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Work Protocol for Cognitive Optimization Intervention Using Computer Applications in Patients with Cognitive Impairment after Stroke

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***Abstract*—The proposed research theme consists in designing a work protocol for cognitive optimization therapy and evaluating the effect of the cognitive optimization intervention using computer applications according to this protocol to patients who have suffered a stroke and whom exhibit cognitive impairments affecting language and communication, attention, concentration, thinking, memory, mental calculation.**

***Index Terms*—Stroke, cognitive impairment, cognitive training, computer applications.**

I. Introduction

Advanced Rehabilitation Technology addresses compensative and restaurative strategies concerning physical as well as cognitive functions impaired in neurological conditions. Specific computerized applications are used in order to train the cognitive functions highlighted as in deficit in the psychological assessment. These applications present different challenges to the user, like building items from elements, while following a pattern, rapid sorting of presented elements, mental calculation, maze solving, remembering a memorized pattern in order to locate elements, games with mathematical rows, drag and drop games. Training with these applications improves the reaction speed, logical reasoning, visuo-spatial perception, mental calculation and flexibility, as well as memory, focused attention and observation abilities. The exercises are timed and the user has an objective feedback regarding his/her performance.

Cognitive functions are active in all aspects of the existence of the human being. The optimal cognitive functionality ensures the efficient deployment of all daily activities and the integration of the person into the socio-economic environment. Cognitive functions of the human psyche that can be subjected to an objective evaluation process are described as abilities but also as an act, and fall under one of the following cognitive domains: attention, memory, executive functions, perception and praxis, language. Metacognition, the field of conscious knowledge of one's own cognitive life, is not directly exposed to observation and can be subjectively revealed to us by the person in question.

Cognitive functions are affected following a stroke. The residual cognitive impairment manifests itself with prevalence from 20% up to 80% in persons after stroke [1].

Cognition is not a unitary concept, incorporating several cognitive domains. Stroke residual cognitive impairments may concern one or more cognitive areas and are directly related to the severity of the stroke.

The residual cognitive impairment after stroke is reported in the literature as Vascular Cognitive Impairment (VCI), a generic term that has been introduced to describe a broad spectrum of cognitive changes related to vascular disorders that are not included in the dementia diagnosis [2].

The residual cognitive impairment following a stroke is reversible, unlike the cognitive impairment with reference to the preclinical stage of dementia (MCI) [3]. Cognitive impairment improves spontaneously in the first three months in approximately 16% to 20% of stroke survivors, the recovery may continue for at least one year post stroke [4].

It has recently been discovered that the adult human brain also benefits from the phenomenon of adaptative neuronal plasticity [5]. There are changes in brain activity: diaschisis phenomena and reorganization of the pre-infarcted areas, deactivation of functional areas associated with those affected by the lesion and activation of maps in the motor cortex - vicarian reorganization, whereby the functions of the injured brain areas are taken over by lesion free brain areas. The phenomenon is observed not only within the brain hemisphere in which the lesion is present, but also in the contralateral cerebral hemisphere, early after the stroke [5]-[7].

Cognitive functions seem to recover slower than motor functions associated with tasks in daily living activities. Memory deficits persist 3 months post stroke at 29% of subjects [8].

The term of "*cognitive rehabilitation*" or "*cognitive training*" is used, in a narrow sense, to refer to exercises with a stimulating effect on one or more cognitive domains, impaired after stroke. There is no support for the use of a specific type of memory, logical reasoning or abstract thinking exercice, but there are still studies, limited by the small number of participants, which bring in discussion the benefic effect of this cognitive training on the mental functioning post stroke.

Cognitive training purpose is to develop new strategies with a compensatory role for the cognitive impairment and to

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support the person who suffered a stroke to develop new skills, and to reduce the degree of impairment, in order support the person to reach an optimal level of performance, both in terms of cognitive and participatory capacity.

Cognitive stimulation therapy is one of the neurocognitive, non-pharmacological, rehabilitation techniques, of interest to researchers in the field, tending towards stimulating, uniformly or concomitantly, one or more residual cognitive areas. The current state of research on the efficacy of cognitive stimulation therapies indicates both the increased efficiency of post-intervention operability and the existence of valid cognitive assessment tools. One of the limitations of cognitive stimulation therapy is generated by a severe language disorder related to stroke.

The World Health Organization (WHO) highlights the importance of integrating cognitive optimization therapy into the medical rehabilitation program and also the existence of several therapeutic approaches to cognitive training [9].

The diversity of work tasks proposed in cognitive optimization sessions varies from simple to complex. The level of difficulty is directly proportional to the degree of cognitive impairment.

II. Work Methodology

This paper presents the development of a specific work strategy for the cognitive rehabilitation intervention in the case of stroke patients and undergoes a complex medical rehabilitation program from the initial contact until the discharge from the Medical Rehabilitation Department of the Elias University Hospital.

The Cognitive Recovery Guide of the European Federation of Neurological Societies, made available to our specialists by the Romanian Society of Neurology, is an analysis of various studies that attempted to evaluate the effectiveness of different therapeutical approaches of cognitive training for several cognitive domains (attention, memory, language, unilateral space neglect) and issues a series of general recommendations, but does not bring the therapist's attention on specific techniques as representing the optimal exercising strategy version for a specific cognitive domain and for a specific degree of specific residual cognitive impairment, nor does it indicate a workflow upon which a rehabilitation program can be based [10].

Since there is no national working protocol on cognitive optimization intervention, we have developed this "guide" to provide a direction in terms of evaluation, initiation and the level of optimal assistance during the cognitive optimization intervention.

A first step in this attempt was to design a working protocol on the evaluation, initiation and support of the cognitive optimization program dedicated to stroke survivers with cognitive deficits (Fig. 1).

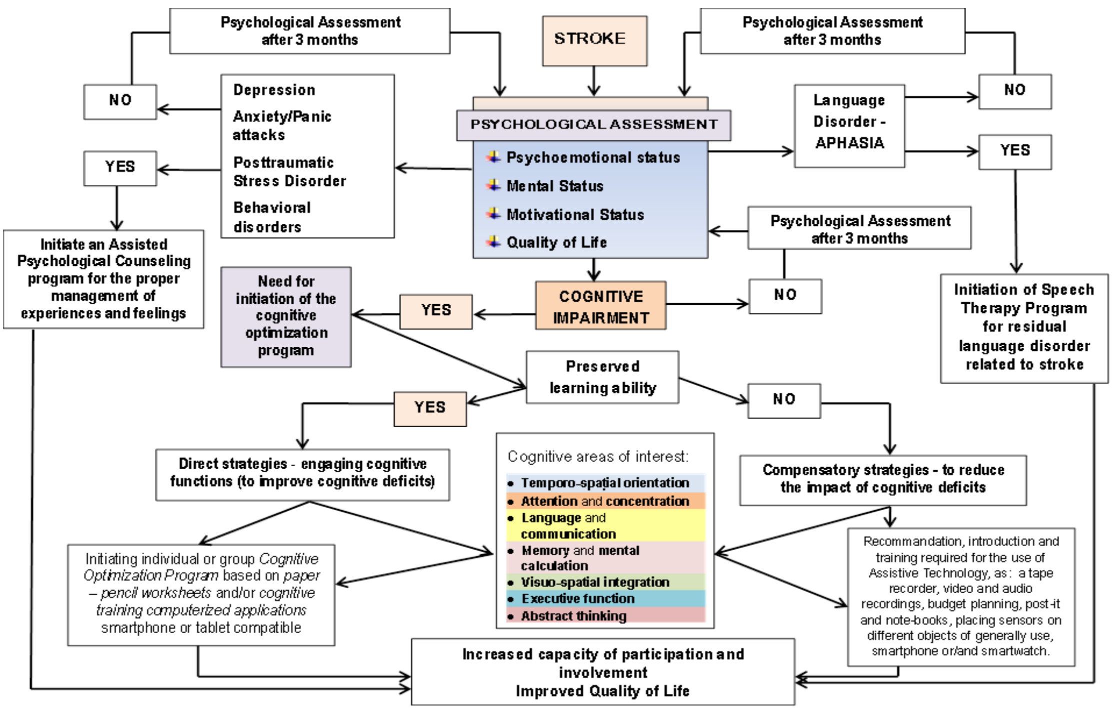

Fig.1. Working protocol on the evaluation, initiation and support of the cognitive optimization program.

The rationale behind the elaboration of the protocol has as its starting point the patient who suffered a stroke. The patient referred to the clinical psychologist is subjected to psychological assessment.

The algorithm of the protocol makes obligatory scrolling the entire decisional tree hereby presented, from box to box, without jumping over any stage, observing the route required by the switching thresholds.

Repeated assessment of cognitive functions is necessary along the rehabilitation process, in order to allow the fine adjustment of the interventions.

Clinical Practice Guides recommend the psychological evaluation of all stroke survivors for the detection and quantification of residual deficits [11], [12].

Not detecting a cognitive impairment at the initial psychological evaluation makes necessary that the person will periodically undergo cognitive evaluation, in order to make the necessary intervention possible, if such a deficit appears without jumping over any stage, observing the route required by the switching thresholds.

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Not detecting a cognitive impairment at the initial psychological evaluation makes necessary that the person will periodically undergo cognitive evaluation, in order to make the necessary intervention possible, if such a deficit appears lately. Specialty literature draws attention to the risk that cognitive deficits after stroke remain undetected and unidentified [13].

The therapeutic cognitive optimization protocol is a necessary and useful organizational tool that ensures the fluidity of the optimization process, allowing a unitary and comprehensive approach from the patient's referral to the clinical psychologist for evaluation and the evaluation procedure prior to patient discharge establishing the functional progress achieved as a result of the cognitive optimization intervention.

The therapeutic cognitive optimization protocol is also a tool for organizing the workflow in clinical research studies in clinical psychology.

After establishing the cognitive parameters and the specific objectives of the cognitive optimization phase in which the patient is located:

- cognitive areas requiring intervention;
- type of approach;
- type of therapeutic instruments;
- level of assistance;
- intensity of training.

The planned cognitive optimization intervention, according to individual patient problems and based on residual cognitive capacities, can be effective!

III. Study Design

The methodological approach of the study consists of three different stages:

1. *Initial psychological evaluation* – was performed with specific psychometric tests for the assessment of mental status. Since there is no currently standard protocol for the evaluation and diagnosis of post stroke cognitive impairment [14], we used the Montreal Cognitive Assessment (MoCA) for cognitive screening and WMS (Wechsler Memory Scale) I – highlighting the mnesic quotient (QM). The used tools are valid and confirmed as valuable tools in assessing the post stroke cognitive impairment.

2. *The cognitive optimization intervention* according to the elaborated working protocol. The cognitive optimization intervention took place over a period of 10 consecutive days, with a frequency of 1 session / day, the time allocated to each session being 60 minutes.

The individual cognitive optimization intervention consisted in the application of *pencil-paper work sheets* and *cognitive* training *applications* (Brain Wars [15]), smartphone or tablet-compatible, according to the protocol presented in order to train the cognitive functions highlighted as in deficit in the psychological assessment.

The difficulty level is variable, both for pencil-paper work sheets and computerized applications, this being directly proportional to the degree of cognitive impairment.

Cognitive training applications have the role of training attention, mental calculation capacity, working speed, memory, logical reasoning, precision and control [16].

These are perceived by some patients as more engaging than pencil-paper work sheets, cognitive training computerized applications being friendly and accessible to anyone no matter what their computer / tablet skills are. The limited, preset working time of cognitive training applications is a challenge for patients, a sense of competition (with itself), and rapid feed-back received at the end of the application being a motivating factor for some patients.

A disadvantage of cognitive training computerized applications is considered by the specialists to be the redundant effect of repeated application of the same type of exercise [17], at which point the intervention becomes useless and requires a change in the type of approach. It is considered that the improvement of working times in this case may be due to "battering the route". To prevent the redundant effect, we have alternated the use of computerized applications with the application of pencil-paper workheads.

3. *Final psychological evaluation (post cognitive optimization intervention)* – at the end of the 10 consecutive working sessions, to determine whether or not there is a certain degree of improvement in the cognitive performance indices.

Patient recruitment was performed according to the inclusion / exclusion criteria presented in Table I.

TABLE I: Inclusion / Exclusion Criteria in the Cognitive Optimization Intervention Study

Inclusion criteria	Exclusion criteria
• mild to moderate cognitive impairment • keeping the learning ability • mild to moderate expresive/receptive aphasia, without significant receptive damage	• severe cognitive impairment - patients with a MoCA score <11 or those who are in treatment for dementia will not be included in the study • moderate to severe expresive/receptive aphasia – patients with an index lower than 60% obteained on the language assessment will not be included in the study* • severe depression**

* *receptive aphasia prevents neuropsychological testing and limits the patient's degree of participation. Also, severe verbal production disorders disable the patient in conducting the tests and limit his access to cognitive stimulation intervention. In both cases, another type of therapeutic approach is needed.*

** *depressive affective disorder may influence the results obtained in assessing the mental status of the patient, knowing that "sometimes depression may mimic dementia or may be associated with dementia" [18], which is why the application of specific clinical scales to assess depression is imperative in order to establish a clear diagnosis with the ultimate goal not to influence the final results of the research.*

Due to ethical and practical reasoning, in the present study it was decided not to opt for a batch of control patients, although this type of approach would be ideal for clearly identifying the effect of cognitive optimization intervention.

Nouchi et al., in a randomized controlled trial conducted to evaluate the beneficial effects of cognitive training in healthy elderly people, used as a control group persons on the waiting list, having a choice between this method and the one that includes the non-contact person group control, as in the case of studies conducted by Levine [19], Basak [20], McDougall [21].

Other authors [22], [23] used active control groups to verify, in which case, the participants in that group perform activities such as the selection of letters in a newspaper, playing video games, reading non-important news.

From a methodological point of view, it is better to use an active control group in such a study, but the ethical considerations relate to the benefits that the control group members will have. Running activities with meaningless tasks and lacking the prospect of functional gains is inappropriate [24].

The use of a placebo control group did not prove to be necessary for this type of study because there is no difference between the progress of these participants and the participants of a non-contact group [25].

Were recruited for the study those patients with specific therapeutic indication - referring to the cognitive optimization intervention, as a result of the psychological evaluation performed and in accordance with the general recommendations of the members of the medical rehabilitation team.

A number of 50 participants, aged 23 to 77 years, with post stroke cognitive impairment were recruited from patients hospitalized in the Medical Rehabilitation Department of the Elias University Hospital. The study was conducted to obtain informed consent and with the approval of the Ethics Committee of the Elias University Hospital. The proportion of men vs. women were 56% vs 44%, 76% of participants living in the urban environment. Level of education - 48% of the participants in the study are graduates of higher education, while about 38% are high school graduates.

The clinical trial conducted is a series of cases longitudinal study. The evolution of the cognitive performance parameters as a result of the cognitive optimization intervention was followed dynamically.

We established the *main variables* the scores obtained at the MoCA test, total QM and CDT. The mmezic quotient (QM) was calculated for 39 participants - WMS was applied to people with higher education and people who completed high school studies. The demographic and comorbidity characteristics of this subgroup are comparable to those of the complete group.

We established as *secondary variables* the scores obtained at the attention tests, space representation, language and WMS subtestes.

Determining *the pattern of cognitive performance* that characterizes the group of participants included in the study is necessary and is the first step of the cognitive optimization intervention.

IV. Results

One of the followed results is *to analyze cognitive performance scores at baseline* (t1) - prior to the cognitive optimization intervention *in order to obtain a global image of the cognitive impairment* at the group level so that the starting point of the research will be to establish the initial level of cognitive impairment.

According to the results obtained from the statistical analysis of the variables at t1, an average QM of 101.71 and a DS of 17.010 were highlighted. The average for MoCA scores at t1 was 23.05, with a DS of 3.36. By reference to the above mentioned score, it is found that the group of patients included in the study has cognitive deficit.Frequency analysis indicates 15% of participants who achieved a QM score at t1 of over 111 points.

According to the scores obtained at the application of the MoCA- adjusted to the level of education at t1 - cognitive optimization preintervention, 27 patients had a MoCA score in the scores category: 0-23, and 23 patients had a MoCA score in the scores category : 24 - 30.

The study participants had a MoCA score adjusted to the level of education between 14 and 28 points.

The secondary variables results of the cognitive indices at t1, are the scores obtained in the spatial attention and spatial representation tests, respectively the scores obtained in the WMS subtests, at t1 (pre-intervention).

Low scores were recorded in attention and concentration tests. The average of AD2 score is 4.87 (maximum score = 10) and DS of 2.56 with a median of 5.00. Yerkes scores are 6.40 (max score = 15), with a DS of 3.67 and a median of 5.00. For language, a mean of .80 (maximum score = 1) and a median of 1.00 with a DS of 0.40 were recorded in the patient group.

Data analysis obtained from the WMS subtests indicates, at the level of the study participants, a temporo-spatial orientation score with an average of 4.45 (maximum score = 5) and a DS of 0.65; ability to listen information orally reproduced - with an average of 8.60 (maximum score = 23) and a DS of 2.56; mental control with an average of 5.00 (maximum score = 9) and a DS of 2.01; ability to reproduce images from memory with an average of 7.17 (maximum score = 14) and a DS of 2.96; immediate learning ability of verbal associations on multiple exposures, with an average of 13.63 (maximum score = 21) and a DS of 4.25.

The second result followed in the study consists in *observing and statistical analisys of changes in the cognitive performance indices at t2* – post cognitive optimization intervention, compared to t1. The cognitive optimization intervention was carried out according to the elaborated working protocol. We will consider that people who obtained a MoCA score adjusted to the level education of over 24 points, QM over 111 points and CDT over 8 points at t2, fall into the "normal" category. Pre (t1) and post (t2) cognitive stimulation scores comparison showed significant differences in t2 vs t1 in all cognitive assessment tests. The average for the adjusted MoCA cognitive score is 23.05 (t1) vs. 26.02 (t2) and for QM is 101.71 (t1) vs. 115.91 (t2). It follows that, at the level of the study participants, was exceeded the QM threshold of 111 points, respectively the MoCA test score adjusted to the tuition level by 26 points post intervention.

Frequency analysis shows a proportion of about 40% of participants who achieved a QM score at t2 of over 111 points (vs. 15% at t1).

Frequency analysis for the MoCA 2 test - grade scores, adjusted to the level of education, indicates a proportion of 78% of participants which they have obtained over 24 points at the final (t2) cognitive assessment (post-intervention) vs. 46% prior to cognitive optimization intervention (t1).

To indicate the statistical significance of the differences identified for total WMSQM scores and the scores obtained on WMS subtests, we used the non-parametric Wilcoxon bivariate test. We have been following the change of cognitive performance indices pre and post cognitive optimization interventions.

The results of the statistical analysis of the non-parametric Wilcoxon test for both the WMSQM total and the MoCA adjusted to the level of education, as well as the WMS subtests that measure the functionality on different cognitive domains affected after stroke (mental control, logic memory, memory digits, visual memory, associative memory) and comparison of the results of the attentional tests (AD2, maze), spatial representation (Yerkes) pre (t1) and post (t2) cognitive optimization intervention, all these show statistically significant improvements of the cognitive abilities during the rehabilitation program. The Wilcoxon test is recommended to compare pre- and post-treatment outcomes within the same group of participants (without a group control) [26].

Cognitive performance scores obtained at t2 increased after cognitive optimization intervention, this increase having statistical significance: p-value = .000.

The results of the statistical analysis indicate significant differences between the results of the attention scores (p-value = .000), graphical representation (p-value = .000), language (p-value = .003) and WMS subtests at t2 relative to t1.

For WMSQM, median differences in scores values at t2 vs. t1 were 15 (12-17 confidence intervals 95%).

The results of the statistical analysis indicate significant differences (p-value = .000) between the results of the scores of the mnesic quotient (WMS QM2) at t2 - post-intervention and the score of the mnesic quotient (WMS QM1) at t1 (pre-intervention).

V. Discussion

Frequency analysis indicates a proportion of approximately 40% of patients who achieved a QM score at t2 of more than 111 points (versus 15% at t1), indicating an improvement in the mnesic quotient, respectively an improvement in of the overall cognitive ability of the persons included in the study, improvement that may be due to cognitive optimization intervention, since it is certified that, without rehabilitation intervention, cognitive capacities will, following a stroke, have a downward trend, at least for people with chronic stroke (the study includes 18 people with subacute stroke - up to 6 months after stroke, and 32 people with chronic stroke - more than 6 months post-stroke).

The synthesis of Cicerone et al., conducted in 2005, taking into account 47 comparative analyzes between different therapeutic interventions, indicates that cognitive optimization interventions have an improvement effect at the level of perception and vision, space, attention, memory and communication. In 78.7% of cases (in 37 of the 47 comparative analyzes), cognitive optimization intervention was superior as an alternative approach. The study of Barker S. et al., in 2009, indicates the effectiveness of a therapeutic intervention for cognitive optimization for post-stroke attention deficits (p-value <0.01) [27].

We have not found studies to apply WMS I for assessing the effect of a cognitive recovery intervention or studies evaluating the effectiveness of a complex cognitive optimization intervention that addresses all cognitive domains within the same program.

VI. Conclusion

The study argues in favor of the idea that the cognitive optimization intervention designed according to the developed and presented protocol, individualized according to the elaborated algorithm, leads to the modification of the parameters that measure the cognitive performance in the persons who suffered a stroke.

Combining, in a person centered approach, computer applications based training with pencil paper worksheets training and adjusting the intensity and complexity of the training to the individual needs at the specific moment in the rehabilitation program proves to be the best therapeutical approach, in terms of outcome.

MoCA and mnesic quotient (WMSQM) are sensible and useful measurement tools to evaluate the improvement of quantifiable parameters of cognitive function after cognitive optimization intervention in patients who suffered a stroke and are hospitalized for a complex rehabilitation program.

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