) yet more than 4% better than the first assessment.

Table 2. Results for sentence intelligibility in comparison with the original study

	Pre M(SD)	post M(SD)	FU M(SD)

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% Sentence intelligibility	this study	53.53	91.82	**78.19**
	original study	86.55(16.39)	94.91(7.31)	**93.54(11.03)**

Pre: pretreatment; Post: posttreatment 1; FU: follow-up

Table 3. Comparative outcomes for diadochokinetic rate and maximum phonation time

		PRE	POST	FU
Diado	/pe/	3.6	3.6	**2.53**
	te//	2.2	1.9	**1.7**
	/ke/	1.2	1.9	**2.35**
	/pe,te,ke/	1.2	1.7	**1.4**
MPT		14.3	15.61	**15.36**

PRE: pretreatment; POST: post-treatment; FU: follow up; MPT: maximum phonation time

Table 4. Mean of speech rate and percentage of repeated words

	PRE	POST	FU
WPM	75.78	60.78	**57**
PRW%	25.58	9.41	**20.83**

WPM: words per minute; PRW: percentage of repeated words

3.2 Everyday communication outcomes

The psychological impact of dysarthria from the perspective of speaker was investigated with Dysarthria Impact Profile (DIP), a questionnaire in 5 section, in 3 assessments phases in "Be Clear" program (Walshe et al., 2009). DIP evaluates the impacts of dysarthria on affective and communicative aspects. Since the questioner has not been translated in Persian, the participant was asked to descript his communicative alterations. He wrote:

"Previously everybody did not understand my words but I trust I'm doing better now. My memory is picked up. My relationship with friends has notably improved. I went to (Ministry of) Industry, Minerals, and Metals to visit two mines. I am going to the office once or twice a week. I am kind of confident to get re-hired".

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Since this study focused solely on speech skills, the memory and consciousness of the participant were not thoroughly measured, meanwhile, reports from him and his family appeared to indicate a notable progress in this regard.

3.3 QEEG measures

Resting-state 19 channels QEEG suggested a focal slowing at P3, P4, T8, T6, and C2 favoring nonspecific brain dysfunction. Spectral topography suggested increased alpha range in posterior regions.

Task data analyses revealed event-related desynchronization (ERD) at T4 and T3 with generalized slowing at T5, T6, P3, and P4. ERD in speech tasks was also seen at FP2, F4, and F3. The beta-2 range at 15-18 HZ in bi-hemispheric frontal polar areas and frontotemporal zones needed to gain.

The NRsign software was used to analyze the real time data with respect to spectral and spatial distribution of the brain waves including α (alpha), β (beta), θ (theta) frequency and β2 as the user defined range (15-18 Hz).

General assessment of EEG signals showed no abnormality in terms of focal or paroxysmal EEG signals including sharp waves or spikes across brain regions.

The amplitude of distributed signals was mapped on a multi window heat color map showing an increased amplitude for theta frequency in bilateral centrotemporal area as well as bioccipital brain regions. Beta range frequency was increased power in right centrotemporal while the subject was re_ assessed following interventions, after 10 sessions as outlined in Figure 2-C. Subsequent QEEG-based evaluation demonstrated an improved in spectral and spatial distributions in brain waves showing that theta and alpha distributions were more pronounced in specific brain regions predominantly involved in speech. There was also apparent alpha-theta coherence in the left posterior brain regions as well as centrotemporal areas. The spectral up-band was set at 6 microvolts across frequency bands.

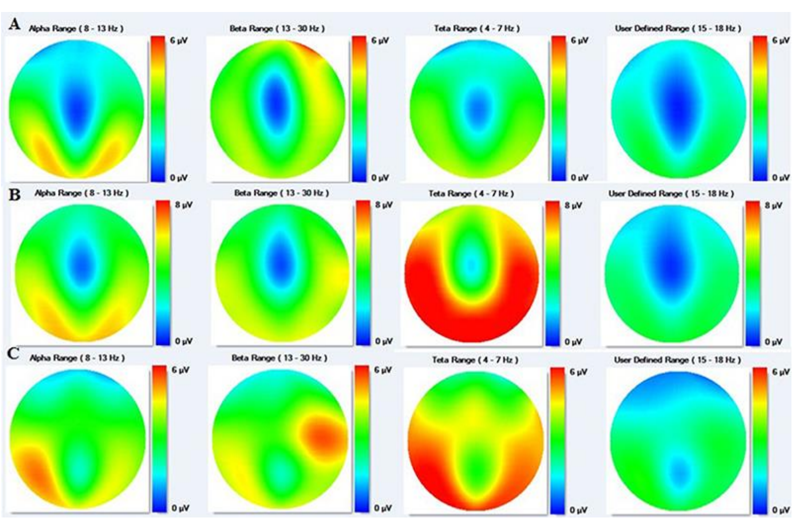

Figure 2. the color_coded quantitative EEG brain map A) Resting state: focal slowing at P3, P4, T8, T6 and C2 favoring nonspecific brain dysfunction, B) Upon speech tasks pre intervention: High amplitude for theta frequency in bilateral centrotemporal are as well as bioccipital brain regions, C) Upon speech tasks post intervention: increasing power of beta range frequency in right centrotemporal.

4 Discussion

In this study, we investigated the feasibility of an intensive treatment, adopted from the "Be Clear" program, designed to improve speech intelligibility in a participant who had affected by dysarthria following TBI, associated with tDCS. He demonstrated remarkable improvement following intervention on perceptual ratings of speech intelligibility that maintained after 4 months. In these paired comparison ratings none of the native listeners, despite the "Be Clear" programs, mentioned pretreatment samples easier to understand. In fact among 32 comparisons were done between pretreatment/post-treatment and pretreatment/follow up all judgments except for 2 cases were in favor of post-treatment and follow up speech samples which were than the "Be Clear" program. Measures of intelligibility in formal assessments carried out by independent SLPs also increased more than ones in "Be Clear" program. We attribute this superiority to application of tDCS since its effectiveness in speech and language disorders (Baker et al., 2010, Monti et al., 2013, Marangolo, 2013) and even for improvement of language skills in healthy people (Sparing et al., 2008) has been proven.

The striking issue with our participant was very low speech intelligibility at the start of the work (53.53%). However, this measure reached over 90% after the intervention. One of the negative points in this study was a decrease of approximately 13% after 4 months, although the intelligibility was still above 24% higher than the initial estimation. This can be attributed to the short duration of the intervention.

Although the main study reported that the effect of intervention on improving communication attitudes was not significant, the participant in the present study presented a very positive report of his communicative progress. This can be attributed to very low initial intelligibility. Of course, we believe that the role of tDCS application should not be ignored. According to his report, it seems that part of this improvement has been due to increased levels of participant`s consciousness. This finding is consistent with studies investigated the effect of tDCS on the level of consciousness in normal people (Lauro et al., 2014) and patients with abnormal levels of consciousness (Zhang et al., 2017, Bai et al., 2017). The reduction of speech rate and decreasing palilalia were other goals of this study. Although initial speech rate was lower than normal (about 75 WPM), explosive pattern with fast words and phrases repetition following prolong pauses due to spastic dysarthria and blocks in vowel and back consonants resulted in very low ineligibility along with an unusual pattern of speech. Memory and vigilance problems contributed in these pauses. Of our aims was reduction the speech rate to increase the participant's control over the acoustic speech signal using KR feedback.

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The result of this intervention is evident in the reduction of repetitive words percentage in the post-treatment evaluation.

Despite the fact that the advancement of case has been maintained in the reduction of speech rate, there has been an increase in the number of repetitions in the follow up phase. Given the subcortical origins for palilalia, it seems that nonspecific, hypoxic brain damage leads to this symptom in this case. Although tDCS and tACS have the potential to influence the abnormal cortical-subcortical network activity that occurs in Parkinson's Disease (Hess, 2013), We suspect that the low efficiency of sub-cortical effects of tDCS would have outcomes that were not sustained in this case.

As it was said, among the other problems were strained-struggled voice and blocked vowels and back consonants. It seems that application of KP feedback (easy onset) and KR feedback (attention to explosive nature of speech signal) resulted in increasing DDRof /ke/ in post-treatment and follow up phases. Reduction of DDR of /pe/ and /te/ was contrary to our expectations and our possible justification is that he tried to increase the clarity with a slowdown of speech.

In line with speech and vigilance alteration there were improvements in QEEG results. According to Gehrig et.al (2012) speech production tasks is expected to decrease alpha power primarily in visual and auditory cortices. A decrease in inhibitory alpha could engage these brain regions in the reading / speech production network and alpha decrease is markedly lateralized to the left in secondary auditory cortices (Gehrig et al., 2012). Increased amplitude for theta frequency in bilateral centrotemporal areas as well as bioccipital brain regions which is more prominent in left hemisphere in post-treatment and follows up phase is consistent with this research. On the other hand, though Giraud and his colleagues believe that slow fluctuations in 3–6 Hz EEG rhythms correlate most strongly with spontaneous neural activity in the right auditory region, while higher-frequency fluctuations in the 28–40 Hz range shows left hemispheric predominance (Giraud et al., 2007), we have seen almost the opposite because of increasing beta power for right centritemporal after intervention.

A general illustration of this person with chronic dysarthria shows a significant improvement in speech intelligibility, the most important symptom measured in dysarthria (Morgan, 2013), after two weeks of intervention. This is opening a new avenue to study this protocol with tDCS in ameliorating symptoms of dysarthria following TBI whereby sham tDCS would be compared with real tDCS.

5 Conclusion

According to the preliminary assessment and post intervention measurement of speech function of this specific subject, we conclude that tES may have potential applications in remediating speech insufficiencies mainly intelligibility in cases with TBI. Meanwhile further research would be required to shed more lights on mechanistic specific on such an impact on ameliorating speech problems following TBI. More investigation using traditional speech therapy with sham TDCS versus verum would be a value to explain the clinical significance of such an approach in a small scale studies.

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